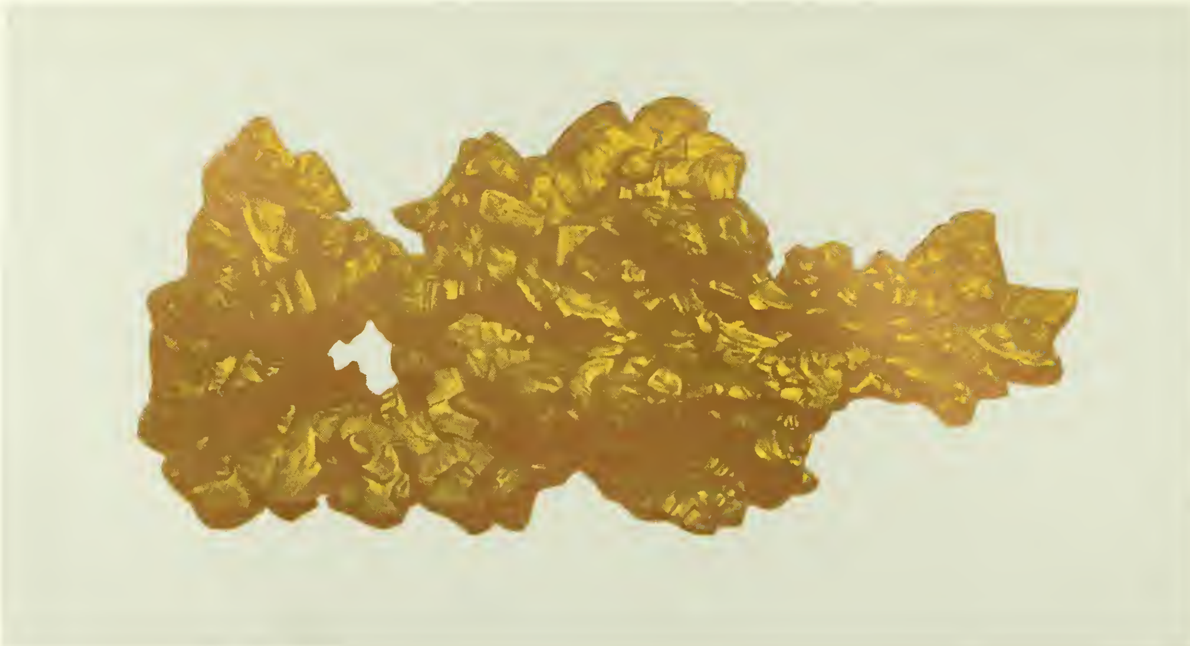
GOLD



CRYSTALLIZED GOLD.

THE LATROBE NUGGET.—Natural size. Weight, 23 ozs. 9 dwts.

(British Natural History Museum.)

GOLD:

ITS GEOLOGICAL OCCURRENCE AND GEOGRAPHICAL DISTRIBUTION

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PREFACE.

The writer who would add one more treatise to the literature of the study of ore-deposits must needs show justification. He must present either new facts or a new and more scientific arrangement of already-published data. It is hoped that, to some degree at least, both these ends have been attained in the present volume. In order that the value of the collected facts may be in no wise impaired by possibly erroneous correlation, speculative inferences have here been sharply differentiated from the data of observation. This arrangement of the subject is presented with the more confidence since it is believed that absolute progress in the science of ore-deposits will, in the future, be made largely, if not entirely, by inductive reasoning. A compilation of the known facts concerning the deposition of a single metal, and of one possessing fairly well-defined characters, both native and in combination, has therefore seemed a not unnecessary contribution towards the foundation on which a stable hypothesis of ore-deposition must be erected. The correlation of the data obtained has for the present been considered of minor importance, and every effort has, on the other hand, been directed towards the presentation in readily accessible form of the salient facts of auriferous deposition.

Some apology may be deemed necessary for crudities of style. The collection of data was commenced without any thought of publication, and the book itself has been written during a period snatched from professional work—a period that, though long in itself, is short when regard is had to the importance of the subject. The literature of gold is stupendous, and as all the authorities quoted, with hundreds of others, were carefully read, and as the contents of a single volume of handy size are limited, it has been necessary to sacrifice other considerations to the essential claims of accuracy and brevity.

Whatever apologies may be due in the foregoing respect, it is felt that none are necessary in respect of the general inconclusiveness and vagueness of the speculative sections of the volume. With the facts at command inconclusiveness is unavoidable in dealing with the subject, and the writer or professor who, from the security of the study or the lecture-room, cries order where there is no order, is not materially advancing his science, inasmuch as the student on passing to the mine and failing to observe there those sharp divisions of ores and ore-deposits he had hitherto looked upon as fundamental, is disposed to ascribe the lack of correspondence between hypothesis and observation to an innate inability to grasp the relations of the subject, and the services of a promising observer are soon lost to science. Even the very broad grouping of gold-deposits adopted in this volume must certainly be materially modified when the general principles underlying auriferous deposition come to be more fully understood.

In the collection of the notes embodied herein I have visited the principal gold-districts of Europe, India, Eastern and Western North America, Australia, and New Zealand; the data adduced for other regions is therefore derived entirely from the authorities quoted. Even for those goldfields examined, the facts obtained have in the majority of cases been largely the result of the observation of local geologists, for it rarely happens that a sojourn of a few days on a goldfield results in the acquisition of new, and at the same time accurate information. Often the sole, but by no means unimportant result of personal examination has been the ability to discriminate between the essential and the trivial in the published literature of the given field. It has manifestly been impossible, even had it been desirable, to include a complete bibliography of the literature of gold, but it is confidently believed that reference to the authorities quoted will give, not only a wide conspectus of the geological knowledge of any goldfield, but also a fairly complete bibliography of its literature, since those authorities, who follow the excellent practice of including bibliographies of the subject treated, have, wherever possible, been cited.

This opportunity is gladly taken of acknowledging my obligation to Mr. W. Rupert Jones, Assistant Librarian of the Geological Society of London, both for the courtesy with which his unique bibliographical knowledge has been placed at my disposal, and for his complete annual catalogues of geological literature, the use of which has materially lightened the labour of research. Acknowledgments are also due to the various mining engineers who have so kindly furnished either information or illustrations; it is trusted that it may not be deemed invidious to mention more particularly in this respect the name of Messrs. John Taylor and Sons. Finally, my indebtedness must be expressed to those scientific societies and geological surveys whose volumes have been laid so freely under contribution to furnish data and illustrations.

MALCOLM MACLAREN.

London,

November, 1908.

Abbreviations of Principal Serials cited.

Abh. k.-preuss. geol. Landesanst. Abhandlungen der königlich-preussischen geologischen Landesanstalt. Berlin.

Amer. Geol. American Geologist. Minneapolis (Minn.). See *Econ. Geol.*

Amer. Jour. Sci. American Journal of Science. New Haven (Conn.).

An. Mus. Nac. Salvador. Anales del Museo Naçional de Salvador. San Salvador.

Ann. Chim. Phys. Annales de chimie et de physique, Paris.

Ann. des Mines, Paris. Annales des Mines. Paris.

Ann. Rep. Bur. Mines, B.C. Annual Report of the Bureau of Mines, British Columbia. Victoria (B.C.).

Ann. Rep. Dep. Mines, N.S.W. Annual Report of the Department of Mines and Agriculture, New South Wales. Sydney.

Ann. Rep. Dep. Mines, Queensl. Annual Report of the Under Secretary for Mines, Queensland. Brisbane.

Ann. Rep. Geol. Surv. Canada. Annual Report of the Geological Survey of Canada. Ottawa.

Ann. Rep. Geol. Surv. Natal. Annual Report of the Geological Survey of Natal. Pietermaritzburg.

Ann. Rep. Geol. Surv. Queensl. Annual Progress Report of the Geological Survey of Queensland. Brisbane.

Ann. Rep. Geol. Surv. Transvaal. Annual Report of the Geological Survey of the Transvaal. Pretoria.

Ann. Rep. Geol. Surv. W. Austr. Annual Progress Report of the Geological Survey. Perth (W. Austr.).

Ann. Rep. Sec. Mines, Victoria. Annual Report of the Secretary of Mines, Victoria. Melbourne.

Ann. Rep. State Min. Cal. Annual Report of the State Mineralogist, California.

Ann. Rep. U.S. Geol. Surv. Annual Report of the United States Geological Survey. Washington (D.C.).

Ann. Sci. Univ. Jassy. Annales scientifiques de l'Université de Jassy. Jassy (Rumania).

Ann. Soc. géol. Belg. Annales de la Société géologique de Belgique. Liége.

Archiv. Mus. Nac. Rio de Janeiro. Archivos do Museu Nacional do Rio de Janeiro. Rio de Janeiro.

Atti R. Acc. Lincei, Rendic. Atti della Reale Accademia dei Lincei, Rendiconti. Rome.

Atti R. Acc. Sci. Torino. Atti della Reale Accademia delle Scienze di Torino. Turin.

Aust. Min. Stand. Australian Mining Standard. Sydney.

Berichte Chem. Gesell. Berichte der deutschen chemischen Gesellschaft. Berlin.

Berg-hütt. Jahrb. Wien. Berg- und hüttenmännisches Jahrbuch der kaiserlich-königlichen Bergakademien zu Leoben und Pribram und der königlich-ungarischen Bergakademie zu Schemnitz. Vienna.

Berg- u. Hütt. Zeit. Berg- und Hüttenmannische Zeitung, Freiburg.

Bol. Ing. Minas, Perú. Boletin del Cuerpo de Ingenieros de Minas del Perú. Lima.

Boll. Soc. geog. ital. Bollettino della Società geographica italiana. Rome.

Bol. Soc. Nac. Mineria, Santiago. Boletin de la Sociedad Nacional de Mineria. Santiago de Chile.

Bull. Cal. State Mining Bur. Bulletin of the Californian State Mining Bureau. San Francisco.

Bull. Com. géol. Russie. Bulletins du Comité géologique. St. Petersburg.

Bull. Com. géol. Finlande. Bulletin de la Commission géologique de Finlande. Helsingfors.

Bull. Geol. Soc. Am. Bulletin of the Geological Society of America. Rochester (N.Y.).

Bull. Geol. Surv. Queensl. Bulletin of the Geological Survey of Queensland (Department of Mines). Brisbane.

Bull. Geol. Surv. Victoria. Bulletin of the Geological Survey of Victoria. Melbourne.

Bull. Geol. Surv. W. Austr. Bulletin of the Geological Survey of Western Australia. Perth (W. Austr.).

Bull. Geol. Univ. Cal. Bulletin of the Department of Geology, University of California. Berkeley (Cal.).

Bull. Mus. Hist. nat. Paris. Bulletin du Muséum d'Histoire naturelle. Paris.

Bull. N.Z. Geol. Surv. Bulletin of the New Zealand Geological Survey. Wellington (N.Z.).

Bull. Soc. belge de Géol. Bulletin de la Société belge de Géologie, de Paléontologie et d'Hydrologie. Brussels.

Bull. Soc. franc. Min. Bulletin de la Société française de Minéralogie. Paris.

Bull. Soc. géol. Bulletin de la Société géologique de France. Paris.

Bull. Soc. géog. Paris. Bulletin de la Société géographique de France. Paris.

Bull. Soc. d'Hist. nat. Toulouse. Bulletin de la Société d'Histoire naturelle de Toulouse. Toulouse.

Bull. Soc. Indust. Min. Bulletin de la Société de l'Industrie Minérale. St. Etienne.

Bull. Soc. oural. Sci. nat. Bulletin de la Société ouralienne d'Amateurs des Sciences naturelles. Ekaterinburg.

Bull. U.S. Geol. Surv. Bulletin of the United States Geological Survey. Washington.

Can. Min. Jour. Canadian Mining Journal, Ottawa.

Centralbl. f. Min. Centralblatt für Mineralogie, Geologie und Paläontologie. Stuttgart.

Chem. Centralblatt. Chemisches Centralblatt, Leipzig.

Chem. News. Chemical News. London.

Com. géol. Russ. Bulletins du Comité géologique. St. Petersburg.

C. R. Acad. Sci. Paris. Comptes-rendus hebdomadaires des Séances de l'Académie des Sciences. Paris.

C. R. Congrès géol. internat. Comptes-rendus du Congrès géologique international.

Cons. Rep. Diplomatic and Consular Reports. London.

Echo des Mines. Echo des Mines, Paris.

Econ. Geol. Economic Geology. Lancaster (Pa.).

Eng. Mag. Engineering Magazine. New York.

Eng. Min. Jour. Engineering and Mining Journal. New York.

Expl. géol. Reg. aurif. Sibérie. Explorations géologiques dans les Regions aurifères de la Sibérie. St. Petersburg.

Field Columbian Mus. Field Columbian Museum Publications. Chicago (Ill.).

Földt. Közl. Földtani Közlöny. [Geological Magazine.] Budapest.

Gen. Rep. Geol. Surv. India. General Report on the Work carried on by the Geological Survey of India. Calcutta.

Geogr. Jour. Geographical Journal (Royal Geographical Society). London.

Geol. Foren. Stockh. Förh. Geologiska Föreningens i Stockholm Förhandlingar. Stockholm.

Geol. Mag. Geological Magazine. London.

Geol. Surv. Canada. Geological Survey of Canada. Ottawa.

Geol. Surv. Queensl., Publ. Geological Survey of Queensland: Publications. Brisbane See also *Ann. Rep. Dep. Mines, Queensl.*

Great Britain and Ireland. Home Office. Mines and Quarries. General Report and Statistics. London.

Jaarb. Mijnw. Ned. O.-Ind. Jaarboek van het Mijnwezen in Nederlandsch Oost-Indie. Amsterdam.

Jahrb. f. Berg- u. Hüttenw. Sachsen. Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen. Freiberg.

Jahrb. k.-k. geol. Reichsanst. Jahrbuch der kaiserlich-königlichen geologischen Reichsanstalt. Vienna.

Jahrb. k.-preuss. geol. Landesanst. Jahrbuch der königlich-preussischen geologischen Landesanstalt. Berlin.

Jahrb. k.-ung. geol. Anst. Jahrbuch der königlich-ungarischen geologischen Anstalt. Budapest.

Jahresb. k.-ung. geol. Anst. Jahresbericht der königlich-ungarischen geologischen Anstalt. Budapest.

Jour. Am. Chem. Soc. Journal of the American Chemical Society, Washington.

Jour. Asiat. Soc. Bengal. Journal and Proceedings of the Asiatic Society of Bengal. Calcutta.

Jour. Canad. Mining Inst. Journal of the Canadian Mining Institute. Ottawa.

Jour. Chem. Soc. Journal of the Chemical Society. London.

Jour. Geol., Chicago. Journal of Geology. Chicago (Ill.).

Jour. prakt. Chem. Journal für praktische Chemie. Leipzig.

Jour. Roy. As. Soc. Journal of the Royal Asiatic Society. London.

Jour. Roy. Soc. N.S.W. Journal and Proceedings of the Royal Society of New South Wales. Sydney.

Jour. Soc. Arts. Journal of the Society of Arts. London.

Mater. Geol. Russ. Materialien zur Geologie Russlands. Herausgegeben von der kaiserlichen mineralogischen Gesellschaft. St. Petersburg. See also Materialen zur Mineralogie Russlands, von Kokscharov. St. Petersburg.

Mém. Com. géol. Russie. Mémoires du Comité géologique. St. Petersburg.

Mem. Geol. Surv. India. Memoirs of the Geological Survey of India. Calcutta.

Mem. Geol. Surv. N.S.W. Memoirs of the Geological Survey of New South Wales. Sydney.

Mem. Geol. Surv. Victoria. Memoirs of the Geological Survey of Victoria. Melbourne.

Mem. Mysore Geol. Dep. Memoirs of the Mysore Geological Department. Bangalore.

Mem. Soc. cient. "Ant. Alzate." Memorias y Revista de la Sociedad cientifica "Antonio Alzate." Mexico.

Min. Mag. The Mineralogical Magazine and Journal of the Mineralogical Society. London.

Mines and Minerals. Mines and Minerals. Scranton (Pa.).

Min. Mitth. Mineralogische Mittheilungen; von Tschermak. Vienna.

Min. Jour. Mining Journal. Railway and Commercial Gazette. London.

Mining Mag. Mining Magazine. New York.

Min. Sci. Press. Mining and Scientific Press. San Francisco.

Min. World. Chic. Mining World, Chicago.

Monatsb. deutsch. geol. Gesellsch. Monatsberichte der deutschen geologischen Gesellschaft. Berlin.

Mon. U.S. Geol. Surv. Monographs of the United States Geological Survey. Washington (D.C.).

Natal Rep. Mining. Natal Report on the Mining Industry of Natal. Pietermaritzburg.

Nature. Nature. London.

N. J. f. Min. Neues Jahrbuch für Mineralogie, Geologie und Paläontologie. Stuttgart.

N.S.W. Dep. Mines, Min. Resources. New South Wales Department of Mines. Mineral Resources. Sydney.

N.Z. Mines Record. New Zealand Govt. Mines Record. Wellington.

Oesterr. Zeit. für Berg- u. Hütt. Oesterreichische Zeitschrift für Berg- und Hüttenwesen. Vienna.

Papers and Rep. Min. and Mining, N.Z. Papers and Reports relating to Minerals and Mining, N.Z. Wellington (N.Z.).

Perak Gov. Gaz. Perak Government Gazette. Taiping.

Peterm. Mitth. Petermann's Mittheilungen. Gotha.

Phil. Mag. Philosophical Magazine. London.

Pogg. Ann. Annalen von Poggendorff. Halle.

Proc. Cottesw. Nat. F.C. Proceedings of the Cotteswold Naturalists' Field Club. Gloucester.

Proc. Geol. Soc. S.A. Proceedings of the Geological Society of South Africa. Johannesburg.

Proc. Inst. C.E. Minutes and Proceedings of the Institution of Civil Engineers. London.

Proc. Linn. Soc. N.S.W. Proceedings of the Linnean Society of New South Wales. Sydney.

Proc. Rhodesia Sci. Assoc. Proceedings of the Rhodesia Scientific Association. Bulawayo.

Proc. Roy. Soc. Victoria. Proceedings of the Royal Society of Victoria. Melbourne.

Proc. and Trans. N.S. Inst. Sci. Proceedings and Transactions of the Nova Scotia Institute of Science. Halifax (N.S.).

Prof. Papers, U.S. Geol. Surv. Professional Papers, United States Geological Survey. Washington.

Q. J. G. S. Quarterly Journal of the Geological Society. London.

Rec. Geol. Surv. India. Records of the Geological Survey of India. Calcutta.

Rec. Geol. Surv. N.S.W. Records of the Geological Survey of New South Wales. Sydney.

Rec. Geol. Surv. Victoria. Records of the Geological Survey of Victoria. Melbourne.

Rep. Austral. Assoc. Adv. Sci. Report of the Australasian Association for the Advancement of Science. Sydney.

Rep. Bur. Mines, Canad. Report of the Bureau of Mines, Canada. Ottawa.

Rep. Dep. Mines, Mysore. Report of the Chief Inspector of Mines in Mysore. Bangalore.

Rep. Dep. Mines, N.S. Report of the Department of Mines, Nova Scotia. Halifax (N.S.).

Rep. Dep. Mines, N.S.W. Report of the Secretary of the Department of Mines. Sydney.

Rep. Dep. Mines, Transvaal. See *Transvaal Mines Dep.*

Rep. Dep. Mines, Vict. Report of the Department of Mines, Victoria. Melbourne.

Rep. Dep. Mines, W. Austr. Report of the Department of Mines, Western Australia. Perth (W. Austr.).

Rep. Geol. Surv. Newfoundland. Report of the Geological Survey of Newfoundland. St. John's (N.F.).

Rep. Geol. Surv. Queensland. Report of the Geological Survey of Queensland. Brisbane.

Rep. Geol. Surv. Transvaal. See *Transvaal Mines Dep., Rep. Geol. Surv.*

Rep. Inst. Mines & Forests, Brit. Guiana. Report of the Council of the Institute of Mines and Forests on the Gold and Forest Industries of British Guiana. Georgetown (Demerara).

Rep. Ontario Bur. Mines. Report of the Ontario Bureau of Mines. Toronto.

Rep. Surv. Dep. Egypt. Report on the Work of the Survey Department. Cairo.

Rev. Sci. Revue Scientifique. Paris.

Russ. Min. Gesell. See *Verh. russ.-k. Min. Gesellsch.*

St. Petersburg Min. Soc. See *Verh. russ.-k. Min. Gesellsch.*

Tasm. Dep. Mines. Reports of the Department of Mines, Tasmania. Hobart.

Trans. Am. Inst. M.E. Transactions of the American Institute of Mining Engineers. New York.

Trans. Austr. Inst. M.E. Transactions of the Australasian Institute of Mining Engineers. Melbourne and Sydney.

Trans. Geol. Soc. S.A. Transactions of the Geological Society of South Africa. Johannesburg.

Trans. Inst. Min. Met. Transactions of the Institution of Mining and Metallurgy. London.

Trans. Inst. M.E. Transactions of the Institution of Mining Engineers. Newcastle-upon-Tyne.

Trans. N. Engl. Inst. Min. & Mech. Eng. Transactions of the North of England Institute of Mining and Mechanical Engineers. Newcastle-upon-Tyne.

Trans. N.Z. Inst. Transactions and Proceedings of the New Zealand Institute. Wellington (N.Z.).

Trans. S. A. Phil. Soc. Transactions of the South African Philosophical Society. Cape Town.

Transvaal Mines Dep., Rep., Geol. Surv. Transvaal Mines Department. Report of the Geological Survey. Pretoria.

Verh. deutsch. wissensch. Ver. Santiago. Verhandlungen des deutschen wissenschaftlichen Vereins zu Santiago de Chile. Valparaiso.

Verh. naturh. Ver. preuss. Rheinl. Verhandlungen des naturhistorischen Vereins der preussischen Rheinlande, Westfalens und des Regierungs-Bezirks Osnabrück. Bonn.

Verh. russ.-k. min. Gesellsch. Verhandlungen der russisch-kaiserlichen mineralogischen Gesellschaft. St. Petersburg.

Zeit. angew. Chem. Zeitschrift für angewandte Chemie. Leipzig.

Zeit. anorg. Chem. Zeitschrift für anorganische Chemie. Hamburg and Leipzig.

Zeit. deutsch. geol. Gesellsch. Zeitschrift der deutschen geologischen gesellschaft. Berlin.

Zeit. Berg-, Hütt.- u. Salinenw. Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate. Berlin.

Zeit. für Kryst. Zeitschrift für Krystallographie und Mineralogie. Leipzig.

Zeit. für prakt. Geol. Zeitschrift für praktische Geologie. Berlin.

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GOLD:

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PART I.

The General Relations of Auriferous Deposits.

INTRODUCTORY.

Before entering on the discussion of the subject proper, it will be necessary to outline certain fundamental premises of belief, and incidentally to demand certain postulates that have, from unchallenged reiteration, assumed more or less axiomatic force but which are, none the less, mere assumptions. Than the logical instability of the broad hypotheses upon which the philosophical literature relating to ore-deposits is based, no one feature is brought more prominently into relief by a close examination of the subject, and it cannot therefore be expected that the special section hereafter to be treated will be free from the stigma of speculation that attaches to the whole. Frequently in the history of the study of the genesis of ore-deposits have hypotheses based upon isolated reactions in the laboratory, or upon imperfectly correlated observations in the field, failed in their broader application; and though it is certain that, with increase of chemical knowledge, and by the multiplication of observations from which the personal factor is almost totally eliminated, there will, in course of time, be evolved a theory which must approximate very closely to the truth, yet it is equally certain that the speculative element which now bulks so largely in problems of this nature will never be entirely absent, so long as man is unable to reproduce at will the widely varying conditions, or to regulate the many interdependent reactions, attendant on the natural deposition of ores.

Condition of the Interior of the Earth.—In the first place, some space must be given to the consideration of the probable condition of that portion of the earth's bulk which is not available for direct observation. It is unnecessary at the present moment to closely examine the various theories put forward from time to time as explanatory of the observed phenomena, but it seems clear that all hypctheses regarding the condition of the earth's interior must be based on three main premises :—

(*a*) That while the mean density of the thin outer shell accessible to our observation is only 2·5, the density of the earth as a whole is 5·6 ;

(*b*) That the earth is a rigid body, certainly as rigid as a sphere of glass ; and

(*c*) That the earth's interior is very highly heated.

And though the last is at best only an inference, yet from analogy with other celestial bodies, and from other considerations, there seems no possible reason for refusing to admit it as a fundamental premise.

Taking the diameter of the earth as 8,000 miles, and assuming the simplest rate of increase of density, viz., an increase directly proportional to the depth, we find from mathematical considerations that the zone of mean density (5·5) will be reached at a depth of about 1,000 miles, and that the density at the centre may be estimated at 14·5. With other rates of regular progression, the zone of mean density will be passed at much greater depths. From considerations of temperature and pressure, it may reasonably be concluded that the earth from its surface to its centre may be divided into three zones :—

(*a*) A crust solid to a depth of, say, 25 miles.

(*b*) A liquid magma highly heated and under great pressure, extending to a depth of, say, 200 miles.

(*c*) A gaseous magma extending to the centre, the high viscosity and relative incompressibility of the magma rendering the whole as rigid as steel.

Of the last-mentioned sphere nothing may here be said. It lies even beyond the domain of geological speculation, and its problems may be attacked only by the physicist. Its outer portion merges gradually into the liquid magma, not through successive concentric shells of substances that have reached their critical temperatures, but rather through an irregular and indefinite mixture of gaseous and liquid constituents. The junction between the centrosphere (the *barysphere* of Posepny, or the *geite* of Milne) and the liquid magma is placed at about 200 miles, on the assumption that the rate of increase of temperature at great depths is identical with that observed at the surface—an assumption for or against which few arguments can be urged.

Between the liquid magma and the solid crust there must likewise lie a zone of transition, in which some of the mineral constituents have already commenced to separate out from the parent magma. It is not probable that the boundary between the solid crust and the liquid magma is more than rudely spherical in form, for the thickness of the solid crust must vary considerably; its lower limit approaching, in regions of extensive vulcanicity, much closer to the earth's surface than is elsewhere the case. From this boundary outwards the probable condition of the "crust" must be dealt with in detail, for it is in this outer 25 miles of the earth's mass, and in this alone, that the essential operations of ore-deposition take place. If this be granted, and there seems every reason to consider the postulate at least justifiable, it follows then that, in dealing with the problems afforded by ore-deposits, the whole zone so dealt with may be considered to be precisely similar in physical character and in chemical composition to that with which we are more immediately conversant. For since it has already been assumed that the rise in density with increasing depth from the earth's surface is, in all probability, regular, and at 1,000 miles this is only from 2·5 to 5·5, then at the comparatively insignificant depth of 25 miles the increase in density or the change in chemical combination is negligible.

Following Van Hise[a] in principle, two main divisions of the solid crust may be recognised, according to the manner in which the rocks of each division adapt themselves to the varying stresses induced by the movements of the crust:—

(*a*) Zone of flowage: This is the zone immediately above the liquid magma; here the rocks yield to stress by differential movements of the individual particles, each accommodating itself to the strain by a fresh disposition of its dimensions with respect to those of its neighbours. Small though the individual movement may be at any time, the aggregate result is stupendous; its degree is occasionally revealed to us by time and consequent denudation. Since the pressure in this zone is enormous, it follows that no fissure can exist, for the mass must be supposed to be sufficiently plastic to flow, and so to close any fissure formed in the not improbable event of a sudden shock, as of a movement in the crust above, momentarily overcoming the cohesion of the rock. We have here in the upper portions of the zone, as Van Hise justly points out, the fissures of the overlying zone of fracture gradually becoming narrower, and at length dying out in depth.

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[a] "Principles of North American Pre-Cambrian Geology," 16th Ann. Rep. U.S. Geol. Surv., 1894–5, Pt. I, pp. 598 *et seq.*; "Metamorphism of Rocks and Rock Flowage," Bull. Geol. Soc. Amer., IX, 1898, pp. 295–313, 318–326; "Some Principles controlling the Deposition of Ores," Trans. Amer. Inst. M.E., XXX, 1901, p. 45.

(*b*) Zone of fracture : This zone lies along the outer solid portion of the lithosphere. Its depth must be extremely variable, its lower surface lying approximately parallel to the boundary of the liquid magma and ranging from near the surface in regions of extensive and active vulcanicity, to considerable depths in regions of long continued sedimentation. Of the average depth of the zone it is impossible to say much. It is possibly more than eight, but is probably less than ten miles. In this zone, as the name signifies, the solid rocks adapt themselves to stress by fracturing along lines of weakness, thus producing in the strata the manifold variations observable at the surface, for even in the case of folded rocks. the convolutions are generally produced by the formation of numerous minute parallel faults. A limited acquaintance with mining operations is generally quite sufficient to demonstrate the almost universal prevalence of larger faults.

Van Hise raises the transition rocks between these two zones to the dignity of a third zone ; but inasmuch as, from the very nature of the change, there cannot be found any salient feature by which the transition belt may be designated, and since it can be described only by more or less negative terms, the general statement is here given its simplest expression.

Fissures in the Zone of Fracture.—A fissure may in all cases be regarded as evidence of release from past strain. and since stresses may be of indefinite force, act through indefinite time, and through indefinite space, and on rocks varying greatly in composition, texture, hardness, and toughness, we may expect to find, and do find, fissures of almost infinite variety. Further, since these fissures in the zone of fracture become the water channels of the surface rocks, and since percolating waters and their dissolved salts act with more or less effect—purely solvent or metasomatic as the case may be—on the walls of the fissures, the form of these and the nature and composition of the walls—two of the features which have been relied on as classificatory—become greatly modified if not completely changed. It will therefore be apparent that any genetic classification—and none other is scientific—of these fissures (as distinguished. of course, from the veins which are afterwards formed in them) is impossible.

Classification of Ore Deposits.—Classifications of ore-bodies based on the form of the filled fissure were those of Whitney,[a] of Pumpelly,[b] of J. A. Phillips,[c] of Louis,[d] and of others. As

[a] "Geol. Surv. of the Mississippi Lead Region," Albany, 1868. p. 224.
[b] "Geol. and Mining Industry of Leadville," Washington, 1886. p. 373.
[c] "Treatise on Ore Deposits," London, 1886, p. 3.
[d] "Treatise on Ore Deposits" by J. A. Phillips, revised by H. Louis, 2nd Ed., London, 1896, p. 10.

may be readily seen, the distinction between "fissure," "bedded," "contact," and "gash" veins, "stockworks," and "massive" deposits is merely one of degree of complication, or of chance environment, and is in no wise related to the genesis of the original space in which the deposits are now found. F. Posepny[a] appears to have been one of the first to clearly recognise this fact, for he, followed afterwards by Monroe and Kemp,[b] suggested a more or less genetic classification, dividing all ore-deposits into those formed in "spaces of discission" and those formed in "spaces of dissolution." The differentiation here, however, is not real, for it is not possible to conceive of a "space of dissolution" in a soluble rock that had not its origin and its general direction determined by a rock fracture, however small. Since, therefore, it must be admitted that the form of a fissure may be modified indefinitely by percolating waters, it follows that "spaces of dissolution," when considered genetically, cannot be separated from "spaces of discission." A better classification, and certainly at first sight a more scientific, is that of Waldemar Lindgren.[c] Here, fissure-veins, which are, in effect, any form of a mineral mass filling a fissure, are classified according to the distinctive metasomatic processes that have taken place within the fissure. From a genetic point of view, the weakness of the classification lies in the fact that the same waters may, and certainly do, produce different results in different rocks. Owing, however, to the general insusceptibility of gold to the solvent action of the percolating waters that so readily affect the country walls, and to the fact that the gangue of an auriferous vein is most often quartz, a mineral even less susceptible to these solutions than gold, the classification based on metasomatic changes loses much of its value when applied to auriferous veins. Indeed, our knowledge of the processes of auriferous deposition is much too scanty to admit of close and particular classifications, which, being based largely upon assumptions presented in the guise of fact, are, by obscuring the real issues, harmful rather than beneficial. Form, position and associates (the last in qualified degree) are most unreliable classificatory factors, and yet they have formed the basis of most classifications hitherto presented. The weakness of systems dependent on the two first-named has already been indicated, and it will be shown later that the ions of gold are so loosely balanced that the introduction of almost any foreign vagrant ion will be followed by the aggregation and deposition of the gold. This treatise is therefore largely a plea for a franker confession than is usual of ignorance of the conditions

[a] Trans. Amer. Inst. M.E., XXIII, p. 197.
[b] "The Ore Deposits of the United States," New York, 1893, p. 52.
[c] Trans. Amer. Inst. M.E., Vol. XXX, p. 578.

of auriferous deposition, and for the adoption of a classification that, while as narrow as possible, is yet no narrower than is justified by our actual knowledge. The presence of fluorite in the gold-telluride deposits of Cripple Creek has caused Lindgren,[a] to create a separate division of "Fluorite-gold-tellurium veins," and yet there is nothing either in the present writer's examination of that region or in the literature of those deposits to show that the presence of fluorite is not purely adventitious, that it has had any effect whatever upon the deposition of the gold, or that it was in any way originally in genetic connection. On the other hand, it will be shown later that Tertiary andesites of the character of those of Cripple Creek furnish, in many parts of the world, veins and auriferous associates (with the exception of fluorite) similar to those of Cripple Creek, and this relation has therefore been selected as the narrowest to which, in the given instance, classificatory value may be attached.

Source of Metallic Ores.—An ore-body is in nearly every case the result of long continued concentration, generally in a fissure or permeable belt in the zone of fracture. Ore-bodies may occur in igneous or in sedimentary rocks ; but, however occurring, the primary source of the metallic ore is to be looked for in igneous magmas, through which the heavy metals have once been diffused, and from which they have been separated : (*a*) by magmatic differentiation, (*b*) by the leaching action of percolating solutions, or (*c*) by the mechanical separation effected by running water during the process of denudation. Analytical research by many chemists[b] has shown that nearly all the common metals, including gold, are to be found in the igneous rocks, both plutonic and volcanic. Harrison, for example, examining the igneous and metamorphic rocks of British Guiana, found that of 29 rocks selected, only one was free from traces of gold. The maximum quantity of gold obtained was 43 grains per ton ; the mean was 6·5 grains. While in many of the cases above cited it is possible, and in some cases probable, that the metallic content was introduced by wandering solutions after the consolidation of the magma, there yet remains sufficient evidence to fully justify the assumption that the great bulk of the metals of the crust was brought within reach of percolating meteoric waters or of denuding agents by inclusion within upward-moving magmas

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[a] Trans. Amer. Inst. M.E., XXX, 1900, p. 578, *et seq.*

[b] Forchhammer, Pogg. Annal., XCV, p. 60 ; Sandberger, "Untersuchungen über Erzgänge," Wiesbaden, 1885 ; Becker, Mon. U.S. Geol. Surv., III, 1882, p. 223 ; Idem, op. cit., XIII, 1888, p. 350 ; Curtis, op. cit., VII, 1884, p. 80 ; Robertson, Bull. Missouri Geol. Surv., VII, 1894, p. 479 ; Harrison, Rep. Mines Dep. Brit. Guiana, 1905 ; Dieulafait, Ann. chim. physiq., XVIII, 1879, p. 349 ; and by many others.

of certainly much greater density than those highly aqueous solutions which may, with reason, be deemed to form a portion of the more tenuous end-products of magmatic differentiation. Of the nature of the combination of the metals or, indeed of their associates or hosts within the magmatic mass, nothing may be said. It seems reasonable to assume that authigenic metallic ores will be found with the ferro-magnesian silicates or with the heavy oxides (magnetite, rutile, &c.), for it still remains doubtful whether metallic sulphide minerals may be regarded as original in igneous rocks. In the majority of investigated cases metallic sulphides have certainly been introduced subsequently to the consolidation of the rocks in which they are found, and, notwithstanding the mass of evidence adduced, for example, for the magmatic hypothesis of origin of the Sudbury sulphide-ores,[a] there are many authorities[b] who have ascribed the concentration of sulphide-ores found in that place and elsewhere to deposition from circulating aqueous solutions. In whatever form the heavy metals may be combined, their percentage of the total magmatic mass is always far too small to constitute an ore. Iron alone occurs in any quantity, its average percentage in igneous masses being estimated at 4·46 only.[c] Before the heavy metals can be aggregated in sufficient quantities to be termed ore-bodies, they must be leached or washed from their matrix of igneous rock and re-deposited in concentrated form. Assuming for the moment that magmatic differentiation is of dubious efficiency in the concentration of ores, the universal agent of solution and concentration is therefore the water that is always in motion in the fissures and crevices of the solid crust. Except in the case of beach iron-sands, mechanical concentration by running or moving waters plays little part in the formation of ore-bodies from consolidated igneous rocks.

Source of Underground Waters.—Two, and only two, sources of the waters which traverse the fissures of the earth's crust are possible, viz., (*a*) magmatic, and (*b*) meteoric waters.

Observers who have noted the vast quantities of steam accompanying many volcanic eruptions have not hesitated to claim for the liberated water vapours an origin authigenic with that of the lavas from which they have emanated, a view that of recent years has met with very wide acceptance among Continental and American geologists. The arguments for this view have been

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[a] Walker, Q.J.G.S., LIII, 1897, p. 40; Coleman, Rep. Ontario Bureau Mines, 1905, Pt. III; Barlow, Econ. Geol., I, 1906, p. 454.

[b] Campbell (W.) and Knight, Eng. Min. Jour., LXXXII, 1906, p. 909; Dickson, Jour. Can. Min. Inst., IX, 1906, p. 239, and others.

[c] Clarke, Bull. U.S. Geol. Surv., No. 330, 1908, p. 26.

especially well presented by Professor J. F. Kemp.[a] Much stress is laid in his argument on the fact that the zones of deep mining operations show the rocks to be comparatively dry. It is perfectly true that the great majority of mines are drier, or at least are no wetter, in depth than near the surface, and many more instances than those cited by Professor Kemp may be adduced, but it may not therefore be assumed that all strata of the depths quoted—2,000 to 5,000 feet—present the like phenomenon. The deeper mines of Charters Towers, Queensland, in granite and tonalite, are so dry at depths of 2,000 to 2,600 feet that water for drilling and other mining purposes is sent from the surface, yet in the same State, an artesian well in sedimentary strata is yielding 200,000 gallons water per diem from a depth of 5,045 feet, and some wells, from depths of over 4,000 feet, have outflows of 1,000,000 gallons and more daily. Again, while a mine may be "dry" in the miner's sense, or may even be dusty, its rocks may yet contain water. In many cases, a little water is tapped in sinking, representing perhaps the accumulation of years, and that no more is subsequently observed is due to the fact that the total amount furnished by the rock fissures is dissipated by evaporation. Too little regard has been paid to the probability of the chief work in underground fissures having been performed, not by great flows of water circulating with that rapidity which implies pumping when met with in mines, but rather by bodies of water standing in closely-confined spaces and moving with almost inconceivable slowness. But, in any case, the present deficiency of waters in a fissure has no bearing whatever on the origin of the gangue or metalliferous contents, and is indeed as little an argument in favour of an origin from magmatic as from meteoric waters: a quartz-vein merely indicates that at the period of its formation underground waters were circulating. The supply of siliceous and metalliferous waters may have subsequently been cut off, or, by the very act of deposition, the channels may have been closed, in either case giving the dry fissure or closed vein now met with. While not denying the possibility, or even the probability, of the derivation of a certain proportion of the stock of underground waters from a magmatic source, the present writer is inclined to ascribe to meteoric waters nearly all metalliferous deposits of economic importance: this premise is regarded as fundamental in the speculations that are subsequently offered. The magmatic origin claimed by Suess, Weed, and others, for the waters of most geysers and hot springs can certainly not be granted, for it has been shown[b] that the great

[a] Trans. Amer. Inst. M.E., XXXI, 1902, pp. 169-198.

[b] Maclaren, Geol. Mag., Dec. V, III, 1906, p. 511.

Waimangu geyser, in the Hot Lakes region of New Zealand, depended for its water supply on a superficial source; viz., on the waters of an adjacent lake.

Circulation of Underground Waters.—The motive power inducing the circulation of meteoric water is primarily gravity, which is greatly assisted in its work by the expansion of waters due to the high temperatures encountered in depth. This deep circulation has been compared to that in the pipes of a hot-water system in a house, but though the simile may give the simplest expression to the idea, the actual circulation must, in fact, be extremely complicated, both ascending and descending currents receiving contributions from sources far removed from each other, and dividing often to travel along planes differing widely in direction and in extent. At great depths and under the pressure obtaining at those depths, much of the transference of water is probably effected through capillary openings, which may broadly be defined as those less than ·508 mm., if circular, and ·254 mm. if tabular, and greater than ·0002 and ·0001 mm. respectively.[a] In any case the rate of percolation at great depths must be exceedingly slow. Since the whole case for the assumption of a deep underground circulation of meteoric waters rests on hypothesis, the inferior limit to which meteoric waters may reach cannot be indicated with any approach to accuracy, but it may reasonably be assumed to extend the whole depth of the zone of fracture.

A clear distinction must however be drawn between the deep underground circulation above referred to and that shallow surface circulation which is indicated by springs and by the waters of perennial streams. The latter moves in a zone that is alternately wet and dry, or that is filled with surface waters moving towards the lowest drainage exit of the surrounding country. Ordinarily, the region of shallow surface circulation (the "vadose" region of Posepny) does not descend much below the normal drainage level, but in special cases, as in an artesian basin or in a region of springs owing their origin to conditions approximating to those necessary for an artesian system, or in arid desert regions that upon occasions receive a rain-fall, surface vadose waters may reach great depths.

Filling of Fissures.—It may be stated as a general law that increase in temperature or in pressure increases the solvent power of a liquid. It will therefore be apparent that as meteoric waters descend, their action on the metallic salts with which they come in contact is intensified *pari passu* with the depth to which they

[a] Slichter, 19th Ann. Rep. U.S. Geol. Surv., Pt. II, p. 317.

penetrate. The metallic salts on which they act may be those already deposited in the waterways, or may be those contained in the adjacent walls of "country," and the breadth of the water channel is here considered to be co-terminous with the extent of the lateral penetration of the circulating waters from the fissure. So much, therefore, of the original restricted lateral secretion theory may be admitted, viz., that percolating waters may gain their metallic contents from the rocks immediately contiguous to the fissures through which they are passing. That they must deposit ore in those fissures cannot, as was originally demanded, be generally conceded.

In addition to the above supplies of metallic salts for vein-filling, there must be admitted another, viz., that yielded to meteoric waters by metalliferous vapours, potential or actual, which are assumed to be a possible result of magmatic differentiation. These vapours are generally, but not always, incorporated with the meteoric waters at great depths. Magmas may cool at comparatively shallow depths, and indeed, some, as we know, are so close to the surface that they are enabled to extrude a portion of their bulk, unattended by any seismic phenomena such as would indicate forcible expulsion from a considerable depth. It is these solutions containing uprising magmatic vapours that furnish the essence of the original ascension theory.

These three sources of supply—already-formed fissure deposits and metasomatic replacements of country, authigenic deposits in igneous rocks or in sediments, and magmatic vapours (in reality they are but one, for all have been derived primarily from igneous magmas)—then, furnish the ores of metalliferous veins. To the last mentioned, the writer is inclined, as already stated, to grant a subordinate position, holding that, though in this case we are dealing with a *vera causa*, and though the igneous rocks are certainly to be considered as the primary source of the earth's accessible ores, yet the metallic content of the igneous rocks has been yielded after rather than before their consolidation, and, indeed, is the result of leaching by magmatic aqueous vapours or magmatic waters rather than of differentiation. No one source may, therefore, be postulated for any given ore in a fissure. We see that the component parts of a single crystal of a homogenous mineral may have been derived from a previously existent vein crystal, from a rolled fragment in a sedimentary rock, from an authigenic crystal in an igneous rock, and from vapours arising from magmatic differentiation.

Broadly speaking, the ores filling fissures (as distinguished from the gangue) may be divided into two great divisions, according to the chemical character of the water of transportation. Below the ground-, or permanent, water-level, where waters are hot and alkaline, sulphides and tellurides are deposited, and are characteristic of that zone. In the upper or vadose zone, waters are cold and acid, and sulphides and kindred salts are decomposed, with end-products of metals, oxides, certain silicates, and sulphates. These products, and especially the last mentioned, are not of necessity deposited in the vadose zone, but may under given conditions pass downwards to the ground-water level and there be re-precipitated as sulphides. The geological agent promoting this change is denudation, which, by locally lowering the earth's surface, slowly lowers the ground-water level, thus continually exposing the top of the sulphide zone to the play of oxidising waters.

Secondary Enrichment.—It has been seen that, within the mass of igneous rocks, metals are too widely diffused to furnish ores, at least of the heavier metals. Nor when the metals are leached out and deposited in the fissures of the deeper circulation are they generally in a state of sufficient aggregation to furnish ores. Exceptions to this rule do occur, and are far more numerous than would be supposed from a perusal of the recent literature of ore-deposits. Nevertheless, most ore-bodies, and certainly nearly all in the upper portions of vein-fissures or ore-channels, owe a large proportion of their economic value to repeated accretions of ore or to repeated subtractions of gangue. This phenomenon is termed "secondary enrichment"; but the term is restricted in use to vein and other deposits in rock, and does not cover those concentrations resulting from the sorting action of running waters, as in the case of gold placers. Secondary enrichment may be positive or relative: it may result from the actual addition of metallic matter or from the removal of base matter, the total quantity of metal present being, in the latter case, unaffected. It may take place in the vadose zone or in the sulphide zone. In the former, relative enrichment is more common than in the latter. In the former also, growth by simple mass-action is prevalent. Thus metals, oxides, silicates, and sulphates are drawn from passing solutions and added to the already-deposited metal or salt. Enrichment below the ground-water level normally takes place by the reducing action of unaltered sulphide minerals on sulphate solutions moving downward from the vadose zone. There is thus formed at, or somewhat below, the ground-water level, a zone of sulphide enrichment, and as the ground-water level is continually being lowered, and the accumulated mineral of many hundred of feet of vein originally overlying is there being deposited and re-deposited, notable ore-bodies may result.[a] From the chemical analogies of the tellurides and sulphides, a similar horizontal zone of telluride enrichment may be expected in gold-telluride veins, and indeed is indicated by the mining experience gained in working the telluride ores of Kalgoorlie, Western Australia. The question of secondary enrichment being one of the highest importance in the consideration of auriferous deposits, further attention will be given to the subject in a later section.

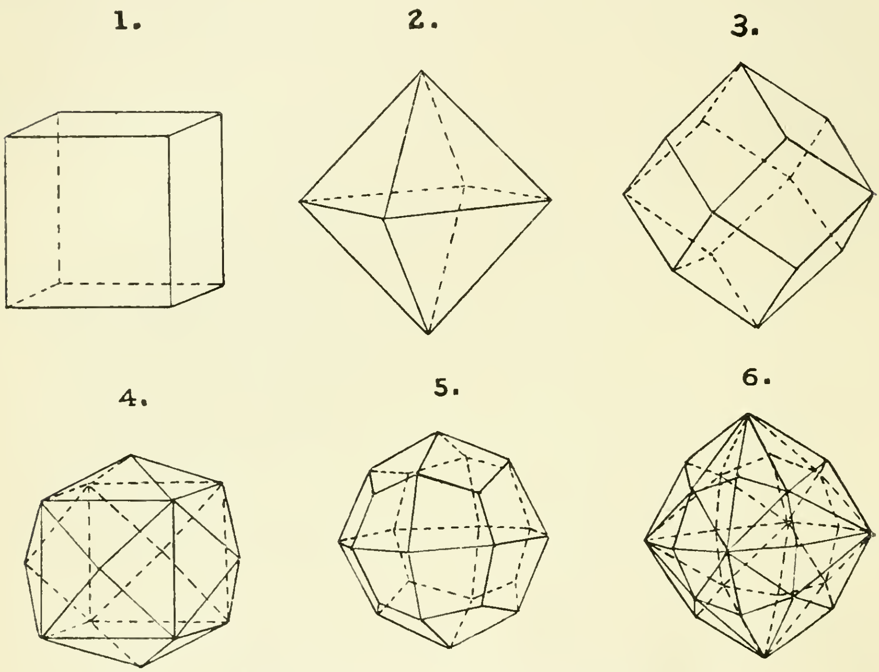
[a] Weed, Bull. Geol. Soc. Amer., XI, 1899, p. 179; Idem. Trans. Amer. Inst. M.E., XXX, 1900, p. 424; XXXIII, 1903, p. 747; Emmons (S. F.), ib., p. 177.

THE PHYSICAL AND CHEMICAL CHARACTERS OF GOLD.

Native Gold.—Gold is very widely diffused in nature. It is found native in irregular masses, strings, scales, plates, and crystals, in quartz or sulphide veins, or as impregnations in the country adjacent to fissures. In alluvial gravels it occurs as scales, grains, slugs, and nuggets (pepites, Fr.). Regarded broadly, it rarely shows crystalline form, but where the conditions are favourable, as in cavities in the upper or vadose zones of fissures, or in loose permeable alluvial gravels, where expansion is not hindered by lack of space, and where the directive lines of growth are not determined by the shape of a cavity, or by the concurrent growth of another mineral, as calcite or serpentine, gold obeys the natural laws of its crystal growth and crystallizes in various isometric (cubic) forms. The largest and most perfect crystals are always those derived from alluvial gravels, since there the growing crystal has apparently often been able to accrete with equal facility matter from all sides. Gold-crystals from placer deposits may attain a length of from 1½ to 2 inches, in which cases they are nearly always octahedra. The most perfect crystals have been derived from the gravels of Victoria, Australia. Large crystals, especially when octahedral, often possess deeply recessed faces and salient edges, indicating either a comparatively high local concentration of gold in the surrounding solution, or, more probably, a rapid replenishment of its gold content at the time of growth (Fig. 7). Recessed faces further indicate the absence, in the immediate vicinity of the crystal, of solutions that have only just passed the point of saturation, since the normal work of these in crystal growth is to reduce the inequalities arising from irregularity in concentration or in supply of gold from solution. The concentration necessary to secure growth of gold-crystals does not prevail throughout the whole mass of solution in the gravel or in the vein-fissure, but is to be regarded as obtaining solely in the immediate neighbourhood of already deposited gold and to arise from the action of inherent forces of growth. The salient edges of alluvial gold-crystals are often quite sharp, presenting thus evidence of the absence of agents of attrition or of solution. The presence of large gold-crystals in alluvial drifts, together with the unworn edges often shown by them, is largely relied upon, as will be seen later, to support the hypothesis of the growth of gold *in situ* in alluvial deposits. Liversidge[a] has

[a] Jour. Chem. Soc., LXXXI, 1897, pp. 1, 125.

shown that polished and etched sections of rounded and water-worn alluvial nuggets almost invariably show them to possess an internal crystalline structure. A rare development in the crystallization of gold is shown in the formation of blister-like protuberances on the octahedral faces of a specimen from California (Plate I). These are not capable of a ready explanation, since they do not appear to be comparable to ordinary curved faces, which are often to be referred to the action of solvents, which normally work by first attacking the crystal edges. The gold-crystals of the vadose zone of fissures are on the whole

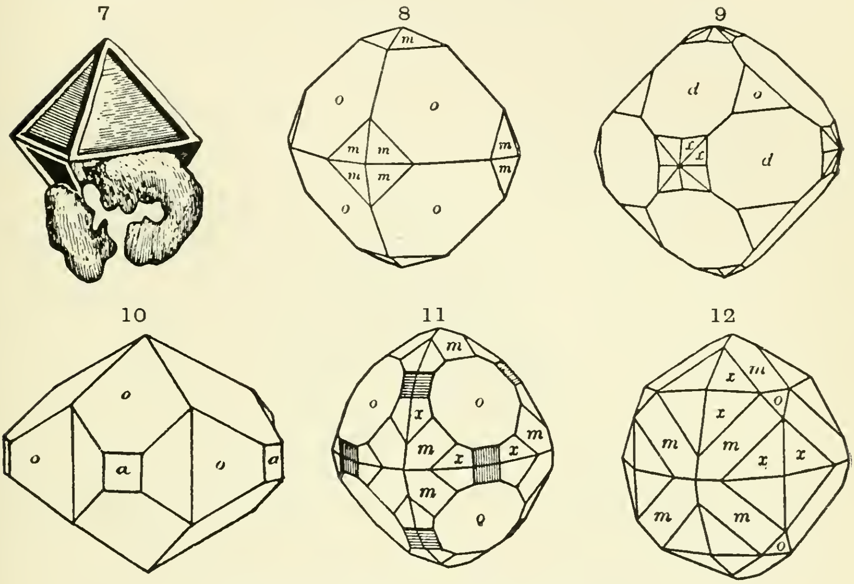


FIGS. 1-6. SIMPLE FORMS OF GOLD CRYSTALS (rarely obtained in nature).
Fig. 1. Cube. Fig. 2. Octahedron. Fig. 3. Rhombic dodecahedron. Fig. 4. Four-faced Cube. Fig. 5. Trapezohedron. Fig. 6. Six-faced octahedron.

much smaller, much less perfect, and much more complex in aggregation than those of the alluvial drifts. This difference is probably due largely to environment and, possibly, to differing degrees of concentration of auriferous solutions, since, chemically regarded, there cannot be conceived to exist any radical difference between waters percolating in the upper portions of fissures above the permanent water-level and those passing through placer gravels. At times the degree of auriferous concentration in the waters of vein-fissures must be relatively high, in which case rapid deposition is expressed by the formation of moss- and leaf-gold.

The gold of quartz-veins is often so fine as to escape ordinary observation. Edman[a] has shown that particles of gold may be less than ·002 mm. in length. When extremely fine particles of gold are dispersed through quartz the whole acquires a greenish hue, a feature which is most distinctly observable perhaps in specimens from the free-gold zones of andesitic regions.

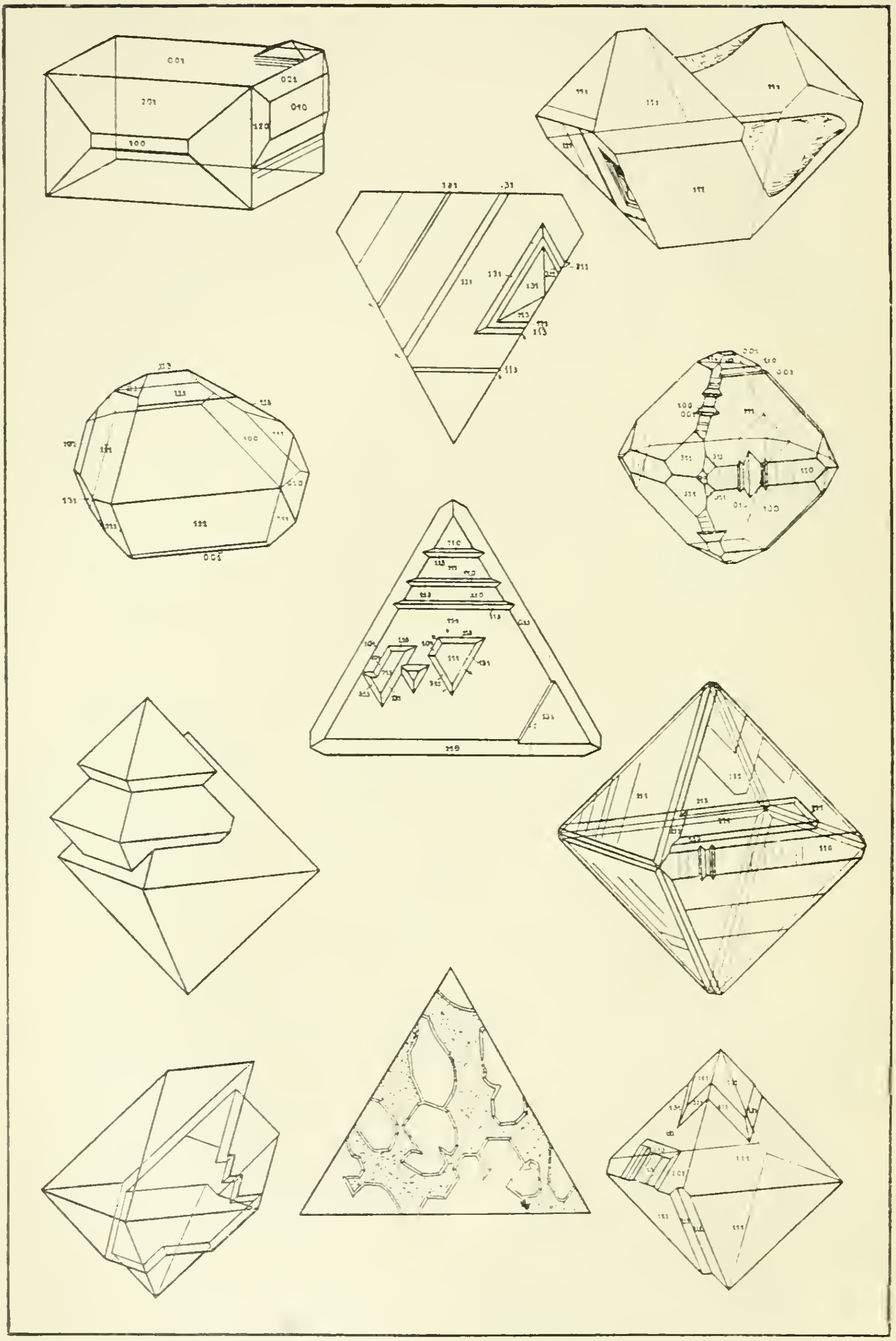
The crystal forms of gold hitherto observed have been the cube {100} ; rhombic dodecahedron {110} ; octahedron {111} ; tetrahexahedra (four-faced cubes) {410}, {310}, {520}, {210} ; trapezohedra {811}, {411}, {311}, {211} ; and hexoctahedra (six-faced octahedra) {421}, {321}, {543}, {18.10.1}.[b] Ideally simple



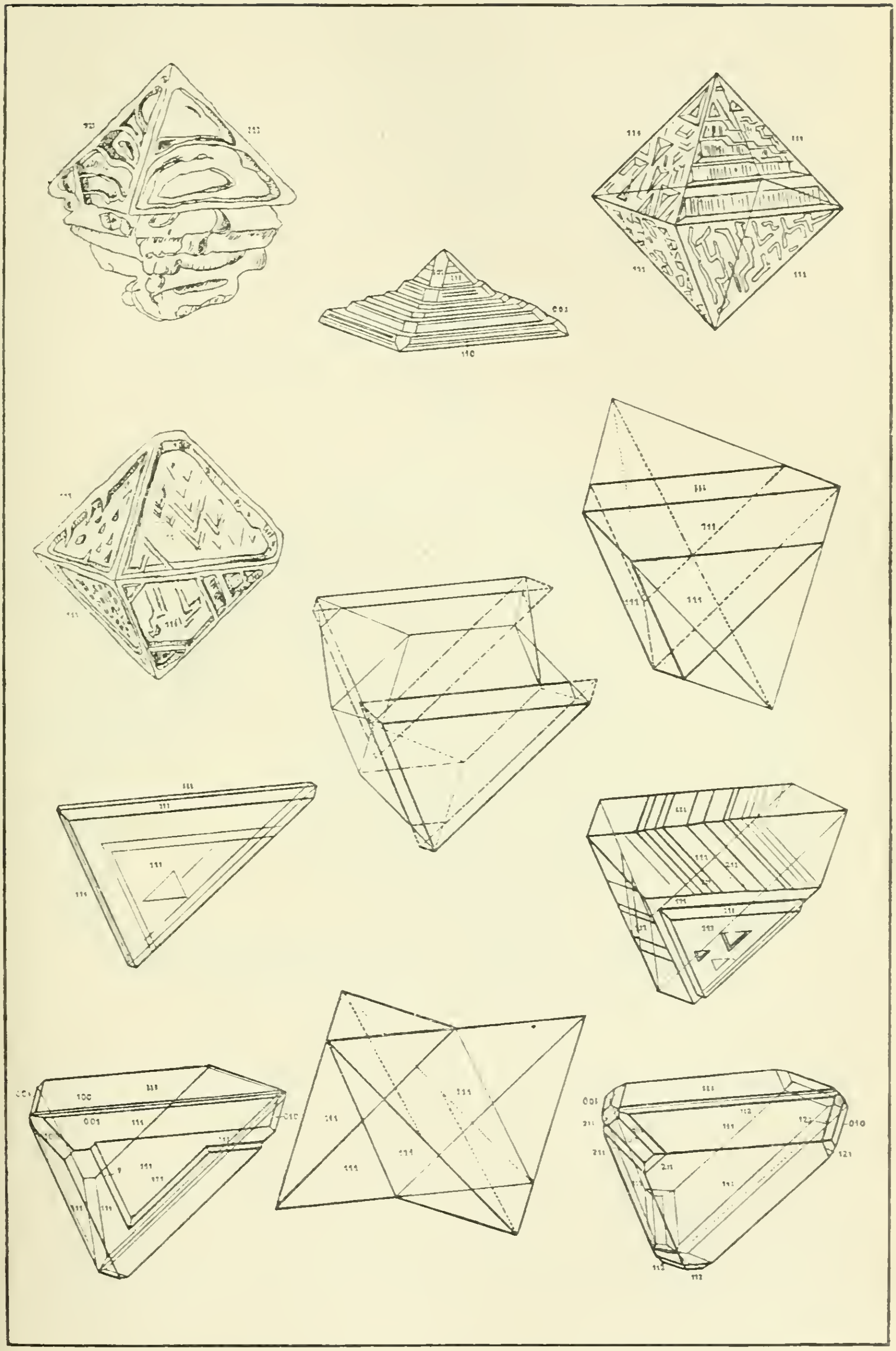
Figs. 7–12. Forms of Crystallized Gold.
Figs. 7 and 8. California. Fig. 9. Urals. Fig. 10. Boicza. Figs. 11 and 12. California.
$a=\{100\}$, $o=\{111\}$, $d=\{110\}$, $m=\{311\}$, $x=\{18.10.1\}$.

forms are rare. Abnormal forms observed in gold crystals have at times been ascribed to inclined hemihedrism, but there is no sound evidence for this assumption, and gold in crystallization may be regarded as always holosymmetric. The crystallization of gold, and particularly of specimens from Transylvania, from the Urals, and from Western North America, has been closely studied by Rose,[c] Helmhacker,[d] vom Rath,[e]

[a] " L'Or dans la Nature," Cumenge and Robellaz, Paris, 1897, p. 40.
[b] This form has been determined as {15.9.1} by Naumann and as {19.11.1} by Rose.
[c] Pogg. Annal., XXIII, 1831, p. 196.
[d] Min. Mittheil., 1877, App. No. 1.
[e] Zeit. für Kryst., I, 1877, p. 1.



Figs. 13–23. Forms of Crystallized Gold, Sysertsk, Urals (*Helmhacker*).



FIGS. 24–34. FORMS OF CRYSTALLIZED GOLD, SYSERTSK, URALS (*Helmhacker*).

Werner,[a] Dana (E.S.), and others.[b] Considerable aberration from the ideal forms of isometric symmetry is general, as will be seen from an inspection of the accompanying figures. Abnormal forms are to be explained by simple or compound twinning parallel to the octahedron or by elongation or flattening along a di-trigonal axis of symmetry (a cube diagonal), and one, therefore, normal to faces of the octahedron. Twinning and elongation may produce rhombohedra. The form shown in Fig. 45 is apparently a com-

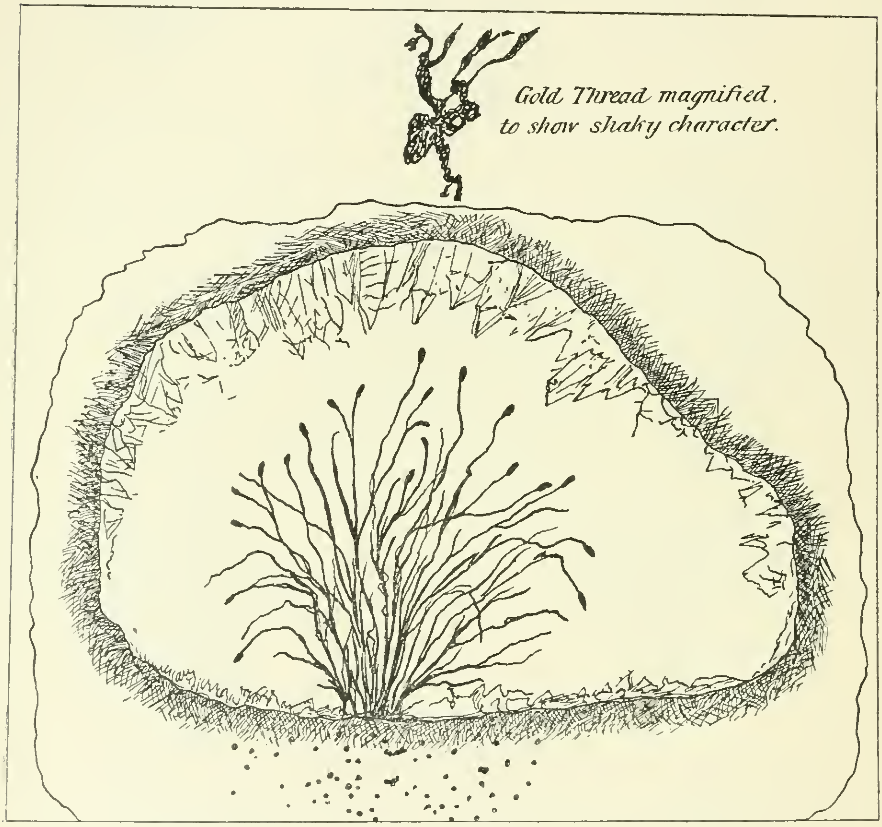


FIG. 35. FILAMENTARY GOLD IN QUARTZ VUGH, CALEDONIAN MINE, NEW ZEALAND (*Ward*). About ½ natural size

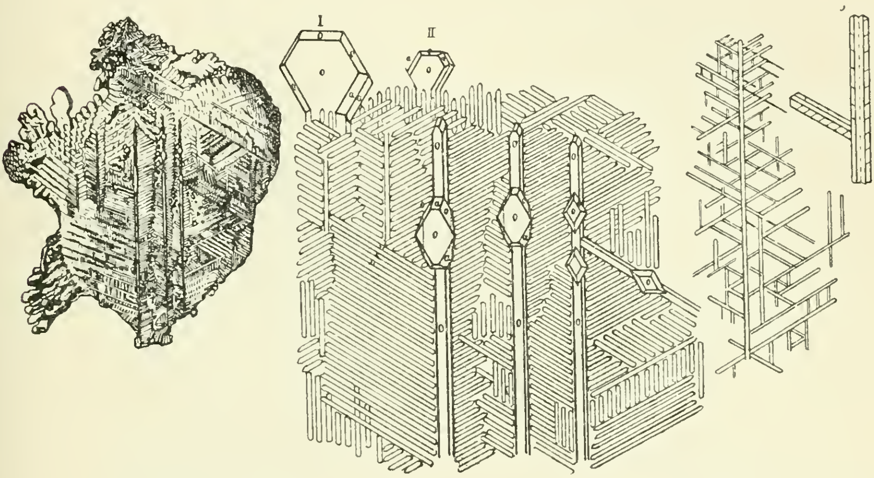
bination of three separate rhombic prisms (with angles of 70° 32′) terminated in each case by pyramid faces. In reality each branch is a combination of two elongated cubes (*a*) twinned along an octahedral plane and terminated by faces of the tetrahexahedron (*e*), in this case, {210}. The faces of the cube are further striated

[a] Neues Jahrb. für Min., I, 1881, p. 1.

[b] Am. Jour. Sci., XXXII, 1886, p. 132.

parallel to their intersections with the faces of the terminating tetrahexahedron, indicating probably successive stages of parallel growth. On the other hand, flattening along an axis normal to the octahedral face may produce forms that simulate very closely monoclinic plates. (Figs. 46 and 47.) Other faces beside those of the cube may be striated. Lewis[a] has noted deep striations on the faces of the trapezohedron {811} parallel to their line of intersection with the faces of the cube.

Moss-gold, wire-gold, and dendritic forms may ordinarily be taken to indicate incipient crystallization along di-trigonal axes of symmetry, accompanied by abnormal elongation along those axes. In some cases, as in the wire-gold from the Santa Isabel mines of Colombia, elongation is accompanied by twinning. A

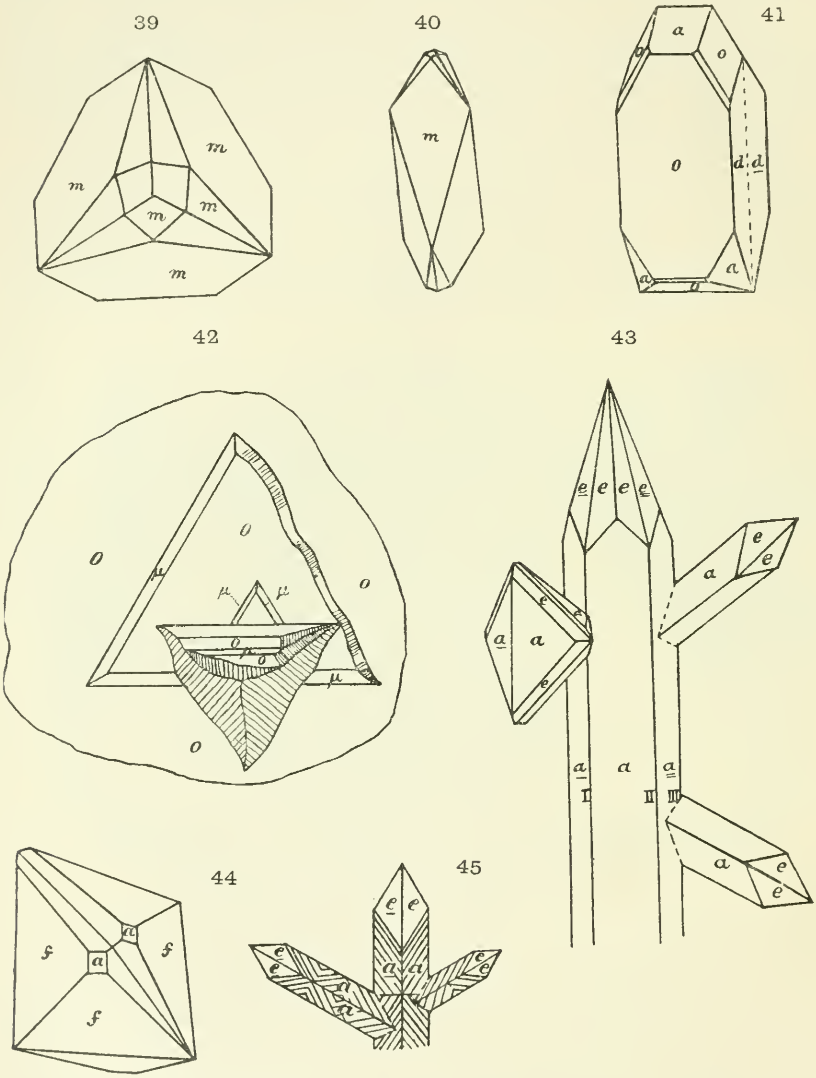


FIGS. 36–38. INCIPIENT CRYSTALLIZATION OF GOLD, VERESPATAK (*Vom Rath*).
$a=\{100\}$, $o=\{111\}$.

remarkable form of moss-gold is shown in Fig. 35 from the formerly famous Caledonian mine, Thames, New Zealand. The whole grew in a cavity lined with quartz crystals. The filaments were sufficiently strong and sufficiently interlaced to maintain an upright position. They were, curiously enough, terminated by well-defined crystals of chalcopyrite, crystals of which were also attached like buds to other parts of the threads.[b] Filaments of gold simulating moss- and tree-gold have been produced by Liversidge[c] by roasting auriferous mispickel, but it is nevertheless extremely improbable that any

[a] Phil. Mag., III, 1877, p. 456.
[b] Ward. Min. Mag., III, 1879, p. 81.
[c] Proc. Roy. Soc. N.S.W., XXVII, 1893, p. 1.

natural filamentary gold has been deposited otherwise than from aqueous solution. Gold occasionally shows crystalline skeletal growth as parallel octahedra united on octahedral faces. Much



Figs. 39–45. Forms of Crystallized Gold.

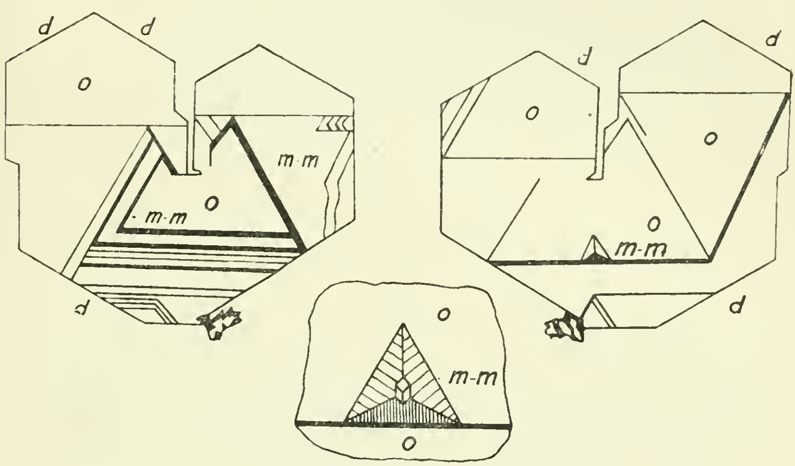
Figs. 39 and 40. Oregon (*Dana*). Fig. 41. Verespatak, Transylvania (*Vom Rath*). Fig. 42. Verespatak (*Werner*). Fig. 43. Twin-crystals, Verespatak (*Vom Rath*). Fig. 44. Berezovsk, Urals (*Fletcher*). Fig. 45. Twin-crystals, Zdraholez (*Vom Rath*).

$o=\{111\}$, $a=\{100\}$, $d=\{110\}$, $m=\{311\}$, $e=\{210\}$, $f=\{310\}$, $\mu=\{411\}$.

more rarely does it occur as successive cubes disposed along an axis of di-trigonal symmetry. The last form is common enough for skeletal growths of native silver, as from Kongsberg, Norway, but has been noted, by the present writer at least, only in a few specimens, of which one of the most perfect, from an unknown locality, is in the Cambridge University Mineralogical Museum. Indications of the same form of growth may also be observed in the La Trobe nugget, figured in the frontispiece of this volume.

The percentage of silver admixed with gold appears to exercise but little influence on crystallization, as might indeed be inferred from the isometric symmetry of native silver. Neverthcless there are some grounds for a suggestion that the tendency of the purer gold is to adopt the simpler forms (octahedra and cubes) in crystallizing rather than the trapezohedra, hexoctahedra, &c., found

46 47



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FIGS. 46–48. CRYSTALLIZED GOLD, HAURAKI ASSOCIATED MINE, COROMANDEL (*Maclaren*).
Figs. 46 and 47. Opposite sides of same plate, $\times 1\frac{1}{2}$. Fig. 48. $\times 6$.
$o=\{111\}$; $d=\{110\}$; $m\text{-}m=\{m\,11\}$.

most commonly in electrum or low-grade "gold." The problem is, however, complicated by the fact that crystals of the purer gold are, as a rule, found in alluvial gravels, while those of electrum (native gold-silver alloy) are derived from fissures in the vadose zones. The distinction, such as it is, may therefore arise from accompanying physical conditions, and not from inherent properties of gold and of gold-silver alloy respectively.

Even the purest native gold contains some silver. The finest gold yet recorded is that from the Great Boulder mine, Kalgoorlie, Western Australia. It was obviously derived from the decomposition of auriferous tellurides and was 999·1 fine. A small quantity of gold from the Pike's Peak mine, Cripple Creek, Colorado, showed on assay a fineness of 999, while a very large portion of the outcrop gold of the famous Mount Morgan mine, Queensland, was 997 fine.[a] The last has furnished probably the greatest bulk of fine gold, for the two first-mentioned results were obtained from assays of small picked samples, rather than from the mass of the gold recovered on a commercial scale.

Alluvial gold directly derived from the degradation of auriferous veins is invariably higher in quality than the gold of the parent vein, since meteoric waters act on all sides of the liberated grains and particles, and remove much of the more soluble silver. It is commonly noted that alluvial gold-dust from the lower reaches of any given river is much higher in quality than the coarser grains and nuggets of gold found in the upper waters of the same stream, the increase in purity arising, of course, from the greater total surface exposed, in the case of the finer dust, to the action of silver solvents.

Pure Gold.—Pure gold is a clear yellow metal, unaffected by the atmosphere or by its contained impurities. The colour may be varied considerably by alloy with other metals, admixture with copper producing a reddish tinge, while a certain percentage of silver, notably 15 per cent. according to Leach,[b] yields a distinctly green colour. Finely-divided gold is purple by reflected and green by transmitted light. The metal is exceedingly malleable. Its density when perfectly pure and when in ingots reaches 19·3 at 70° C., but this density is, of course, never attained in nature. According to Kahlbaum and Sturm[c] the density of soft gold is 19·2601; and of hard-hammered gold, 19·2504. The melting point of gold is in the neighbourhood of 1,064° C. The following temperatures have been arrived at experimentally: 1,061° (Callendar), 1,061° (Heycock and Neville), 1,064·3° (Holborn and Day), 1,065·6° (D. Berthelot), 1,067·4° (Jacquerod and Perrot). When molten, gold appears to take on a greenish tinge. It may be readily volatilised in the electric furnace. With a current of 350 amperes at 110 volts no less than 60 grammes (nearly 2 ounces) were volatilised in 6 minutes. With a current of the same voltage but of 500 amperes 13·3 per cent. of an ingot weighing 150 grammes (nearly 5 ounces) was vaporised in 6½ minutes.[d] The gold thus volatilised condenses either as deep yellowish-green spherules, coated often with a purple glaze, or as filaments, or occasionally as minute, brilliant yellow cubical crystals. In a vacuum gold commences to volatilise at a

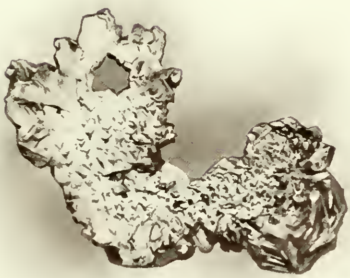
[a] Leibius, Proc. Roy. Soc. N.S.W., XVIII, 1884, p. 37.

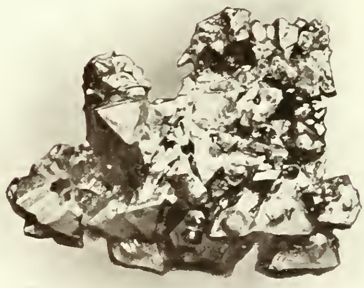
[b] Min. Sci. Press, Feb. 28, 1908, p. 195.

[c] Zeit. anorg. Chem., XLVI, 1905, p. 244.

[d] Moissan, Compt. Rend. Acad. Sci., Paris, CXLI, 1905, p. 977.

Plate I.





Alluvial Gold,
Otago, New Zealand.
(Nat. size.)

Vein Gold,
Sentaschli River, Orenburg, Russia.
(Photo. Dr. Hatch. ¾ nat. size.)

Vein Gold,
Antioquia, Colombia.
(British Museum. Nat. size.)

Gold Crystals
with Blistered Faces, California.
(British Museum. Nat. size.)

CRYSTALLIZED GOLD.

temperature of 1,070° C.,[a] and boils at 1,800° C.[b] Under atmospheric pressure the boiling point of gold is estimated at 2,530° C.[c]

Gold is attacked in the dry way by fluorine at a temperature of 300° C., and by chlorine under the same conditions at 200° C. In the former case the fluoride formed is decomposed on increase of temperature. Tellurium vapour, according to Margottet, attacks gold, yielding a crystalline telluride.[d] Neither sulphur nor selenium are known to combine directly with gold; and few acids have any effect on it. Mitscherlich,[e] as far back as 1827, reported its solubility in selenic acid. Gold is attacked by iodic acid in the presence of sulphuric acid and by hydriodic acid in an ethereal solution. The usual solvent used in the arts is, of course, *aqua regia* (nitro-hydrochloric acid). Gold is also soluble in fuming hydrochloric acid, in oxygenated hydrochloric acid, in permanganic acid, &c. The last and other solvents well known in the laboratory, however, appear to have little scope for action in nature and need not be discussed in this place.

NATIVE ALLOYS OF GOLD.

Electrum.—The electrum of Pliny (probably named on account of its yellow colour, from the Ηλεκτρον, or amber, of Strabo) was defined as a natural alloy containing one-fifth of silver. The term is occasionally used by modern writers to cover natural gold-silver alloys, but has not met with general acceptance, its place being supplied by an extension of the term "gold." Electrum is derived almost entirely from the Tertiary andesitic goldfields of North, South, and Central America, New Zealand, and Hungary. Its colour varies, with the percentage of silver present, from yellowish white to pale yellow; its specific gravity ranges between 12·5 and 15·5. The proportions of gold and silver present are often molecular, and may for the given cases indicate definite chemical compounds, as was first pointed out by Boussingault.[f] It is, however, probable that in the majority of occurrences electrum is composed of an exceedingly intimate mixture (an isomorphous solid solution) of gold and silver.

The occurrence of electrum or low-grade gold in the veins of the younger volcanic deposits alone may possibly be regarded

[a] Schuller, Zeit. anorg. Chem., XXXVII, 1903, p. 69.

[b] Krafft and Bergfeld, Berichte Chem. Gesell., XXXVIII, 1905, p. 254.

[c] Moissan, loc. cit. sup.

[d] Margottet, Ann. de l'École normale, VIII, 1879, p. 247.

[e] Ann. Phys. Chem. Pogg., IX, 1827, p. 623.

[f] Ann. Chem. Phys., XXXIV, 1827, p. 408.

as evidence of a more or less direct magmatic origin for the electrum. Here the gold is still associated with the metallic impurities of the solfataric waters in which it has made its ascent towards the surface; the alloy has not yet been subjected to those selective agents of solution and precipitation that have had abundant opportunities in time and space to refine the gold of the older vein deposits. Even if the gold of ancient veins does not represent the end-product of processes of solution and precipitation many times repeated, at least it often, as in the Ordovician rocks of Victoria, denotes a long journey in space through fissures of rocks capable of exercising a selective action on the metals of passing solutions.

Maldonite.—Maldonite or bismuth-gold is a well-defined compound of gold and bismuth. It was discovered and described by Uhlrich[a] from the quartz of the Nuggetty Reef, Maldon, Victoria. It occurred, when originally described, only as minute grains and specks, but the outcrop and upper zones of the Nuggetty Reef contained considerable quantities of the bismuth-gold, or "black gold," as it was termed by the miners. Its mineralogical characters are: hardness, 1·5 to 2·0; malleable; very sectile; very bright metallic lustre and pinkish silver-white colour when freshly broken, but tarnishing gradually on exposure, first to a dull copper colour and ultimately to black. No crystal forms have been observed. Heated on charcoal before the blowpipe it readily melts in the oxidising flame to a bead of gold, yielding the usual yellow bismuth incrustation on the charcoal. The following analyses have been made:—

Au.	Bi.	Analyst.
64·5	35·5	Newbery.
65·12	34·88	McIvor.[b]

To this group belongs the somewhat doubtful *bismuthaurite* of Shepard[c] from Rutherford County, North Carolina, where the mineral occurred in small malleable palladium-like grains. Hardness, 2 to 3; and specific gravity, 12·44 to 12·90. It has generally been considered an artificial product, and is not mentioned by Genth in his catalogue of the minerals of North Carolina.[d]

[a] Contrib. Mineral. Victoria, Melbourne, 1870, p. 4.

[b] McIvor, Chem. News, LV, 1887, p. 191.

[c] Am. Jour. Sci., XXIV, 1857, pp. 112, 281.

[d] Bull. No. 74. U.S. Geol. Surv., 1891.

Nenadkevitch[a] reports bismuth-gold approaching to bismuth-aurite from the telluric and bismuth ores of Schil-Isset in the Urals.

Rhodite.—The rhodium-gold alloy or rhodite of Adam[b] is of doubtful occurrence in nature. It has been described only by Del Rio, and that nearly a century ago,[c] from material afterwards said to have come from the placers of Mexico and Colombia. It was said to contain 34 to 43 per cent. of rhodium, and to have a specific gravity of 15·5 to 16·8. It is certainly not evident from Del Rio's original paper (communicated by the famous traveller, Humboldt) that the substance examined was a natural alloy, being, indeed, designated by Del Rio simply "un alliage d'or."[d] The material was, moreover, obtained at the Apartado (mint) of Mexico, and from the terms of Del Rio's description it would appear that the alloy described had been obtained after melting.[e]

Porpezite.—Palladium-gold or porpezite was named in error by Fröbel,[f] after the supposed name (Porpez) of the locality (Pompeō) in which it was first found.[g] Porpezite of a dark or bronze-like, or bright copper-red colour, containing 5 to 10 per cent. of palladium, together with a little silver, is found in the Minas Geraes province, Brazil (at Jacutinga, Condonga, Sabara, Gongo Socco, &c.). Seamon[h] found in porpezite from Taguaril, Brazil, Au 91·06 and Pd 8·21 per cent., corresponding therefore to the formula $Pd\,Au_6$. Its specific gravity was 15·73. Palladium-gold has also been reported from gold-washings in the Caucasus, near Batoum.[i]

Ruer,[j] however, concludes from an examination of the freezing-point curves of artificial alloys of gold and palladium that these alloys form a continuous series of mixed crystals, and that there is no indication of chemical combination. The fact that none of the three elements, copper, silver, and gold, enter into chemical combination with palladium is further considered by Ruer to exemplify Taumann's rule,[k] according to which either all or none of the

[a] Min. Jour., Oct. 19, 1907.

[b] Tableau Mineralogique, 1869, p. 83

[c] Annales de Chemie et de Physique, XXIX, 1825, p. 137; Ann. des Mines, XII, 1826, p. 323.

[d] Ann. de Chem. Phys., XXIX, p. 138.

[e] I can find no authority for the statement (*e.g.*, Cumenge and Robellaz, "L'Or dans la Nature," Paris, 1898, p. 65) that the material examined came from Colombia.

[f] Haidinger, Handbuch der bestimmenden mineralogie, 1845, p. 558.

[g] Dana, System of Mineralogy, 1892, 6th Edition, p. 15.

[h] Chem. News, XLVI, 1882, p. 216.

[i] Wilm, Zeitsch. anorg. Chem., IV, 1893, p. 300.

[j] Ib. LI, 1906, p. 391.

[k] Jour. Chem. Soc., 1906, A. II, p. 346.

elements of a natural group in the narrower sense enter into chemical combination with each other.

Amalgam.—Gold amalgam occurs native. It contains a variable proportion of mercury, and is apparently of indefinite composition. Amalgam with 57·4 per cent. mercury is reported from the alluvial placers of Colombia.[a] Amalgam from Mariposa, California, yielded, on analysis, 61 per cent. mercury, and had a specific gravity of 15·47.[b] In placer mines that have long been worked much of the amalgam now found is doubtless of secondary origin, due to the union of gold with quicksilver lost by the old miners. Native amalgam is found in the gravels of the Pek river, Servia, where it is termed "zivak," and in Victoria, in the quartz of the German Reef, Tarrangower.[c] Artificial crystals of gold-amalgam show faces of the octahedron, cube, rhombic dodecahedron, and trapezohedron.[d]

[a] Schneider, Jour. prakt. Chem., XLIII, 1848, p. 317.

[b] Sonnenschein, Zeit. deutsch. geol. Gesell., VI, 1854, p. 243.

[c] Uhlrich, Berg. u. Hütt. Zeit., XVIII, 1859, p. 221.

[d] Id., Contrib. Min. Vict. 1866, p. 82.

NATURAL COMPOUNDS OF GOLD.

Tellurides of Gold.—Of the numerous salts of gold only those which occur, or which may possibly occur, in nature, will here be considered. Gold is an element forming stable compounds with difficulty even in the laboratory under the conditions obtaining at or near the earth's surface ; in nature its stable salts are restricted to the telluride group, if, indeed, even these be definite chemical compounds. Members of this group were first described from Zalathna, Transylvania, by Klaproth, in 1802. They form notable additions to the gold content of the veins of Nagyag and Offenbanya, in Hungary, where they have been mined for many years. Telluride-ores of gold nevertheless assumed economic importance only with the discovery of the rich camps of Cripple Creek, in Colorado, and of Kalgoorlie, in Western Australia. Prior to the discovery of the Cripple Creek field telluride-ores had been known in Colorado since 1872, and had been worked, with indifferent success, in Boulder County, and in the La Plata and San Juan mountains. Though their presence has been reported during the past 10 years from other regions, the two great goldfields above-mentioned remain the only telluride fields of economic importance. Gold-tellurides occur at Deutsch-Pilsen, Bohemia ; Nagyag, Offenbanya, Zalathna, and elsewhere in Hungary ; Mount Morgan,[a] and Gympie,[b] Queensland ; South Lepanto, Phillipine Islands ; Hauraki Goldfields, New Zealand,[c] where it has been determined only by analysis ; Rhodesia, South Africa,[d] also by analysis ; Moss Township, Ontario (sylvanite) ; Dahlonega, Georgia (sylvanite) ; King's Mount, North Carolina (nagyagite) ; Taku, South Yukon (sylvanite) ; Tonopah and Goldfield, Nevada ; and Shasta and Calaveras Counties, California.

It is characteristic of the known great deposits of telluride-ores that they occupy zones or belts of impregnation or fill minute fissures, and are not associated with quartz deposition in vein-fissures or with silicification of the country adjacent to fissures. There is, nevertheless, no ground for a consequent assumption of pneumatolytic origin for telluride-ores ; they, as well as the great majority of sulphide ores impregnating country or filling fissures,

[a] Rickard, T A., Trans. Amer. Inst. M.E., XXX, 1900, p. 713.

[b] Dunstan, Rec. Geol. Surv. Queensland, No. 2, 1904.

[c] Allen, Trans. Aust. Inst. M.E., VII, 1901, p. 95 ; Baker, *in litt.*

[d] Mennell, Proc. Rhod. Sci. Assn., 1902.

may best be considered to arise from deposition from heated aqueous solutions. In this connection, however, it is interesting to note that Cossa[a] determined the presence of tellurium in fumarolic concretions from the crater of Vulcano (Lipari), and succeeded in separating 2½ grammes of pure tellurium from three kilograms of the concretionary material. The concretions contain also selen-sulphur, arsenic sulphide, and hieratite (2 K F. SiF_4), together with rarer minerals, the whole forming a most suggestive assemblage. Tellurides of gold and silver when brought within reach of surface oxidising waters are readily decomposed, and the gold, at least, is reduced to the metallic state, in which condition it serves as a nucleus for the precipitation of gold from wandering solutions. As Lenher has recently shown, reduction is also effected by any of the natural metallic tellurides. There may therefore, in the oxidised zone of a gold-telluride vein, be found both a dull finely-divided mossy gold ("mustard gold") derived directly from the decomposition of the tellurides, and a bright lustrous form precipitated from solutions. It is, on the whole, very probable, as suggested by Lenher[b] from his failure to produce definite compounds by synthetical methods, that the natural tellurides are also not definite chemical compounds, but are rather in the nature of alloys, thus controverting the earlier work of Brauner,[c] who had asserted that definite crystalline polytellurides were obtainable in the laboratory.[d]

It may be regarded as more than a coincidence that the tellurides of gold are confined to regions of characteristic andesitic facies, or to the Archæan hornblendic schists, which are, as will be seen later, probably to be considered merely as metamorphosed prototypes of the Tertiary andesitic complexes. It is true that through the auriferous Archæan schists there ramify numerous diabasic dykes of much later age, but it will be shown later that the work of these dykes, so far as it relates to auriferous deposition, has been the formation of quartz lodes with free gold. The speculation may therefore be advanced that tellurides of gold are directly and genetically connected with magmas of intermediate composition.

In the following pages the various naturally occurring tellurides are described with some detail.

Calaverite.—Calaverite, associated with petzite, was discovered by Genth[e] in ore from the Stanislaus mine, Calaveras County,

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[a] Atti. del. Accad. Scienze, Torino, XXXIII, 1897, p. 450.

[b] Jour. Am. Chem. Soc., XXIV, 1902, pp. 358, 919.

[c] Jour. Chem. Soc., LV, 1889, p. 391.

[d] See also Margottet, Ann. de l'École normale, VIII, 1879, p. 247.

[e] Am. Jour. Sci., XLV, 1868, p. 314.

California. It is found in considerable quantity at Cripple Creek, Colorado, and is also the principal gold-telluride ore of the famous Kalgoorlie field in Western Australia. It usually occurs massive, and such crystallized specimens as have been found have been too imperfect to admit of the determination of the crystallographic system. Its colour is pale bronze-yellow ; when scratched it gives a yellowish-grey streak. Its hardness varies from 2 to 3, and its specific gravity from 9·311 to 9·377. Unlike sylvanite and krennerite it has no perfect cleavage, and breaks with an uneven fracture. Its composition is best represented by the formula Au Te_2 (Au 56·3, Te 43·7) to which, indeed, its analyses show it to be fairly constant.

	Te.	Au.	Ag.		Analyst.
Cripple Creek	57·60	39·17	3·21	Insol. 0·33, Fe_2O_3 0·12	Hillebrand
,, ,,	57·40	40·83	1·77	....	,,
,, ,,	57·30	41·80	0·90	....	,,
Kalgoorlie	56·65	41·76	0·80	....	Mingaye
,, ...	59·69	38·70	1·66	Cu, Fe, S, Pb, Bi, Zn, 0·48 ..	Rogers
,, ...	58·63	37·54	2·06	Cu, Fe, Ni, Se, S, gangue, 1·81 ..	Klüss
,, ...	60·30	33·93	4·82	Cu, Fe, 0·63	Carnot

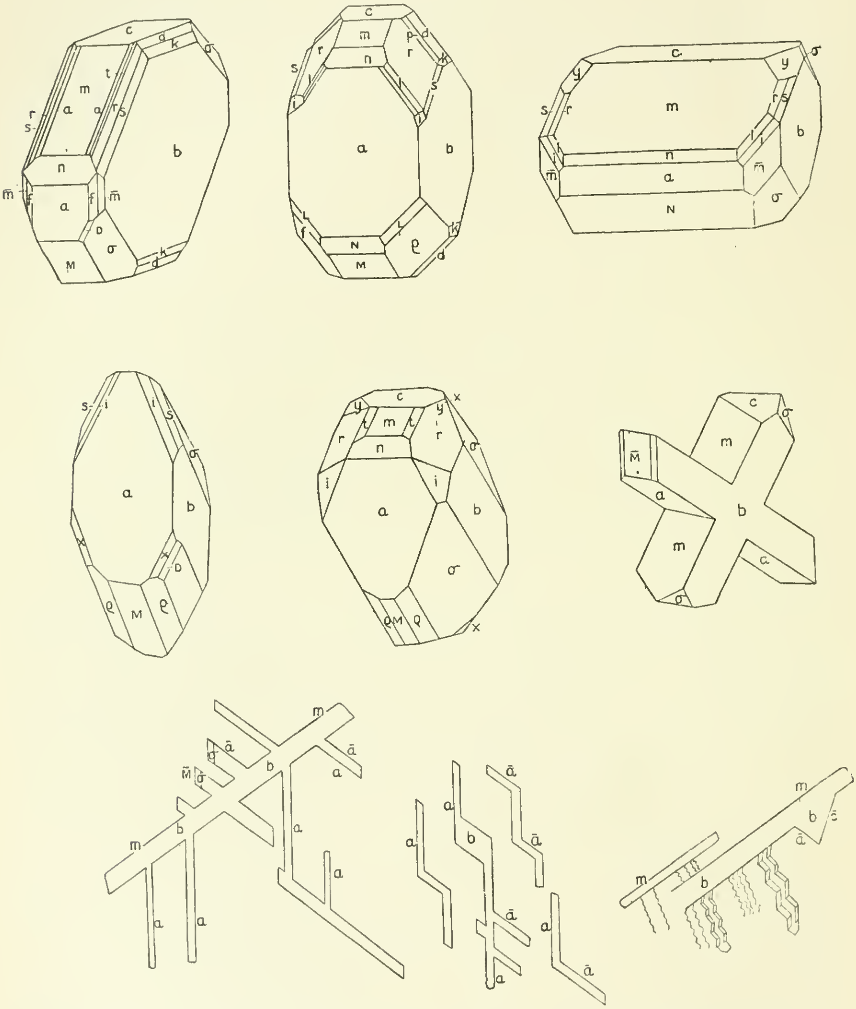
Before the blowpipe on charcoal, calaverite fuses with a bluish green flame, leaving a yellow bead of gold. Heated in the closed tube, it gives a black sublimate of metallic tellurium, and a less volatile yellow (hot) or white (cold) sublimate of tellurous oxides. The gold beads obtained either on charcoal or in the closed tube often show the phenomenon of *recalescence*—a sudden secondary flashing and glowing of the bead, due probably to the presence of a small quantity of tellurium.[a]

Calaverite has been recorded from the Stanislaus mine, Calaveras County, California, associated with petzite ; from the Red Cloud, Keystone, and other mines, Boulder County, Colorado, associated also with petzite ; from the Cripple Creek district, Teller County, Colorado ; and from the mines of Kalgoorlie, Western Australia, where it occurs with sylvanite, krennerite, and petzite. It is said to occur also in the Southern Lepanto district, Phillipine Islands.

Sylvanite.—Telluride of gold and silver. Type formula : (Au Ag) Te_2 ; but the mineral as occurring in nature appears

[a] Spencer, L. J., Min. Mag., XIII, 1903, p. 270.

to have a fairly constant composition that may be represented as Au Ag Te_4. Axes; $\grave{a} : \bar{b} : \acute{c} = 1{\cdot}63394 : 1 : 1{\cdot}12653$; $\beta = 89° \ 35' = 001 \wedge 100$. System of crystallization: monoclinic. The observed forms have been: orthopinacoid (100); clinopinacoid (010); basal plane (001); unit prism (110); orthodiagonal prisms



FIGS. 49–57. SYLVANITE (Graphic Tellurium) FROM NAGYAG AND OFFENBANYA (*Schrauf*).

a=(100), b=(010), c=(001), m=(110), f=(210), d=(001), x=(012), M=($\bar{1}01$), N=($\bar{2}01$), $\bar{m}$=(101), n=(201), Q=($\bar{1}11$), D=(221), r=(111), σ=(121), L=($\bar{5}22$), p=(341), s=(121), y=(123), i=(321), t=(323), l=(211), $\propto$=(414).

(210), (310), (510); clinodiagonal prism (120); orthodomes ($\bar{1}01$), ($\bar{2}01$), ($\bar{3}01$), (101), (201), (301); clinodomes (001), (012), (021); hemi-octahedrons ($\bar{1}11$), ($\bar{1}12$), ($\bar{2}23$), ($\bar{2}21$), (111), (112), (221);

orthodiagonal pyramids (414), (314), (313), (311), (621), (525), (723), (521), (213), (212), (211), (421), (323), (321), (542); ($\bar{7}$21), ($\bar{6}$21), ($\bar{3}$11), ($\bar{5}$22), ($\bar{5}$21), ($\bar{2}$13), ($\bar{2}$12), ($\bar{2}$11), ($\bar{4}$21), ($\bar{3}$23), ($\bar{3}$21), ($\bar{5}$42); clinodiagonal pyramids (341), (343), (231), (121), (122), (123), (381), (131), (141), (292), (161); ($\bar{6}$71), ($\bar{3}$41), ($\bar{2}$31), ($\bar{1}$21), ($\bar{1}$22), ($\bar{1}$23), ($\bar{3}$81), ($\bar{1}$31), ($\bar{1}$41). Twinning plane: the orthodome ($\bar{1}$01). Twinned members occur as contact twins, as twinned lamellae, and as penetration twins, giving rise to branching arborescent forms crossing at angles of 69° 44′ and resembling written characters (whence the name *graphic tellurium*, Ger., Schrifttellur). Skeletal forms common, also bladed, and imperfectly columnar to granular. Cleavage: perfect, parallel to the clinopinacoid (010). Fracture uneven. Brittle. Hardness, 1·5 to 2. Specific gravity, 7·9 to 8·3. Lustre: metallic, brilliant. Colour and streak pure steel-grey to silver-white, sometimes nearly brass-yellow. The following are the principal analyses available:—

Locality.	Te.	Au.	Ag.		S.G.	Analyst.
Offenbanya ..	59·97	26·97	11·47	Cu 0·76, Pb 0·25, Sb 0·58	8·28	Petz
Nagyag ..	61·98	26·08	11·57	Pb tr., Cu 0·09, Fe 0·40	8·036	Hankó
Red Cloud, Colorado ..	59·78	26·36	13·86	....	7·94	Genth
Kalgoorlie ..	60·83	28·55	9·76	Cu 0·32, Fe 0·16, Ni 0·10, Se 0·20	..	Krusch
Cripple Creek ..	60·82	26·09	12·49	Fe 1·19, Insol. 1·02	8·161	Palache

In the open-tube sylvanite yields a white sublimate of tellurium oxide, which near the assay is grey; the sublimate when treated with the blowpipe flame fuses to clear transparent beads. When heated before the blowpipe on charcoal, sylvanite fuses to a dark-grey globule, covering the coal with a white coating, which, treated with the reducing flame, disappears, giving a bluish-green colour to the flame; after long blowing a yellow malleable metallic globule of gold is obtained. Most varieties give a faint coating of lead oxide and antimony trioxide on charcoal.[a]

Sylvanite derived its name from its earliest known occurrence in the Transylvanian mountains (Franciscus and Barbara mines, Offenbanya). Elsewhere in the Siebenbürgischen Erzgebirge it

[a] Dana, "System of Mineralogy," 6th Ed., 1892, p. 104.

occurs at Zalathna, Nagyag, and Faczebaj. An occurrence has been noted from Deutsch-Pilsen, Hungary. In the United States of America it has been recorded from the Stanislaus and Melones mines, Calaveras County, California; from the Red Cloud, Grand View, and Smuggler mines, Boulder County, Colorado; from many Cripple Creek mines; and from Balmoral and Preston in the Black Hills of South Dakota, where gold-telluride ores occur in a dolomitic limestone.[a] In Canada, sylvanite is reported from the Huronian mine in the Thunder Bay district of Ontario. Large quantities have also been found at Kalgoorlie, Western Australia.

Müllerine.—Müllerine is a brass-yellow telluride of gold, silver, antimony, and lead, from Nagyag, Transylvania. It appears, however, to be merely a variety of sylvanite or of krennerite, the presence of antimony and lead being due to impurities. Like krennerite it decrepitates under the blowpipe, and as, according to Krenner and Schrauf, its angles are identical with those of krennerite, it should perhaps be referred to that species rather than to sylvanite. The following analyses have been made of the mineral and have served as the foundation on which the species has been differentiated :—

	Te.	Sb.	Au.	Ag.	Pb.	S.G.	Analyst.
White Crystals	55·39	2·50	24·89	14·68	2·54	8·27	Petz
,, ,, ...	48·40	8·42	28·98	10·69	3·51	7·99	,,
Yellow Crystals	51·52	5·75	27·10	7·47	8·16	8·33	,,
Yellow, Massive....	44·54	8·54	25·31	10·40	11·21	..	,,
,, ,, ...	49·96	3·82	29·62	2·78	13·82	..	,,
,, ,, ...	44·75	..	26·75	8·50	19·50	..	Klaproth

The *goldschmidtite* of Hobbs[b] has proved on further examination of the type crystals and of fresh material to be referable to sylvanite, representing, however, a peculiar crystal habit of that mineral. The original material on which the term goldschmidtite was founded came from the Gold Dollar mine, Cripple Creek, Colorado. The differentiation of goldschmidtite as a distinct mineral species has therefore been abandoned by Hobbs.[c]

Krennerite.—Krennerite was first described by Vom Rath.[d] It differs from sylvanite only in crystallization, and when both are massive the separation into species is impracticable. It crystallizes

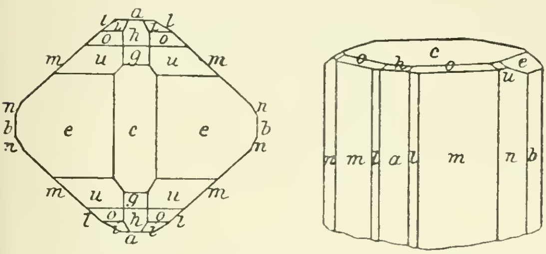
[a] Smith, F. C., Jour. Pract. Chem., VI, 1898, p. 67.

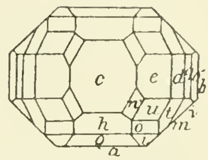
[b] Am. Jour. Sci., VII, 1899, p. 357.

[c] Palache, Am. Jour. Sci., X, Ser. 4, 1900, p. 426.

[d] Zeitsch. Kryst., I, 1877, p. 614.

in the rhombic system. Axes, $\breve{a} : \bar{b} : \dot{c}$: = 0·94071 : 1 : 0·50445. The crystal forms observed on krennerite have been :[a] Basal plane (001) ; macropinacoid (100) ; brachypinacoid (010) ; unit prism (110) ; macrodiagonal prisms (210), (320) ; brachydiagonal prisms (120), (130) ; macrodomes (102), (101), (201), (301) ; brachydomes (011), (021), (031), (041) ; unit pyramid (111) ; macrodiagonal





FIGS. 58 AND 59. KRENNERITE, NAGYAG (*Vom Rath*). FIG. 60.—KRENNERITE (*Miers*).
a = (100), *b* = (010), *c* = (001), *l* = (320), *m* = (110), *n* = (120), *h* = (101), *e* = (011), *d* = (021), *q* = (031), *σ* = (041), *h* = (110), *g* = (102), *Q* = (201), *w* = (124), *u* = (122), *t* = (121), *v* = (362).

pyramids (211), (322) ; brachydiagonal pyramids (122), (124), (121), (362).

Crystals of krennerite are usually prismatic and vertically striated. Its cleavage is basal and perfect. Fracture, sub-conchoidal to uneven. Brittle. Hardness ranges from 2 to 3 ; specific gravity : 8·3533. Lustre : metallic, brilliant. Colour : silver-white to brass-yellow. Opaque. Its composition, like that of sylvanite, may be represented by the general formula (Au Ag) Te_2, but while the proportions of silver and gold in sylvanite are fairly constant, considerable variation has been observed in krennerite, as is shown in the following selected analyses :—

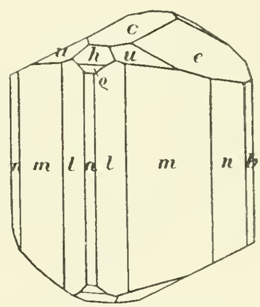


FIG. 61. KRENNERITE, CRIPPLE CREEK (*Penfield*).

Locality.	Te.	Au.	Ag.	Sb.		S.G.	Analyst.
Nagyag	39·14	30·03	16·69	[9·75]	S. 4·39	5·598	Scharizer
,, ...	45·59	34·97	19·44	..	..	..	,,
,, ...	58·60	34·77	5·87	0·65	Cu 0·34 Fe 0·59	8·353	Sipöcz
Cripple Creek	55·68	43·86	0·46	..	....	..	Chester
Kalgoorlie	58·63	36·60	3·82	..	....	..	Frenzel
,, ...	56·65	41·76	0·80	..	....	..	Pittman

[a] Dana, loc. cit., p. 105 ; Miers, Min. Mag., IX, 1890, p. 184.

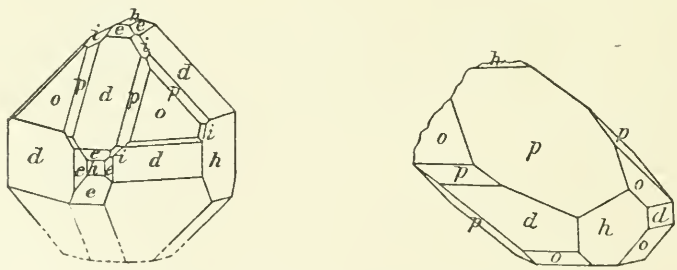
When heated before the blowpipe, decrepitates violently, but is otherwise like sylvanite or calaverite. Occurs at Nagyag, Transylvania, in the Independence mine ; Cripple Creek, Colorado, and, somewhat doubtfully, at Kalgoorlie.[a] In Western Australia it is also reported from near Lake Lefroy and from Broad Arrow.

Petzite.—Petzite is a telluride of silver and gold. It has not been observed in crystal form. Fracture, sub-conchoidal. Slightly sectile to brittle. Hardness, 2·5 to 3. Specific gravity, 8·7 to 9·02. Lustre, metallic. Colour, steel or iron-grey to iron-black ; often tarnished. Its composition is represented by the general formula $(Ag\ Au)_2\ Te$, as indicated by the following analyses :—

	Te.	Ag.	Au.		Analyst.
Nagyag	34·98	46·76	18·26	....	Petz
Stanislaus Mine, California	32·23	42·14	25·63	....	Genth
Red Cloud Mine, Colorado	33·49	40·73	24·60	Bi, Pb, Zn, Fe, SiO_2 = 2·12	,,
Kalgoorlie	32·60	40·70	24·33	Cu, Fe, Ni, Se, S, SiO_2 = 2·08	Wölbling
,, ...	31·58	43·31	23·58	Hg, Cu, Fe, Sb, = 1·38	Carnot

The actual formula may therefore be written $3\ Ag_2\ Te\ Au_2\ Te$, or $Ag_3\ Au\ Te_2$.

Before the blowpipe petzite is much more refractory than the other gold-silver tellurides, requiring the addition of sodium carbonate for reduction to a metallic bead. It is with difficulty distinguishable by its physical characters alone from coloradoite, the mercury-telluride.



FIGS. 62 AND 63. HESSITE FROM BOTES, HUNGARY (*Becke*).
h = (100), *d* = (110), *e* = (210), *o* = (111), *i* = (211), *p* = (221).

Hessite.—Hessite is normally a silver-telluride, but since variable portions of the silver are occasionally replaced by gold, some mention of it must here be made. It crystallizes in the cubic

[a] Spencer, L. J., Min. Mag., XIII, 1902, p. 262.

system with the observed forms: Cube (100); octahedron (111); dodecahedron (110); tetrahexahedron (310), (210); trigonal trisoctahedron (221), (331); trapezohedron (311), (211), (322). Cleavage, indistinct. Fracture, even. Somewhat sectile. Hardness, 2·5 to 3. Specific gravity, 8·31 to 8·45; another determination is 8·89. Lustre, metallic. Colour, between lead-grey and steel-grey. Its composition is ordinarily represented by the formula Ag_2Te, but with a considerable quantity of gold present it approaches petzite. The following are analyses showing high percentages of gold:—

Locality.	Te.	Ag.	Au.		Analyst.
Nagyag	34·98	46·76	18·26	....	Petz
Stanislaus Mine, California	44·45	46·34	3·28	Pb 1·65, Ni ·471	Genth
,, ,,	32·52	41·93	25·55	....	,,
Red Cloud Mine, Colorado	37·17	59·75	3·33	Fe, Cu, SiO_2 = 0·39	,,
,, ,,	34·91	50·56	13·09	Fe, Cu, Pb, Zn, SiO_2 = 1·45	,,
,, ,,	32·97	40·80	24·69	Fe, Zn, SiO_2 = 1·54	,,

Before the blowpipe hessite behaves like petzite, fusing to a black globule, and requiring the addition of sodium carbonate for the production of a white metallic bead. Auriferous hessite is known from Nagyag and Botes in Transylvania; from the Stanislaus mine, Calaveras County, and the Golden Rule mine, Tuolumne County, California; from the Red Cloud mine, Boulder County, Colorado; from the Kearsage mine, Dry Cañon, Utah; and from the Kara-Issar district in Asia Minor.

The *kalgoorlite* of Pittman[a] and the *coolgardite* of Carnot[b] are two mineral species founded on material obtained from Kalgoorlie in Western Australia. To the former the formula $Hg\ Au_2\ Ag_6\ Te_6$ was given, and to the latter $(Au\ Ag\ Hg\ Cu\ Fe\ Sb)_2\ Te_3$, or more simply $(Au\ Ag\ Hg)_2\ Te_3$, it being therefore regarded as a sesquitelluride of gold. As was first pointed out by Rickard,[c] and confirmed by Spencer,[d] kalgoorlite is in all probability a mixture of coloradoite (Hg Te) and petzite ($Ag_3\ Au\ Te_2$), while the coolgardite of Carnot is regarded by Spencer as a complex mixture of coloradoite, petzite, calaverite, and sylvanite. To this assumption considerable weight must be attached, since neither Pittman nor

[a] Rec. Geol. Surv. New South Wales, V, 1898, p. 203.

[b] Comptes Rendus, Acad. Sci., Paris, CXXXII, 1901, p. 1298.

[c] Rickard, T. A., Trans. Am. Inst. M.E., XXX, 1901, p. 715.

[d] Spencer, L. J., Min. Mag., XIII, 1903, p. 283.

Carnot have recorded the presence of coloradoite in the samples analysed for the above determinations, although the mercury-telluride occurs in some abundance at Kalgoorlie.

Nagyagite.—Nagyagite is a sulpho-telluride of lead and gold with antimony. Orthorhombic; axes $\breve{a} : \bar{b} : \dot{c} = 0 \cdot 28097 : 1 : 0 \cdot 27607$. The following forms have been observed:[a] Brachypinacoid (010); unit prism (110); brachydiagonal prisms (120), (130), (160); macrodome (101); brachydomes (011), (031), (051); unit pyramid (111); brachydiagonal pyramids (343), (121), (252), (131), (141).

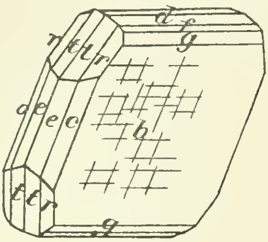


FIG. 64. NAGYAGITE (*Schrauf*). b = (010), e = (120), o = (160), d=(011), f=(031) g=(051), t=(111), r = (121).

Crystals of nagyagite are tabular parallel to the brachypinacoid. Brachypinacoidal faces striated. Generally foliated. Cleavage, perfect, brachypinacoidal. Thin laminae flexible. Hardness, 1 to 1·5. Specific gravity, 6·85 to 7·2. Lustre, metallic, splendent. Streak and colour, blackish lead-grey. Opaque. The composition is deduced by Sipöcz as $Au_2 Pb_{14} Sb_3 Te_7 S_{17}$; by Priwoznik as $Pb_6 Au Te_6 S_8$, and by Schroeder as $Pb_{10} Au_2 Sb_2 Te_6 S_{15}$. The following are typical analyses on specimens from Nagyag:—

	Te.	S.	Sb.	Pb.	Au.	Ag.	Cu.		Author.
(*a*)	30·52	8·07	..	50·78	9·11	0·53	0·99	—	Schönlein
(*b*)	18·04	9·68	3·86	60·27	5·98	..	..	Se Trace	Folbert
(*c*)	17·72	10·76	7·39	56·81	7·51	..	..	Fe 0·41	Sipöcz
(*d*)	17·87	10·03	6·99	57·16	7·41	..	..	Fe 0·32	Hankó
(*e*)	29·38	10·65	..	50·32	7·98	..	..	Se Trace SiO_2 1·56	Priwoznik
(*f*)	19·10	12·24	6·08	53·84	9·53	..	..	—	Schroeder

Before the blowpipe nagyagite forms on charcoal two coatings: one, yellow and near the assay, of lead oxide; the other, further away, white and volatile, consisting of a mixture of antimoniate, tellurate, and sulphate of lead. In the closed tube it gives separate sublimates of antimoniate and tellurate of lead and of antimony trioxide and tellurous oxide. Treated for some time in the oxidising flame a bead of metallic gold results. Occurs at Nagyag and Offenbanya, Transylvania; at Deutsch-Pilsen, Hungary; in Colorado with other tellurides; at the King's Mountain

[a] Schrauf, Zeitsch. für Kryst., II, 1878, p. 239; Fletcher, Phil. Mag., IX, 1880, p. 188.

mine, North Carolina; and doubtfully, at Friedrichsburg in Virginia.

Closely related in physical and chemical characters and to be grouped with nagyagite is the *nobilite* of Adam.[a] This mineral is the *silberphyllinglanz* of Breithaupt.[b] It was found in the gneiss of Deutsch-Pilsen, Hungary.

The compounds of gold hereafter to be treated are well known in the laboratory, but have not been detected or isolated in nature.

Sulphides of Gold.—The sulphides of gold are prepared with ease by passing sulphuretted hydrogen through a solution of auric chloride, either aurous or auric sulphide or variable mixtures of the two being formed according to the temperature of the solution.

Aurous sulphide ($Au_2 S$) in the form of powder is steel-grey when wet, and black when dry. At a temperature of 240° C. it is completely decomposed within a few hours. Sulphuric and hydrochloric acids have no effect on it, but it is soluble in the ordinary gold solvents, and particularly in alkaline sulphides, and also, according to Rose, in alkalis. The formula of the salts resulting in cases of solution in alkaline sulphides is probably of the general form, $Au_2 S_3$, $3 M_2 S$. When freshly prepared it is soluble in pure water to the extent of at least 1 gramme per litre,[c] furnishing a brown liquid. Solutions of aurous sulphide resembling colloidal solutions are readily obtained, but these are not truly colloidal, being formed by the suspension in the solution of exceedingly finely divided material, a fact that assumes some importance when considering the subterranean transport of gold.

Auric sulphide ($Au_2 S_3$) is formed by the action of sulphuretted hydrogen on cold solutions of auric chloride. It is readily soluble in alkaline sulphides forming alkaline thio-aurates. Pure auric sulphide is isolated as black scales having a decidedly graphitic appearance. It is decomposed at a temperature of 200° C.[d] Double auric and argentic sulphides have long been known.[e] The artificial double sulphide of gold and silver ($2 Au_2 S_3$, $5 Ag_2 S$) is crystallized, is unalterable at ordinary temperatures, and possesses a specific gravity of 8·159.

Of considerable academic interest also are the complex sulphides of gold, silver, lead, copper, and iron, prepared in the dry way by fusion by Maclaurin[f] in New Zealand. In these the gold sulphide

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[a] Tableau Mineralogique, 1869, p. 35.

[b] Jour. für Chemie und Physik (Schweigg.), I, 1828, p. 178.

[c] Moissan, "Traité de Chimie Minerale," V, 602, Paris, 1906.

[d] Antony and Lucchesi, Gazzet. Chem. Ital., XX, 1903, p. 601.

[e] Muir, Bericht. Chem. Gesell., V, 1872, p. 537.

[f] Trans. Chem. Soc., LXIX, 1896, p. 1269.

invariably showed the formula Au_2S, suggesting an *-ous* combination of the gold in similar natural auriferous sulphides. A sulpho-telluride of gold ($Au_2 S_3$, $Te S_2$) has also been artificially prepared.

Native gold sulphide has from time to time been reported, but the report, as that from Kalgoorlie, has always been based on a misconception,[a] or the occurrence is merely inferential.[b] Gold sulphide, as a mineral species, is, therefore, still unknown, and considering its susceptibility to the influence of reducing agents, its existence in the upper zones of fissures is not probable. For the same reason its isolation, should it indeed exist in nature, has not yet been accomplished, and no practical method has yet been devised for the separation, without possible reduction, of the gold sulphide from the base metallic sulphides that in mining furnish so much of the world's gold. Nevertheless, it is highly probable that the greater part of the gold transported in the deeper zones of circulation, where the waters are normally alkaline, is carried in the form of an alkaline auro-sulphide (or its corresponding ions). This assumption is largely relied on as the basis of a working hypothesis of the transference of gold in the deeper zones. The question will again be referred to in later sections.

Selenide of Gold.—The formula $Au_2 Se_3$ is given by Ulsmann to the black powder obtained by passing seleniuretted hydrogen through a gold chloride solution. The presence of considerable quantities of selenium in the crude bullion of the Waihi mine in New Zealand and of the Radjang Lebong mine in Sumatra, and at Tonopah, Nevada, gives ground for a suggestion that the selenide of gold may be a natural salt, a suspicion strengthened by the natural occurrence of presumably analogous tellurides of gold.

Chloride of Gold.—The readiness with which the chlorides of gold may be prepared artificially has caused many to assume that it is in this form that gold is transported in nature. While this may be, and probably is true for the zone of surface-oxidising waters, in which the requisite acid waters, oxides, and chlorides, may readily be conceded to exist, it is difficult to understand how auriferous chlorides may be formed in the deeper-seated regions, and still more so to see how they can escape decomposition immediately upon formation in either region. The case for the existence of chlorides is well presented by Don,[c] and yet his own experiments[d] go to show that whatever the form in which gold exists in

[a] Hoover, *in verb.*

[b] Atherton, Eng. Min. Jour., LII, 1891, p. 698; Williams, ib., LIII, 1892, p. 451.

[c] Trans. Am. Inst. M.E., XXVII, 1897, p. 599.

[d] Loc. cit., p. 604.

the deep-seated region, it is not as the chloride. Again, did it exist in sea-water or vadose waters as a definite chemical compound, it should, as pointed out by Lungwitz,[a] remain with the mother liquor after the common salt had crystallized out. But no gold has been reported from natural deposits from the mother liquor, such as those of Stassfurt, Lungwitz himself analysing 50 pounds of carnallite without finding a trace of gold. On the other hand, Liversidge[b] reports gold from a number of saline minerals, as sylvine, kainite, carnallite, and Chili saltpetre. The recent researches of Lane,[c] on the deep-seated waters contained within rocks obtained at great depths in the mines of Michigan, have shown that concentrated solutions of alkaline chlorides may exist far below the vadose region. In view of this determination the assumption of the general restriction of the possible chloride of gold to the vadose zone must be held to be subject at any time to revision.

Auric chloride ($Au\ Cl_3$) when prepared in the laboratory may be either hydrated or anhydrous. The latter form occurs as highly deliquescent, deep red crystals, crystallizing in the triclinic system and melting at 288° C. Its density is 4·3. When heated it decomposes to aurous chloride (Au Cl) and chlorine. The decomposition is complete in three years at a temperature of 100° C., and under atmospheric pressure ; at a temperature of 200° C. only 36 hours are required to effect the same change.[d] Solutions of gold chloride are readily decomposed by exposure to heat and sunlight, and also by carbonaceous matter, hydrogen sulphide, sulphurous acid, and other natural agents.

Silicate of Gold.—A possible salt of gold, to which, however, but little attention has been paid, is the silicate of gold. The existence of this salt was indicated by Bischoff,[e] who did not fail to indicate the bearing of the discovery on the question of the origin of auriferous veins. Liversidge[f] reported that gold was dissolved by digestion in a solution of potassium or sodium silicate at a pressure of 90 pounds to the square inch. The silicates were further investigated by Cumenge,[g] who experimented with an alkaline auro-silicate obtained by adding an alkaline aurate to an alkaline solution of sodium silicate (water glass). While Cumenge's experiments have been repeated and confirmed in the

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[a] Eng. and Min. Jour., April 6, 1905.

[b] Jour. Chem. Soc., LXXI, 1897, p. 298.

[c] Amer. Geol., XXIV, 1904, p. 302.

[d] Rose, T. K., "Metallurgy of Gold," London, 1902, p. 24.

[e] Lehrb. Chem. Physik. Geol., III, 1866, pp. 843-6.

[f] Proc. Roy. Soc. N.S.W., XXVII, 1893, p. 303.

[g] Fremy, Ency. Chem., vol. III, L'Or, p. 62.

main by the writer, there is, nevertheless, little doubt that the red and blue solutions resulting from the decomposition of the presumed alkaline auro-silicate are solutions of colloidal gold and not of gold oxides, as suggested by Cumenge.

Colloidal Gold.—A new point of view in the consideration of the transportation and deposition of gold in silicate solutions is furnished by the researches of Schneider,[a] Zsigmondi,[b] and others, on colloidal forms of gold. Uncompleted experiments made by the writer in 1901, on colloidal gold reduced from alkaline auro-silicates by addition of an acid, showed that the colloidal gold, when allowed to stand, exhibited a tendency to aggregate round indeterminate nuclei. When foreign substances, as metallic sulphides, were suspended in the jelly, reaction took place much more rapidly, and a clear zone, half an inch wide, of gelatinous silica represented the distance to which the pyrites, now appreciably gilded, had deprived the jelly of its gold. Colloidal gold, like all other colloids, is, however, so readily coagulated by electrolytes (here including both acids and bases) even when no chemical interaction takes place, that its existence seems to be compatible only with the presence of pure water, a condition probably rarely existing in nature. Both colloidal gold and colloidal silica, moreover, if left to themselves, exhibit the phenomenon of "chemical after-effect," and change spontaneously to less soluble forms—a change greatly accelerated by increase of temperature.[c] On the whole, therefore, colloidal solutions requiring pure water and low temperatures cannot be supposed to play a prominent part in auriferous transportation.

Ionised Gold.—The development of the ionic theory of chemical reaction and equilibrium in solutions illuminates also the subject under present discussion. Since the free energy of the complex gold ions is nearly always greater than that of the elementary aurion, or, in other words, since gold has a greater tendency to exist in elemental form in nature than as a compound, it seems reasonable to assume that the gold which is carried from place to place by underground waters is possibly in the elemental ionised form, viz., aurion. Ostwald,[d] in discussing the question of the natural combination of acids and bases in natural waters, concludes: "The final answer to which we are led by the dissociation theory, is that the acids and bases are not combined at all, but that they—or rather the ions of the salts—lead separate existences, to which

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[a] Zeit. Anorg. Chem., V, 1893, p. 80.

[b] Liebig's Annalen, CCC, 1898, pp. 29, 361.

[c] Zsigmondi, "Zur Erkenntniss der Kolloide," Jena, 1905.

[d] "Foundations of Analytical Chemistry," Eng. Ed., p. 213.

the only limitation is the law that the sum total of the positive ions must be equivalent to the sum total of the negative."

Next to the elementary aurion, a very complex ion appears to be the most stable of the gold ions, and hence, while gold is probably generally transported as aurion, it may be balanced in the vadose regions by chloridion, and in the regions of deeper underground circulation by sulphidion, or in the latter regions the ion may be thio-auranion, as in the alkaline thio-aurates M_2 Au S_2, or auro-silicanion, as in the alkaline auro-silicates (M_2 Au Si O_4), or in double salts corresponding to the members of the silicic acid series.

As a matter of fact, the only natural water in which gold has yet definitely been determined is sea-water. Its existence there was foreshadowed by Forchammer, and confirmed by Sonstadt[a] in 1872. Quantitative experiments conducted by Liversidge on waters from the coast of New South Wales indicated a gold content of 0·5 to 1·0 grain of gold per ton.[b] Don's careful and exhaustive experiments (indeed the only researches yet conducted to solve the general questions of auriferous deposition) gave, however, on waters from New Zealand, a much smaller figure, viz., ·071 grain gold per ton.

In 1892, Munster[c] analysed the solid contents of the waters of the Kristiania Fjord, Norway, finding 5 to 6 milligrams gold, and 19 to 20 milligrams silver per metric ton. Wagoner[d] found gold to the extent of 11·1 milligrams, and silver to 169·5 milligrams per metric ton in the waters of the Bay of San Francisco. Different methods of assay have been used by different chemists, and all are not of the same degree of accuracy. The variation shown above, nevertheless, probably arises from the great distances apart at which the materials for analysis were collected.[e] Liversidge concluded from his researches that Muntz metal (a copper-zinc alloy used for sheathing ships and pier piles) was capable of removing gold from sea-water.[f]

[a] Chem. News, XXV, 1872, pp. 196, 231, 241.

[b] Trans. Roy. Soc. N.S.W., XXIX, 1895, p. 335.

[c] Jour. Soc. Chem. Ind., XI, 1892, p. 351.

[d] Trans. Am. Inst. M.E., XXXI, 1901, p. 806.

[e] See Weisler, "Ueber den Goldgehalt des Meer-wassers," Zeit. angew. Chem. 1906, p. 1795.

[f] Loc. sit. sup.

CLASSIFICATION OF AURIFEROUS DEPOSITS.

Auriferous veins or deposits may be of any form, may occur in any rock, and may have received their gold from various sources. Particular classifications based on obviously adventitious characters, as similarity of form of deposit, or identity of matrix or of associated minerals, can therefore serve no useful purpose, either scientific or economic. Such classifications have been current for many years. Some have certainly been suggestive, but the majority have helped the miner and prospector not a whit, and have proved a source of confusion and embarrassment to the student. In the grouping of the world's goldfields adopted in this treatise, no regard whatever has been paid to the lineal forms assumed by gold-quartz or other gold ores. The shape of a vein-deposit or of an ore-channel is dependent always either on the dynamic conditions prevailing antecedent to vein-filling, or on characters inherent in the enclosing rock or rocks, and problems affecting this question belong either to the mechanical region of geo-dynamics or to the chemical regions of solution, deposition, and metasomatism. In the case of gold, metasomatic criteria are few and of little value, since we are dealing with an element easily precipitated in metallic form and yielding few stable compounds. Nor may any serious consideration, from a classificatory point of view, be given to the problems afforded by the minerals generally found associated with gold in auriferous deposits, for those that may reasonably be assumed to possess genetic value are few in number and are universally associated. They may be sharply separated into two great divisions : (*a*) The metallic sulphide group, which may be extended to include the chemically allied metallic tellurides; and (*b*) quartz. The members of the first group are so readily interchangeable that no subdivision is possible, and their connection with the problems of auriferous deposition must be regarded always from the group point of view rather than from the standpoint of the particular mineral (*e.g.*, galena, pyrite, stibnite, &c.). The gold of the sulphide group is nearly always refractory, and as already seen, is possibly, for the point is not capable of definite proof, in a state of combination as a sulphide. The visible free gold often found associated with sulphides may generally be considered to be due to the partial decomposition of the sulphides, or to the reducing effect of the latter on wandering auriferous solutions. The ores of the auriferous sulphide group may be deposited either in a quartz matrix or may be impregnated through ore-channels or through the country adjacent to fissures.

The quartz-gold group is characterised by the general absence of sulphides of obvious relation to gold, and by the presence of free gold. In many cases, however, the broad separation of gold-deposits indicated above can not be held to be valid, for the free gold of some gold-quartz veins is certainly derived from adjacent sulphide-ores, and, moreover, solutions in the same vein may be so far influenced by the country-walls or by other local conditions as to furnish base sulphide deposits in one part and gold-quartz in another part of the fissure. This feature is exemplified both on a small and on a large scale in the goldfields of Eastern Australia. Veins on the Ravenswood and Etheridge goldfields in Queensland passing from igneous into sedimentary rocks, show a marked transition from pure sulphide veins in the former to gold-quartz with little auriferous pyrite in the latter. On the larger scale it may be noted that throughout the Eastern Australian gold-belt, from Horn Island in Torres Strait to Beaconsfield in Tasmania, gold-quartz veins occur in sedimentary rocks, and auriferous sulphide veins in igneous rocks. Exceptions on both sides do occur, but the exceptions are only apparent, and are nearly always capable of a local explanation. Regarded broadly, there is, as will be seen later, some reason for assuming a common origin for the gold of the various deposits of this belt, and the indicated difference in character may therefore be assumed to be due to the diverse geological nature of the respective country rocks in which the deposits occur.

Auriferous Provinces.—These associations, while certainly indicative of the conditions under which gold is transported and deposited, help us little in the search for the original host of the gold of the earth's surface. The most natural grouping of the world's gold-deposits appears to be reached by a combination of geographical and geological data, resulting in the establishment of fairly definite auriferous provinces, well separated from each other either in time or in space, or in both. The individual members of each group possess strong affinities that can hardly be coincidental. The classification here adopted is to be regarded as merely preliminary, for it must certainly be modified with progress in the knowledge of ore-deposits. Its general value is considered to lie largely in the fact that the differences between auriferous provinces, no less than their resemblances, are emphasized. Of the magmatic factors that have governed the association of gold with igneous magmas of the characters indicated, nothing is known, nor is anything certain with regard to the causes of extrusion or intrusion of these magmas at the earth's surface ; any speculations thereon must be of the vaguest. The writer is therefore at present content to submit the subjoined as the most natural grouping of auriferous

CLASSIFICATION OF AURIFEROUS DEPOSITS.

PRIMARY.

Connected with the extrusion of intermediate or basic igneous rocks (andesites or diabases). (*a*)	Archæan.	Schistose rocks: Western Australia (Kalgoorlie, &c.), India (Kolar, Hutti), Rhodesia.
	Pre-Cambrian.	Arising from intrusion of diabase and diorite dykes through Archæan schists: Western Australia, India (Dharwar), South Africa (Pilgrim's Rest, Witwatersrand, and Barberton), Guianas, Appalachian fields, and Eastern Canada.
	Tertiary.	Andesitic goldfields: Northern Chili, Peru, Colombia, Mexico, California (Bodie), Nevada, Utah, Colorado, Unalaska, Japan, Sumatra, Celebes, New Zealand, Transylvania.
Connected with the extrusion of acid rocks of granodioritic type. (*b*)	(?)	Urals.
	Permo-Carboniferous.	Eastern Australia and Tasmania.
	Jurassic.	Western North America—Alaska, Oregon, and California.

SECONDARY.

Deposits produced or modified by chemical agencies. (*a*)	Free gold in original sulphide and telluride veins.	α Arising from decomposition of auriferous sulphides and tellurides by acid waters or by tellurides below the zone of oxidation.
		β Arising from decomposition of sulphides and tellurides in the zone of oxidation.
	Placer gold (in part).	
Deposits produced by mechanical agencies. (*b*)	Placer gold (in part).	

deposits, and offers no speculative comment on the internal and external relations of the groups indicated.

Far greater regard is had to the character of the rock-magma with which the gold may reasonably be supposed to have had a genetic connection, than to the nature of the rock actually enclosing the deposit, for no great acquaintance with gold-deposits is necessary to render it abundantly apparent that gold will be deposited wherever physical and chemical conditions are suitable, irrespective of the nature of the walls of the fissure or cavity through which the auriferous solution happens at the time to be passing. A wide interpretation is everywhere given in this treatise to geological phenomena. For example, events so far separated in time as the first extrusion of an igneous magma and the solfataric action that, in the same region, accompanies the quieter or the final stages of volcanic activity, are, in the absence of detailed data, regarded as different phases of the same phenomenon. The Tertiary andesites of Cripple Creek, Colorado, and the geysers of the Yellowstone Park—or, to take another case, the Upper Eocene andesites of the Hauraki Peninsula, New Zealand, and the hot springs of the central region of the North Island—have each a common origin, and are respectively separated only in time and, to an unimportant degree, in space. Nor, in the same way, is much regard paid to "lateral secretion" or "ascension" hypotheses of origin of ores. In certain cases in igneous rocks, lateral secretion, even in its older and more restricted sense, may have furnished auriferous vein-filling; in others in the same region the gold may have been brought from great depths, but yet has been derived from the lower portions of the same magma that furnished the intrusions or extrusions now at the surface. Between the lateral secretion deposit and the ascension deposit thus indicated, no logical distinction may be made. It has been assumed that all essential operations of ore-deposition are to be regarded as taking place in the outer 25 miles of the earth's crust, and it is believed that lateral secretion may operate anywhere within that shell, and also that ore-bearing waters may ascend from that and from lesser depths.

A word may be said as to the use of the terms primary and secondary. They are, in an investigation of this nature, purely relative. The primary gold-deposits are those of which we know, for the gold, no prior state of combination and no former locus in space. They include the auriferous sulphides and tellurides, and many free-gold deposits. They may, indeed, have undergone many changes, and they may have, in a former geological age, appeared at or near the then existing surface, for sedimentary and igneous rocks containing gold-quartz veins and deposits may be depressed until they meet with a liquid or potentially liquid magma

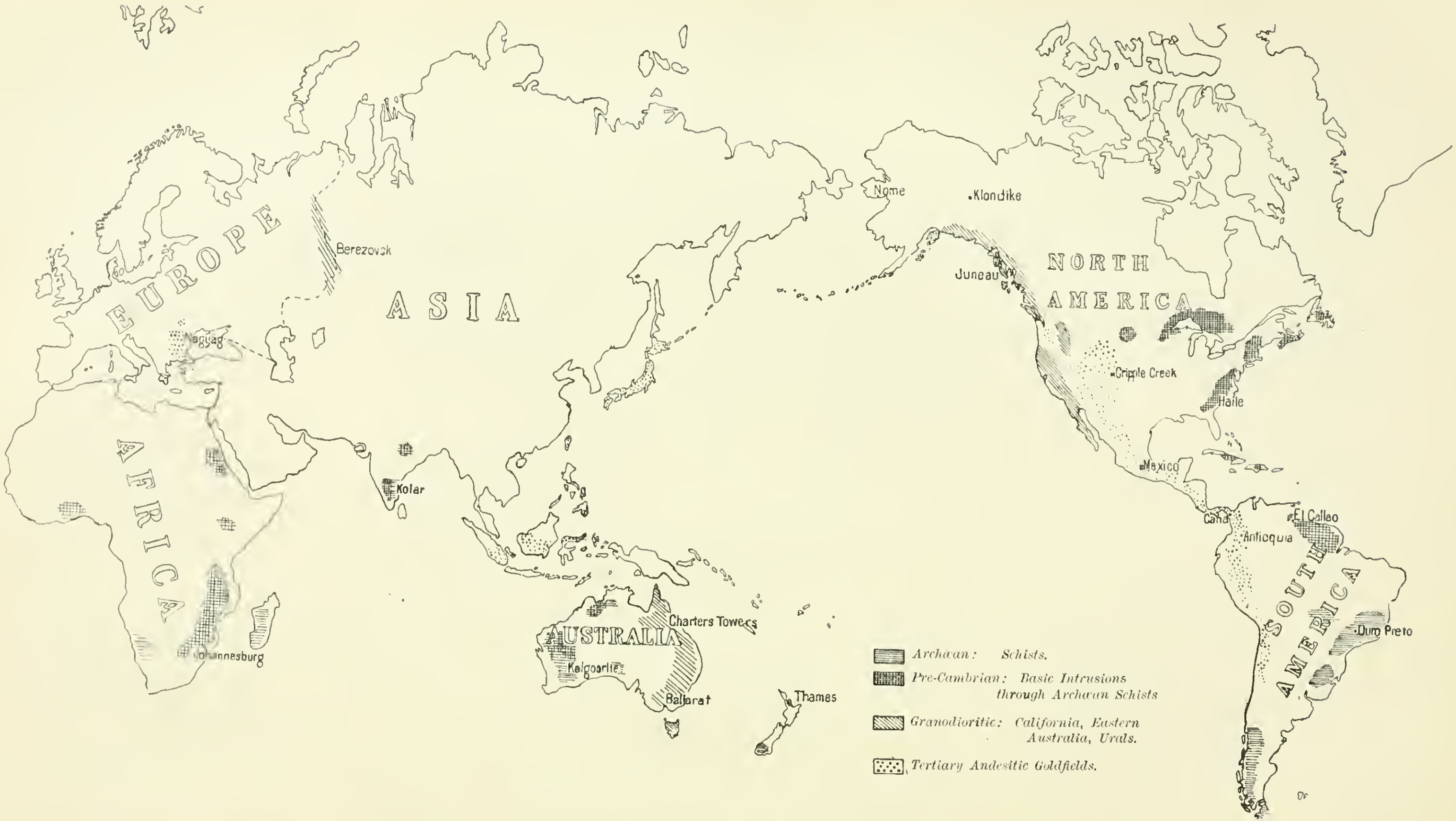

Fig. 65. Sketch Map of the World, Showing Distribution of the Principal Auriferous Provinces.

eating its way to the surface, or deeply-descending waters may carry downward gold in solution; but without actual evidence of these agents, the resultant deposits must be regarded as primary. Secondary gold deposits are those obviously or presumably derived from sulphide or telluride ores or from gold-quartz veins. Examples of this form are found in the "sponge" and "mustard" gold of Kalgoorlie, and, indeed, in the greater quantity of free gold within the surface oxidised zones of veins. Secondary deposits may further be either of chemical origin, as the foregoing, or of mechanical origin, as the placer-gold of gravels.

PRIMARY DEPOSITS.

ARCHÆAN GROUP.

The primary rocks here dealt with are, next to, or perhaps with the fundamental gneisses, the oldest rocks that are available for examination. Partly owing to the conditions prevailing at the time of their deposition, and partly owing to their long subjection to metamorphic agencies that have tended to reduce originally physically and chemically differing rocks to a common facies, they show a remarkable petrological similarity wherever they have been examined, whether in north-west Scotland, North America, India, Australia, or South Africa. All the members have been schisted, many indeed, to such an extent as to render it now difficult to say whether they were originally igneous or sedimentary. Some schists, however, are clearly of igneous origin, and it is in the amphibolitic varieties of these schists that the oldest known auriferous deposits occur. The Archæan schists are of course unfossiliferous, and their correlation in widely separated areas can be performed only by means of petrological characters. Nevertheless, these are often sufficiently akin to warrant a general grouping. The best defined group is probably that found bordering the Indian Ocean, furnishing the rich goldfields of Western Australia, India, and south-eastern Africa. These, though geographically widely separated, present so many points of similarity that a geological description of the various Archæan members and of their internal relations in any given region, would serve, with the mere change of place-names, for any other region of the group. The members are consequently believed to form a single petrological and metallogenetic province. For this province the appellation Erythræan has been suggested.[a]

[a] Maclaren, Trans. Inst. Min. Met., XVI, 1907, p. 15.

In America a similar province is well defined in the Lake Superior region. There, however, its auriferous content is insignificant, and the province is characterised by its copper deposits rather than by its gold. Its southern prolongation is, however, marked by the long chain of goldfields that extends down the eastern slopes of the Appalachians, across the West Indies, and by way of the Guianas and Brazil to Tierra del Fuego. The possibly auriferous character of these Archæan schists is masked by a well-marked auriferous activity due to the intrusion of diabasic and dioritic dykes—an activity which will be seen to be world-wide and will be described as such in later pages. These two great provinces, the Erythræan and the Appalachian, may be said to include all the Archæan schist goldfields of the world, though it may be necessary with increase of knowledge to widen the group to include the auriferous schists of south-eastern Siberia; the sporadic Archæan occurrences of South Dakota, Arizona, &c., are to be regarded merely as outliers of the longitudinal chain of the Eastern Americas.

India.—Dealing more in detail with the various members of the Archæan group, those of India, where the relations are especially well marked, may first be considered. The Dharwars or Archæan schists of India are typically developed in Southern India, where they extend as long narrow bands, with small outliers, from the Bombay Presidency and the Nizam's Dominions southward through the Mysore State.

The series is a complex aggregate of highly metamorphosed rocks.[a] Among the more easily recognisable sedimentary rocks are boulder-beds or conglomerates, pebbly grits, quartzites, limestones, argillites, and chloritic schists. The boulders of the boulder-beds are embedded in a chloritic schist matrix, and are rarely sufficiently closely aggregated to deserve the term conglomerate. This state of aggregation is highly characteristic of the coarser Archæan sedimentaries, and has been assumed by some geologists to denote glacial origin. The feature is, however, paralleled in the great fan-like deposits of many existing tropical rivers (*e.g.*, the Brahmaputra) at their debouchure from the mountains on the plains, and running water is therefore considered to have been quite competent to form these ancient boulder-beds. The quartzites are in places metamorphosed into quartz-schists. With them are occasionally associated limestones, but these are not abundant. By far the most characteristic rock of the Archæan group, and one always associated with the sedimentary members of the series, is a well-banded, generally much contorted,

[a] Maclaren, Rec. Geol. Surv. India, XXXIV, 1906, p. 96.

hæmatite-magnetite-quartz rock of obscure origin. It has been thought to arise from silicification along shearing planes, but it may most reasonably be regarded as due to the metamorphism of ferruginous silicate and carbonate bands in depth, with resultant conversion into ferric oxides and silica. Depression of banded ferruginous clays and sands should eventually yield under the given conditions a rock of this nature.

The members of the Dharwars derived from igneous rocks are mica-schists, hornblende-schists, certain chloritic schists, amphibolites, felsites, and quartz-porphyries, representing probably a succession of fairly basic to acid rocks such as may be met with in many a younger volcanic region. Some of the hornblendic schists retain sufficient of the primary structure to indicate their original diabasic nature, while in certain light-coloured varieties the ophitic structure is so clear that the rocks may fairly be termed diabase-schists. Where the hornblende-schists have been influenced by the intrusion of younger granites, they locally lose their schistose structure, and by reconstitution of their fragmentary felspars and hornblendes, assume an apparently normal dioritic habit. This change, to which reference will again be made, has an important bearing upon the occurrence of metallic gold in seemingly unmetamorphosed igneous rocks.

Two periods of vein formation and auriferous deposition are observable in the Dharwar rocks. The older, with which we are presently concerned, is to be associated with the period of the general dynamic metamorphism of the Dharwars, and finds expression in the veins of bluish grey and bluish black quartz that furnish the gold of the Kolar field in Mysore, and of the Hutti field in the Nizam's Dominions. Microscopic sections of this quartz, especially from the Hutti mine, show that it has been subjected to much of the dynamic stress that has affected the enclosing rock. Its structure is decidedly schistose, and its dark colour is often due, not to impurities, but to total internal reflection from strain surfaces. Its gold is nearly always internal—certain evidence of contemporaneous deposition of gold and of silica. The gold-quartz occurs in "shoots," those of the Kolar vein furnishing probably the best examples known of this form of auriferous disposition.

Western Australia.—To the Archæan rocks must be relegated the "Auriferous Series" of Western Australia. As in Southern India, gneissoid granites are believed to represent the fundamental rocks of the country. On this floor has been laid the great series of rocks to which the general field term "greenstone schists" has fitly been applied. So far as the schists have been examined, they have been found to consist in the main of amphibolitic and hornblendic members, certainly derivative from igneous rocks. Near the younger granitic rocks, the hornblende-schists are occasionally so far reconstituted as to form diorites. Mica-schists, talc-schists, chlorite-schists, and siderite-schists also occur, but the most striking rock here, as in India, is the banded hæmatite-magnetite-quartz rock which runs for great distances parallel with the foliation and direction of the main schistose belts, and furnishes the saw-toothed and serrated ridges that occupy such a prominent position in a greenstone-schist area. On the Kalgoorlie goldfield, where the rocks have been most closely examined, in addition to the prevailing amphibolites and hornblende-schists that carry the auriferous lodes, there also occurs a series of sedimentary rocks ranging from soft shales and sandstones to slates and quartzites. The first are often highly graphitic, and then contain, as might be expected, numerous nodules and crystals of iron pyrites. Two distinct forms of auriferous deposit in these rocks may be referred to the Archæan period : (*a*) "lode formations," and (*b*) quartz veins. The former are the most important loci of gold in the State, and are especially well developed at Kalgoorlie, Kanowna, and Peak Hill. "Lode formations" are merely zones of rock impregnated with fine gold and with tellurides of gold. They merge insensibly into barren solid rock on either side, and are probably belts of sheared and fissured rocks, through which mineral solutions, liquid or gaseous, or both, have had free passage. They have naturally no well-defined walls, and their limits are determined solely by their assay values.

Quartz veins are responsible for the gold on the majority of Western Australian goldfields, and may reasonably be divided into two classes—blue and white. No clear distinction as to their age has yet been made, but the white veins appear to be the younger, since they cut through and mineralize many of the banded hæmatitic quartzites.[a] The white veins will again be referred to when dealing with the later (Pre-Cambrian) period of auriferous deposition in Western Australia. The majority of the older quartz veins occupy shearing planes parallel with the plane of foliation, and within a given zone the country may be so thoroughly traversed by them as to form, with connecting leaders, a stockwork. The more massive veins are characterised by the assumption of a lenticular habit. The characteristic minerals of the chief Western Australian goldfield are the tellurides of gold.

South Africa.—The Archæan rocks of South Africa show many features in common with the Dharwars of India, and with the Auriferous Series of Western Australia. The Barberton Series,

[a] Maitland, Ann. Rep. West Aust. Geol. Surv., 1902, p. 16.

perhaps best developed in Swaziland, resembles very strongly the sedimentary members of the Dharwars. Like them, the characteristic rocks are chloritic schists, talc-schists, argillites, and the ever-present banded hæmatite-quartz rock, which here as elsewhere stands out in bold relief, forming the mountain ridges. To be correlated with these ancient rocks are the series of schists described by Drs. Hatch and Corstorphine as underlying the Witwatersrand Series in the Bezuidenhout Valley.[a] The Barberton Series of Swaziland is carried northwards to the Murchison Range, where the schists are chloritic, talcose, amphibolitic, and quartzitic. The auriferous reefs are there associated with the hornblendic schists.[b] Still further north, in Rhodesia, and obviously connected with the Swaziland schists, are the Buluwayo schists of Mennell, which in the main probably represent basic igneous intrusions. Here also, the banded hæmatite-quartz rock is a dominant feature in the physiography of the region. The ancient metamorphic schists of Zululand and Natal are grouped by Anderson[c] with the Barberton Series of Swaziland, as, indeed, may also be the highly metalliferous schists of Namaqualand, which have very characteristic diabasic and amphibolitic members. These rocks have for German South West Africa been relegated by Voit to the Archæan.[d]

Except in Rhodesia, the Archæan schists of South Africa are not in themselves of economic importance. The rich gold-veins and deposits they contain are generally to be referred to a later (Pre-Cambrian) period than that of their general metamorphism, and will hence be dealt with under their proper head.

Appalachian Fields.—These lie along the outcrop of the Archæan schists of Alabama, Georgia, South Carolina, and North Carolina. The Archæan series contain both sedimentary and igneous members. Representative of the former is the Talladega (Algonkian) Series of Alabama, consisting of slates, quartzites, conglomerates, and dolomites. The igneous series is a complex of green schists, basic schists, diorites, and gneisses. The "green schists" are composed in the main of actinolite, epidote, and chlorite, together with some quartz; they have been grouped as chlorite-epidote schists, actinolite-epidote schists, and chlorite schists. It is difficult to determine exactly the nature of the original rock, but it was certainly a basic eruptive.[e] The semi-crystalline slates of the Goldville region contain great quantities of limonite

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[a] Trans. Geol. Soc. S. Africa, VII, p. 98.

[b] Merensky, Min. Jour., 1905, p. 629.

[c] 2nd Rep. Geol. Surv., Natal, 1904, p. 11.

[d] Trans. Geol. Soc. S.A., VII, p. 77.

[e] Clement and Brooks, Bull. 5, Alabama Geol. Surv., 1896.

pseudomorphous after pyrite. Tetradymite accompanies the gold at King's Mountain, North Carolina, while the deposits near Dahlonega, Georgia, contain tellurides of gold. Eckel's examination of the gold mines of the latter region showed that the veins all occurred at contacts between the soft mica-schists and igneous rocks, either altered schistose diorite (amphibolite) or massive granite.[a]

The schists of the Appalachian goldfields stretch away to the north, and appear to be associated with the classic greenstone-schists of the Lake Superior region. These are again auriferous in the Rainy Lake region, where veins occur in the Coutchiching and Keewatin schists and run parallel with the schistosity.[b] In the Lake of the Woods region, the veins are mainly in the Keewatin schists, though gold-quartz also occurs in the adjacent granites. The auriferous deposition here, however, appears to be associated with intruded diabasic dykes,[c] and must therefore be referred to the second or Pre-Cambrian period of auriferous deposition.

South Dakota.—In the Black Hills, South Dakota, there lies a belt of highly-metamorphosed Archæan schists impregnated with auriferous pyrites and containing numerous lenticular masses of gold-bearing quartz. The best-known example of lodes in these rocks is the Homestake, where a portion of the gold is obtained from a deposit formed along a schistose zone by an aggregation of veinlets containing free gold and low-grade pyrite. The total gold yield for the nineteenth century of these American Archæan rocks, and of their Pre-Cambrian enrichments yet to be described, was about £28,000,000 sterling.[d]

Brazil.—The rocks of all the foregoing Archæan areas are so similar that, did they lie in comparative proximity, they would unhesitatingly be grouped together as a single formation. There are other ancient schistose rocks, as the auriferous schists of the Minas Geraes province, Brazil, that are doubtfully to be grouped under this head. The age of the Brazilian rocks is uncertain, and they have been variously referred to the Archæan and to the Cambrian. The fundamental rocks are granite and gneiss, and these are overlain by a series of schistose rocks. The series in ascending order is micaceous and talcose schist, quartzite, argillaceous schist, itabirite with jacutinga (sandy micaceous iron ore), limestone, and the upper micaceous schist.[e] All, with the exception of the limestone,

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[a] Bull. U.S. Geol. Surv., No. 213, 1903, p. 57.

[b] Geol. Surv. Minnesota, XXIII, 1895, pp. 35, 105.

[c] Trans. Amer. Inst. M.E., XXVI, 1896, p. 856.

[d] Lindgren, Trans. Amer. Inst. M.E., XXXIII, 1903, p. 801.

[e] Scott, Trans. Amer. Inst. M.E., XXXIII, 1903, p. 409.

are more or less auriferous. The chief forms of deposit are (*a*) lodes in the schist, (*b*) contact lodes, and (*c*) auriferous lines of jacutinga in the itabirite. The lodes in schist are the most numerous. They are characteristically lenticular, and dip and strike with the foliation. The gold is generally associated with mispickel and pyrrhotite. The contact lodes are also lenticular masses of quartz intercalated between the itabirites and the underlying quartzites or argillaceous schists. To this class belong the Passagem and the Morro Santa Anna lodes. The Passagem lode contains a considerable amount of kaolinized felspar, and has hence been considered by Hussak[a] and Derby[b] as a pegmatite apophysis rather than as a true quartz vein. The rapidly increasing number of occurrences[c] reported of both orthoclase and albite as vein-filling from undoubted aqueous solutions advise considerable caution in the complete acceptance of this determination. The jacutinga auriferous deposits are now of but little importance. The celebrated Morro Velho mine lies in a zone of highly-sheared calc-schist.[d] The auriferous sulphides are arsenopyrite, pyrrhotite, chalcopyrite, and pyrite, with a gangue of siderite, dolomite, and calcite, with very subordinate quartz and albite felspar. The last also occurs as crystals in the vughs.

The outstanding feature in the descriptions of the Brazilian occurrences is the absence, with one exception, of all mention in the literature accessible to the writer, of igneous intrusions, and these, indeed, appear to be generally absent from the district.[e] The exception is found in a description of the auriferous occurrences of Rapasos,[f] in which it is stated that the schistose rocks are traversed by two diabase dykes and that the ore-bearing solutions are to be considered as associated with these diabase eruptions. It is true also, as already seen, that Hussak demands for the Passagem lode an igneous origin.

Nothing is at present known of the geological relations of the auriferous schists of Southern Chili and of Tierra del Fuego.

New Zealand.—Another ancient schistose area in which igneous intrusions have not been found occurs in the Otago province, South Island of New Zealand. While numerous gold veins have been worked in these rocks, their importance arises from the fact that they have furnished the great alluvial auriferous deposits of

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[a] Zeit. für Prakt. Geol., Oct., 1898, p. 395.

[b] Trans. Amer. Inst. M.E., XXXIII, 1903, p. 283.

[c] Lindgren, Econ. Geol., I, 1905, p. 163.

[d] Derby, loc. cit., p. 284.

[e] But see in this connection Orville Derby, Amer. Jour. Sci., XI. 1901, p. 34.

[f] Berg, Zeit. für Prakt. Geol., 1902, p. 82.

Otago. These schists are obviously of sedimentary origin, and range from phyllites to chlorite- and quartz-schists.[a] There is no direct internal evidence of their age, but they are probably very much younger than Archæan. They are even ascribed to the Carboniferous or Devonian.[b] While there is a possibility that these schists have obtained their vein-gold by lateral secretion from contemporaneously deposited alluvial gold, there is yet reason to believe that auriferous deposition in Otago, as on the West Coast of New Zealand, may be genetically connected with the granite rocks intruded during the Middle Mesozoic uplift of the Southern Alps. Other auriferous schists of indefinite age and of as yet unknown relations are those furnishing the placer deposits of Alaska and of Eastern Siberia.

PRE-CAMBRIAN GROUP.

The auriferous deposits to be grouped under this head are nearly all contained in the Archæan schists already described. In all cases it would appear that the auriferous solutions have been set in circulation by diabasic flows and intrusions, but not even a guess may be made as to whether the gold was brought to its present position by the uprising diabasic magma or whether the diabasic and dioritic intrusions found the schists already auriferous and served only as carriers of heat and of solvent vapours. While the deposits are generally contained within the Archæan schists, notable exceptions, as in Western Australia (Nullagine) and South Africa (Witwatersrand), occur when younger porous strata, as conglomerates, offer ready passage to the auriferous solutions. Following the order adopted in the preceding section, the Indian occurrences will first be detailed.

India.—Throughout the whole Dharwarian Series, as well as through the adjacent crystalline rocks, there ramify numerous diabasic and doleritic dykes, that, showing no schistose structure and no trace whatever of deformation, are certainly later than the period of the final metamorphism of the enclosing rock. These dykes are to be correlated with certain lava flows in the Cheyair group of the Lower Cuddapah system.

The Cuddapahs are unfossiliferous, and little evidence is available to indicate their exact stratigraphical position. They are, however, generally considered to be Pre-Cambrian, and hence this age must also be assigned to the great diabasic outburst which set auriferous solutions once more circulating through the long-closed

[a] Hutton, Trans. N.Z. Inst., XXIV, 1891, p. 359.

[b] Park, Bull. No. 5, N.Z. Geol. Surv., 1908, p. 28.

waterways of the Dharwars. Veins of Pre-Cambrian age occur mainly in argillites and chloritic schists. They are best exemplified in the Gadag belt and the Dharwar belt proper, and are characterised by a white quartz and a disposition of the veins in accordance with the foliation of the country. The quartz lenses in the Gadag area are often connected by graphitic lode-formations, and the main Gadag reef system lies within a highly carbonaceous band in the argillites. In many cases, as at Kolar and at Hutti (Nizam's Dominions), the older Archæan fissures were re-opened, and we thus find the older blue and the younger white quartz lying side by side in the same fissure. The blue quartz has already been seen to show under the microscope evidences of considerable dynamic pressure. The white quartz, on the other hand, shows, in thin sections, no trace of schistose structure and no further strain phenomena than are normal in the quartz of undisturbed veins. The auriferous veins of Chota Nagpur, the northern Dharwar area of India, are, so far as they have been examined, small and poor. They, however, fall in this division, and are to be associated with a great dioritic dyke very similar to those already described, and which, known as the Dulma Trap, sweeps in an arc of a circle through the Singhbhum Division.[a]

Western Australia.—In Western Australia the same general stratigraphical conditions obtain as in India. There also the greenstone schists are intruded by numerous, often parallel, diabasic and doleritic dykes. These, as in India, are generally vertical or nearly so. In addition to the basic intrusions, there are also found a great number of acidic dykes which may be regarded as apophyses from the younger granites, and which range from granites through aplites to a rock which may almost be termed a quartz vein.[b] It is of considerable importance to note that these acidic dykes are themselves barren, and that they appear to have had no effect whatever on auriferous deposition. In the Pilbara goldfield, a northern district, and one displaying the most instructive section of all the West Australian goldfields, the steeply-inclined schists are overlain by a fairly horizontal series of sandstones, grits, conglomerates, and thin limestones associated with amygdaloidal diabases and felsites, as their basal members.[c] To this series the term Nullagine Beds has been given. The presence of the amygdaloidal diabase may afford a clue to the age of the basic intrusive dykes of the "Auriferous Series." The mineralising influence of the diabasic dykes is well marked on the northern gold-

[a] Maclaren, Rec. Geol. Surv. India, XXXI, 1905, p. 74.

[b] Jackson, W.A. Geol. Surv., Bull. 3, p. 21.

[c] Maitland, W.A. Geol. Surv., Bull. 15, 1904.

fields, where the characteristic laminated hæmatite-magnetite-quartz rocks are extensively developed. These latter are not innately auriferous, and it is only where they are crossed by basic dykes, by faults, or by cross veins, that they carry gold, and then only for a few feet on either side of the intersection, forming narrow "shoots" in the quartzite bands.[a]

The white quartz veins of these fields are also apparently to be connected with the diabasic intrusions, since, like them, they cut through and mineralize many of the laminated quartzites.[b] To the same age and to the same influence may perhaps be assigned the auriferous character of the conglomerates of the Nullagine district. These apparently furnish a very close parallel in mode of formation to the famous banket reefs of the Rand. They have been described by Maitland[c] as forming the Mosquito Creek Beds towards, or at the base of, the Nullagine Series. The auriferous conglomerates occur in lenticular masses and contain gold both in thin white quartz veins which are parallel with the bedding planes, and also interspersed through the matrix of the conglomerate. The veins, as might be expected, are much richer than the conglomerate matrix, the former averaging 2·82 ozs. and the latter only ·62 ozs. per ton.

South Africa.—In South Africa, numerous diabasic dykes break through the Barberton Series, and some of these have, at Barberton itself, exercised a notable influence on auriferous deposition, furnishing in the Barberton laminated quartzites well-marked "shoots"[d] akin to those of Western Australia. To this period of auriferous activity we may now reasonably ascribe the infiltration and auriferous impregnation of the Rand "banket." The stratigraphy of the Witwatersrand series has been fully discussed.[e] Excepting that they are much younger than the Swaziland schists and older than the Devonian rocks of the Cape System, little can be said of their geological horizon. The Rand Beds consist, briefly, of quartzites, slates, and conglomerates. Of these, the striped and contorted bands, in the Hospital Hill Beds, of alternating layers of jasper, quartz, specular iron, and magnetite[f] are strongly reminiscent of similar beds in the Pre-Cambrian Bijawars of India. In the present connection, however, by far the most important geological feature is the occurrence of numerous uralitic diabase

[a] Maitland, Ann. Rep. W. A. Geol. Surv., 1903, p. 10.

[b] Idem, loc. cit., 1902, p. 16.

[c] Report quoted Aust. Mining Standard, Oct. 25, 1905, p. 399.

[d] Trans. Geol. Soc. S.A., VI, Pt. I, 1904, p. 56.

[e] Hatch and Corstorphine, "Geology of South Africa," London. 1905.

[f] Hatch and Corstorphine, Trans. Geol. Soc. S.A., VII, 1905, p. 98.

dykes ramifying throughout the auriferous series, and of sheets of diabase, often amygdaloidal, which occur at various horizons in the system, and are especially well developed in the Eastern Rand. The period of auriferous infiltration of the Witwatersrand System would seem to be very definitely limited by the occurrence in the overlying Ventersdorp System of occasionally auriferous conglomerate boulders "unmistakably derived from the Witwatersrand Beds."[a] There is, as already stated, at present no evidence to indicate whether the gold of the auriferous solutions was derived from the diabasic magma or was dissolved from the presumably underlying Archæan schists such as those already described as occurring close to the Rand in the Bezuidenhout Valley. The latter assumption is considered the more probable, but the question must remain an academic one until assays for minute quantities of gold in the diabases of the area have been made. Even then, absence of gold from fresh diabase will not conclusively prove that they were not accompanied by auriferous solutions.

Corroborative evidence of the close genetic relation existing in the Transvaal region between diabasic intrusions and auriferous deposition is furnished by the Lydenburg and other goldfields lying along the eastern escarpment of the High Veld. Here diabase sills have been intruded along the almost horizontal bedding planes of the sedimentary rocks (mainly dolomite). Siliceous solutions, apparently set in circulation by the igneous intrusions, have, along flat fissures in the neighbourhood of the diabase sheets, acted on and metasomatically replaced the calcareous rock, with attendant deposition of gold.

In Egypt also, an area which may be regarded as furnishing the most northerly portion of the East African Archæan band, there is an apparent, though not a certain connection between Pre-Cambrian diabasic or dioritic intrusions and auriferous deposition. The little evidence available regarding the gold-deposits of West Africa hardly permits of speculation.

America.—Turning now to the Archæan schists of Eastern America, we are confronted with identical phenomena. Dykes of diabase, little, if at all metamorphosed, are present in some of the gold-mining districts of North Carolina, and have obviously had a considerable influence on ore-deposition. In South Carolina, the Haile is one of the best-known mines. The country rock is a muscovite-schist that, according to Becker,[b] is an altered Archæan volcanic rock. It is intruded by numerous diabase dykes, which cut through the rock without any apparent dislocation. For some

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[a] Loc. cit. sup., p. 149.

[b] 16th Ann. Rep. U.S. Geol. Surv., Pt. III, 1895, p. 262.

distance from the dykes, the muscovite-schist has been very completely metamorphosed. The metamorphosed zones have been thoroughly impregnated with auriferous pyrites, which sometimes forms layers, 4 inches to 6 inches thick, along the surfaces of contact. Mining is carried on in the impregnated schists, the only defined boundary of the deposit being formed by the dyke, whilst the thickness of the deposit is determined solely by its economic value, since it is worked only as far from the dyke as can be done with profit. The Brewer mine, a few miles away, has a similar wall rock. Lindgren,[a] however, points out that the auriferous veins of Dahlonega, Ga., are in genetic connection, not with diabase, but with acid aplitic intrusive rocks. It would therefore appear that the heat of the igneous rock, rather than the nature of the igneous rock itself, has been the controlling factor in the formation of gold-deposits of this type.

Ontario.—In the Lake of the Woods region, Ontario, which may be regarded as the most northerly extension of the Appalachian belt, diabase dykes in a greenstone- or diabase-schist are found intimately connected with the origin, if not with the mineral contents, of some of the veins.[b]

Colorado.—The Pre-Cambrian schists of the Gunnison gold belt, Colorado, are hornblendic rather than micaceous. They are occasionally penetrated by dykes of dark diabase.[c]

Nova Scotia.—These goldfields have been tentatively grouped by Lindgren with the Archæan Appalachian schist deposits already described, but a consideration of their relations seems to bring them most naturally to this place. The auriferous sedimentary rocks are highly pyritous slates and quartzites, sandstones, and conglomerates. Gold-quartz veins also occur in the older schist further east, near Bras d'Or Lake, Cape Breton Island. Their age is not clear, and may be Cambrian or even Pre-Cambrian. From the occurrence of auriferous quartz pebbles in a Lower Carboniferous conglomerate, mineralisation is believed to have taken place prior to that period. The sedimentary rocks are everywhere intruded by granite, and this rock constitutes much of the surface of the auriferous area. Occasional fissure veins are met with, but the general type of vein is one that closely follows the foldings of the slates and, indeed, resembles closely the "saddle reefs" of Bendigo. The gangue is quartz with a little

[a] Bull. U.S. Geol. Surv., No. 293, 1906, p. 124.

[b] Trans. Am. Inst. M.E., XXVI, 1896, p. 856.

[c] Ib., p. 440.

calcite. The veins contain auriferous pyrites, mispickel, and rarely galena and blende.

Guianas.—A well-defined auriferous province extends from the Yaruari basin, immediately south of the Orinoco river in Venezuelan Guiana, through British. Dutch, and French Guiana to the "Disputed Territory" of Brazil, lying north of the Amazon. Owing probably to the unhealthiness of the country and to the dense jungle with which the region is covered, few gold-quartz veins of importance are known. El Callao in Venezuela, and the Peters mine in British Guiana are the only two of economic value. The placer deposits of the region, however, furnish considerable quantities of gold. Everywhere throughout this territory auriferous deposition *in situ* has shown a marked dependence on diabasic and dioritic intrusions, and in many cases the igneous rocks themselves have been proved to be slightly auriferous, though it is not clear whether the gold thus found is authigenic or has been introduced in association with pyrite at a later date.

TERTIARY ANDESITIC GOLDFIELDS.

All the goldfields to be considered under this head lie either in andesite rocks or in rocks very closely allied genetically and petrographically to normal basic (augitic) andesites, or else in igneous or sedimentary rocks in the vicinity of such andesitic intrusions. Their range petrologically may include rocks as acid as quartz-trachytes, and the term andesitic is selected merely as denoting the general type. The range in geological time is from Eocene to Pliocene with a special, though perhaps merely coincidental, development in the Oligocene and Miocene. A glance at the world's andesitic goldfields will show how remarkably closely they follow the existing lines of volcanic activity on the earth's surface; the "Pacific Circle of Fire" is likewise a circle of andesitic goldfields. Andesitic goldfields are sporadically distributed from Valparaiso northwards through the Andes; they attain extraordinary richness in Mexico and the Western States of America, and especially in Nevada, Utah, and Colorado. A break occurs in British Columbia, but the line is again taken up on Unga Island in Alaska.[a] In the Western Pacific, the corresponding line is run by the extensive andesitic goldfields of Japan, through similar fields in Sumatra and Celebes.[b]

[a] Lindgren, Trans. Amer. Inst. M.E., XXXIII, p. 806.

[b] Truscott, Trans. Inst. Min. Met., X. p. 52-73.

The auriferous andesitic occurrences of Kyoukpazat in Burma and of Talan, in Yunnan, are to be regarded as sporadic along meridional lines of Miocene folding that are parallel with, or only slightly divergent from, the main direction of the lines of crustal weakness passing from Formosa to Borneo.

The rich andesitic goldfield of New Zealand may be considered to mark the southern limit of the chain of goldfields in the Western Pacific. The rare occurrences of gold in the Fiji Islands may also owe their origin to Tertiary andesitic influences. All the world's andesitic goldfields, with one notable exception, are on the "circle." The exception is the Transylvanian and similar Hungarian goldfields; their andesites, erupted during the Aquitanian stage, are clearly to be referred to the lines of crustal weakness first developed in Southern Europe in the Oligocene, and now indicated by the active volcanoes of the Mediterranean. The outstanding features of the andesitic type of goldfield are therefore its modernity and its consequent direct connection with existing volcanic phenomena.

All andesitic goldfields present a well-defined and uniform facies. The andesite or allied rock has, under the influence of solfataric agencies, and by the breaking up of its felspars and ferro-magnesian silicates, been converted to "propylite," in which the ferro-magnesian silicates have given place to chlorite and epidote, and the felspars to quartz, chlorite, and epidote.

It has generally been assumed that solfataric action is an end-product of volcanic energy; while this may be, and probably is true for local outbursts, it is certainly not so when the whole Tertiary field of vulcanism is considered, for solfataric action can be shown to have persisted concomitantly with the effusion of lavas, whether of normal or of extreme types. From our present point of view, however, the only important solfataric action has been that which succeeded the extrusion of the augite-andesite lavas, and this, so far from occurring towards the end of the period of volcanic activity, took place relatively soon after the commencement. There, therefore, lies in this feature a weighty objection to the hypothesis of J. E. Spurr,[a] in which highly siliceous solutions (forming quartz veins) and metalliferous solutions (furnishing the filling of the quartz veins) are considered the end-products of the segregation of magmas within the earth's interior. While auriferous deposition would appear to have been most wide-spread in Miocene time, the solfataric action that contributed towards it existed before that period and has persisted to the present day, as is evidenced by the metalliferous deposits of the Steamboat Springs in Nevada,

[a] Econ. Geol., II, 1907, p. 781.

and by the auriferous deposits of the geysers of New Zealand,[a] both occurrences being in well propylitised andesitic provinces, with andesite lavas at least as old as the Miocene period.

The matrix of the gold of the andesitic fields is generally quartz. The bullion is invariably, when of primary deposition, of low grade, and, especially when associated with calcite in veins, is often crystallized. Tellurides of gold and silver, though not restricted to the andesitic goldfields, are characteristic of them. The associates of the gold in rude order of value as "indicators" are:—galena, stibnite, argentite, stephanite, proustite, pyrargyrite, chalcopyrite, nagyagite, sylvanite, native arsenic, pyrite, and, more rarely, zinc blende, grey copper, bournonite, realgar, and orpiment. Andesitic goldfields, as a rule (to which there are, however, several notable exceptions), are characterised by the irregularity of the gold-veins both in value and in extent, the economic value often depending entirely on very local enrichments.

The general distribution of the andesitic goldfields may be considered in detail, and a few of the more important selected for description as typical. The coincidence of these goldfields with the lines of volcanic activity that border the Pacific Ocean has already been indicated. Assuming for the moment that auriferous solutions are a product of andesitic magmas, as the general connection might well indicate, it is difficult to account for the sporadic and irregular distribution of goldfields within andesitic zones. A consideration of the regional distribution of andesitic goldfields and of more ancient auriferous deposits suggests two alternative inferences; either that auriferous andesites may themselves be a *rechauffée* of older auriferous rocks, metamorphic or sedimentary; or that they may have obtained their gold during the passage of their solfataric waters through older auriferous rocks. In either case the gold cannot be considered of direct magmatic origin, and andesites, under such an assumption, are auriferous only when underlying or adjacent rocks have carried gold. From this point of view, therefore, andesitic magmas are to be regarded merely as heat carriers.

South America.—To the southward range of these fields along the Andes of South America it is impossible to place any definite limit; they appear to reach at least as far south as the latitude of Valparaiso (33° S. Lat.). The associated rocks are there, however, liparitic (rhyolitic) rather than andesitic. To the north, in Peru and Ecuador, and to a lesser degree in Colombia, the goldfields are widely scattered and the veins are notable for their silver content rather than for their gold. In any case little definite geological information is

[a] Maclaren, Geol. Mag., Dec. 5, III, 1906, p. 514.

available concerning them. Perhaps the first of the typical andesite fields reached proceeding northwards is the formerly world-famed Espritu Santo mine, in the Isthmus of Darien.

Numerous veins occur in the western portions of the Central American republics of Panama, Costa Rica, Nicaragua, Salvador, and Guatemala.

North America.—It is in the great Miocene petrographical province mentioned as ranging northward through Western North America from Mexico that auriferous andesitic veins attain their greatest development. Of the great number of goldfields in these rocks, three fairly typical areas : Pachuca in Mexico, Comstock in Nevada, and Cripple Creek in Colorado, may briefly be described.

Pachuca.—The Sierra Pachuca lies to the north-east of the City of Mexico. The basement rocks are non-fossiliferous Cretaceous sediments which, during the Middle Tertiary, were broken and upheaved by tectonic disturbances, and were covered by andesites and dacites, with tuffs and breccias, rhyolites, and finally, basalts. The andesites are mainly pyroxenic, and are sometimes diabasic.[a] It is in the andesitic rocks alone that the metalliferous veins are developed. The gangue is quartz with occasional later and subordinate calcite, rhodonite, and rhodochrosite. The associates of the gold are argentite, pyrite, galena, zinc blende, stephanite, and polybasite. The country rock here, as in all auriferous andesitic areas that have undergone propylitization, contains much secondary pyrite, while, near the vein, the country is generally much silicified. The characteristic " shoots " or " bonanzas " furnish most of the product of Pachuca. The yield is mainly in silver, only 20 to 30 per cent. of the value being in gold.

Northward, the chain of andesitic fields is prolonged through New Mexico to Colorado, where they are widely developed, and through Arizona to Nevada and Utah as far north indeed as Silver City in Idaho. Sporadic fields occur further north, as at Monte Christo in Washington, which with the possible exception of the Rossland sulphide occurrences, probably also to be referred to this period, are the most northerly of the Tertiary andesitic fields on the eastern seaboard of the Pacific Ocean.

Comstock, Nevada.—Ancient metamorphic slates occur in the southern portion of the district, and, indeed, form the footwall of the Comstock lode south of the Yellow Jacket and Belcher shafts, but the mass of the country rock is igneous and andesitic. According to Hague and Iddings,[b] the order of succession of the rocks of the

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[a] Aguilera and Ordonez, Boletin del Institut. de Mexico, Nos. 7, 8, 9, 1897.

[b] Bull., U.S. Geol. Surv., No. 17, 1885, p. 123.

district is andesite, dacite, rhyolite, andesite, and basalt. In depth the andesites assume a dioritic and diabasic habit. Propylitization is extensive—the hornblende, augite, and biotite yielding chlorite, epidote, and pyrite, while the felspars furnish quartz and a white, possibly sericitic, material.

The lode is 3 to 4 miles in length. The product was mainly silver obtained from stephanite, argentite, and polybasite. Galena and zinc blende also occur. The bullion contains 6 to 7 per cent. of gold, or about half the value. The matrix is quartz with occasional calcite. Bonanzas have furnished the greater portion of the product. Pyrite is abundantly scattered through the country rock.

Cripple Creek, Colorado.—This field lies in the Eastern Rocky Mountains, about 10 miles south-west of the famous Pike's Peak. Its country rock is the red granite of that mountain. The granite contains occasional Pre-Cambrian schists seamed with diabase dykes. The auriferous area is, however, some 20 square miles of Oligocene or Miocene volcanic rocks. The earliest eruptions and the most extensive were andesitic, and occur both as lavas and as tuffs and breccias, the latter predominating. Following the andesites came phonolitic breccias and dykes, with which may be associated some minor outcrops of syenite and nepheline syenite. Finally, these were intruded by more basic rocks, yielding dykes of nepheline-basalt, felspar-basalt, and limburgite.[a] Hydrothermal agencies have been extremely active in the region, and the breccias are often so highly dolomitised that little of their original character can be discerned.

The veins are very largely replacement veins, and, probably owing to the presence of the phonolitic magma, show a divergence from the vein association usual in andesitic areas, viz., in the occurrence of fluorite. This mineral, together with secondary orthoclase (adularia or valencianite), occurs abundantly in the veins, and also as an impregnation in the surrounding country rock. The ordinary gangue is quartz, but barytes also occurs. Opaline silica is occasionally met with. The veins persist into the granite, in which rock also alteration has proceeded outward from the vein, resulting often in the production of a highly cellular rock. The cavernous rock and the porous breccias may be impregnated for several feet with auriferous tellurides, fluorite, and secondary orthoclase, and it is these telluride replacements rather than the quartz-veins themselves that furnish the bulk of the Cripple Creek gold. The tellurides are principally calaverite, krennerite, and sylvanite, with rare petzite. Other associates of the gold are

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[a] Penrose, 16th Ann. Rep., U.S. Geol. Surv., II, 1895.

galena, chalcocite, stibnite, and zinc-blende. The general disposition of the ore-bodies is in thin shoots.

Similar districts in the Western States of America are Silver City and De Lamar, Idaho [a] and Goldfield, Rhyolite, and Tonopah, Nevada.[b] These and others will be found more fully described in later sections of this volume.

Connection is made between North America and Asia by the islands of the Aleutian chain. Many of these possess still active volcanoes. Gold deposits of the normal andesitic type also occur, but these have not hitherto proved of great importance. The line of volcanic manifestation runs from the Aleutian chain to Japan by way of the Kurile Islands. In Japan there are many gold areas scattered through andesitic rocks. They are not now highly productive, but the upper zones of their veins furnished many million ounces during the 15th and 16th centuries to Portuguese and Dutch merchants. The goldfields of northern Formosa are a direct continuation of the Japanese chain. South of Formosa andesitic goldfields appear to be connected with another zone of crustal weakness running almost at right angles to the Japanese line. The gold occurrences of the Philippines are mainly in older rocks, and no direct evidence is there available of association with Tertiary intrusives.

A great andesitic zone runs through the East Indian Archipelago. Its most northerly fields are doubtfully those of Kyoukpazat in Burma and Talan in Yunnan, which are developed along meridional lines of Miocene crustal weakness, but the first important goldfields are those of Central and Southern Sumatra, the last containing the well-known Radjang Lebong mine. From thence the belt appears to run eastward equatorially, including the goldfields of Bau and Bidi, Sarawak, and others in Southern Borneo, and ends in the scattered goldfields of the eastward prolongation of Northern Celebes. The general relations of the Japanese, Asian, and Archipelagian goldfields are not now evident, and will be understood only with fuller geo-tectonic information concerning south-eastern Asia.

New Zealand.—The New Zealand auriferous andesitic area in the Hauraki Peninsula is only broadly connected with the foregoing ; its position appears to have been determined by the intersection of two of the great Pacific axes of folding and faulting—one running south-west to form the mountain chain of New Zealand, and north-east into the Central Pacific Ocean, where, along its course, several active volcanoes (Kermadecs, Tofoa, Savaii, &c.)

[a] Lindgren, 20th. Ann. Rep., U.S. Geol. Surv., pp. 107-188.

[b] Spurr, U.S. Geol. Surv., Prof. Paper, No. 42, 1905.

have been developed ; the other axis strikes north-west through Norfolk Island to New Caledonia and the New Hebrides. At the intersection of these axes volcanic activity is still extant, and is manifested by the eruptions and geysers of the Hot Lakes region.

The Tertiary eruptives of the Hauraki Peninsula rest on sediments of obscure Mesozoic and Palæozoic age. The oldest of the eruptives are Upper Eocene in age and are flows and breccias of andesites (pyroxenic in the main, occasionally hypersthenic, but sometimes amphibolitic) and dacites that are mainly hornblendic. This series contains the auriferous veins. It was succeeded by a well-differentiated Oligocene or Miocene series (Beeson Island Group) consisting mainly of coarse, somewhat trachytic breccias. Under the microscope, they are, as has been shown by Professor Sollas,[a] mainly hypersthene-andesites and dacites, though many of the latter, especially when hornblendic, might readily be termed trachytes. This series is not auriferous.

Closing the volcanic sequence in the Peninsular area, and developed only on the east and south, are thick deposits of rhyolite, both glassy and pumiceous. Outside the Peninsular area are later eruptions of basalt on the Auckland Isthmus, and of pyroxenic andesite in the Hot Lakes region to the south.

Auriferous deposition is practically confined to the older andesites. and to those only where propylitization has been extensive. Propylitization here, as elsewhere in auriferous regions, has resulted in the conversion of the felspars and ferro-magnesian silicates to chlorite, quartz, calcite, serpentine, sericite, epidote, and pyrite.

This area contains the famous Waihi mine, at the present time potentially the greatest of the world's gold mines. Unlike the majority of veins on andesitic fields, the values of the lodes of Waihi are regular, owing nothing to shoots or bonanzas. The matrix is quartz, which is occasionally chalcedonic. Calcite occurs, but is subordinate and of no importance. Lindgren[b] records the presence of valencianite or secondary orthoclase. The associates of the gold are pyrite, sphalerite, galena, and argentite, and probably chalcopyrite. Pyrite, calcite, and a serpentinous mineral are abundant as metasomatic replacements of the adjacent country rock, while valencianite may occur there in veinlets with quartz and calcite. Manganese oxides occur, which furnish, on analysis, nickel and cobalt. The Waihi bullion carries a small percentage of selenium originally contained in the sulphide-ore.

Hungary.—The only auriferous andesitic region not bordering on the Pacific Ocean is that of Hungary. Its gold-deposits all

[a] "Rocks of Cape Colville Peninsula," Wellington, 1906, p. 56.

[b] Eng. Min. Jour., Feb. 2, 1905.

arise from solfataric action consequent on the extrusion of andesites and trachytes along the inner side of the great Carpathian uplift. Three main areas may be distinguished: (*a*) The Schemnitz area; (*b*) the Transylvanian (Dacian) area, and (*c*) the Nagybanya area. Clearly to be associated with these is the auriferous dacite area of north-eastern Servia.

The Schemnitz region lies about 80 miles north of Buda-Pesth in the Erzgebirge of Lower Hungary. Its basement rocks are Triassic; these are overlain by Eocene Nummulitic shales. Volcanic eruptions commenced about the middle of the Mediterranean stage. The order of succession appears to have been pyroxene-andesite, diorite and quartz-diorite, aplite, biotite- and amphibole-andesite, and lastly rhyolite, which is the predominant rock. The andesitic varieties are now propylitized. Veins are extremely numerous, and some are continued into the adjacent Miocene strata. The Grüner and Spitaler lodes show a persistency in length exceptional in andesitic areas. The latter lode has been traced for 7·2 miles. The gangue and associates of the gold are, with the exception of tellurides, essentially those already mentioned. The Kremnitz lodes further north are in similar rocks.

The oldest rocks of the Transylvanian region are phyllites and crystalline schists. These are hidden by Mesozoic strata which are broken through and covered by andesites, dacites, trachytes, and rhyolites, with later basalts. The andesites, belonging to the Mediterranean stage, have here also been propylitized, and carry gold-quartz veins which are characterised by the presence of tellurides. The principal fields of this area are Nagyag, Offenbanya, Faczebanya, Fericsel, Verespatak, Vulkoj, Botes, Brad, and Boicza. The mineral veins of these fields show the "stockwerk" features characteristic of most andesitic goldfields, with local enrichments at intersections. On the Verespatak field, the veins occur partly in the eruptive rock and partly in the adjacent Carpathian sandstones. The veins in the latter are of clean quartz with free gold, and without the sulphides and tellurides that occur with the gold in the propylites.

The Nagybanya area, which includes, among others, the gold veins of Felsobanya and Kapnik, lies in the extreme eastern province of Hungary about 100 miles north of the foregoing area. It consists of propylitic dacites, rhyolites, and trachytes, and its lodes present the same characters as those of Schemnitz.

A general consideration of the characters of the various rocks that go to make up a normal auriferous andesitic province is of interest in connection with the question of the origin of the great auriferous Archæan schist areas. It is suggested that the metamorphism of such an andesitic assemblage yields a complex made up mainly of amphibolitic and chloritic schists, and, further, that the gold contained in sulphides and as tellurides in the small veins and impregnated areas of the andesitic rocks is, during the metamorphism of the enclosing rock, dissolved and re-deposited generally with quartz in the major thrust-plane fissures developed by folding. Petrological examination of hornblende-schists, such as those of the Kolar field, certainly indicates a derivation from intermediate igneous andesitic rocks that, from their association with boulder-beds and grits, were obviously deposited at the earth's surface. The foregoing assumption, taken in conjunction with the suggestion already outlined, viz., that the gold of an andesitic area is derived from older underlying or adjacent auriferous rocks, indicates a complete cycle in the history of gold, from depth to surface, and from surface to depth. In the present state of our knowledge the relations outlined are to be regarded as highly speculative.

GOLDFIELDS ASSOCIATED WITH ROCKS THAT ARE IN THE MAIN OF GRANODIORITIC TO GRANITIC TYPES.

The characters of the auriferous provinces already outlined are well marked, and the grouping there adopted has been fairly obvious. The affinities of the two principal members of this, the third great group, are not less evident. In each case, viz., in the Californian and Southern Alaskan regions of Western North America in the first instance, and along the mountain axis of Eastern Australia in the second instance, auriferous deposition is clearly genetically connected with a single, often protracted period of igneous activity. The age of the first is probably to be referred to the Jurassic, that of the second to the Permo-Carboniferous period. Considering the general retardation in geological time of the Australian continent the intrusion or extrusion of these magmas may be much nearer in point of actual time than their respective geological horizons would indicate. The relations of the third member of this group, covering as it does the scattered goldfields lying along the eastern slopes of the Ural Mountains in Russia, are by no means so evident as the foregoing ; but it, nevertheless, seems to fall naturally into this section. The general meridional distribution of all three provinces of the group is merely an expression of the general direction of the lines of the earth's crustal weakness along which mountain chains are formed ; it has probably no bearing on the present subject. All three provinces show a characteristic mingling of igneous rocks of various types. While in every case the general facies of the magma has been granodioritic to granitic there are, nevertheless, older or younger rocks of intermediate or even basic types. It is here that the weakness of the classification now adopted for these three provinces lies ; for it is not possible to determine in the present state of our knowledge, whether auriferous impregnation is to be referred to the main granodioritic magma or to the possibly genetically-connected intermediate magmas that preceded or followed. Should it hereafter be demonstrated that the auriferous content of these groups is dependent on intermediate (dioritic) or slightly basic intrusions, a great advance will have been made, since these provinces will then fall into line with the goldfields of Archæan, Pre-Cambrian, and Tertiary times. In the Tertiary igneous auriferous provinces an entirely similar differentiation of magmas has obtained, andesites and dacites being often succeeded by rhyolites and basalts, a succession which may be considered to be entirely analogous to the relations of the granodiorite, granite, and diabase now exposed by denudation.

In an important economic respect, the three provinces of the group agree closely ; they have furnished the great placer-gold deposits of the world. To this feature, however, two factors, one inherent and the other external, have mainly contributed. In the first place, the gold of the veins of this group is generally free and coarse, and has been enclosed within a quartz matrix from which it has been dissociated with ease ; secondly, these areas have, during Tertiary times, been, in general, areas of elevation. The erosion and degradation of the upper portion of their gold-quartz veins, with a consequent separation and sorting of their heavy minerals has thus been rendered possible. It is further characteristic of the gold-quartz veins of this group that they show no very decided dependence for country on the igneous members of the various complexes in which they are found, but occur indifferently in igneous rock or in adjacent sedimentary or metamorphic rock, favouring, perhaps, carbonaceous shales or slates.

Western North America.—The auriferous granodioritic region of Western North America has been closely studied. From the State in which it shows the greatest development, it has generally been termed the Californian belt. It may be traced northwards from the Lower California peninsula in Mexico to the flanks of the great Sierra Nevada chain, through the western foothills of which it runs the length of California. In Oregon it carries goldfields of minor importance. With the main Californian belt are probably to be grouped the rocks of the gold-quartz veins of the Blue Mountains in north-east Oregon ; those north of the Snake river, in Idaho; and many of the auriferous vein occurrences of Montana. The sulphide deposits of Rossland across the international boundary in Canada are possibly also to be grouped here. Whatever may be the relations of these last, there is, however, no doubt of the close connection of the auriferous occurrences of the Southern Alaskan seaboard with those of California; they are certainly to be considered as forming a northward continuation of the Californian belt.

Lindgren[a] has clearly shown that the gold-quartz veins of the Californian belt are always closely associated with the "metamorphic series," comprising, in this case, a great assemblage of rocks ranging in age from Early Palæozoic to Jurassic, and containing among its sedimentary members altered slates, sandstones, and limestones, together with more or less metamorphosed quartz-porphyrite,[b] augite- or hornblende-porphyrite, diabase, and amphibolite as representatives of probably intercalated igneous rocks. Gabbros and serpentines also occur, but are not abundant. Through all of these, and also through the later granite and granodiorite (quartz-mica-diorite with a little orthoclase), there run auriferous quartz veins, which certainly seem to be more closely connected with the granodiorite than with any other intrusive rock.

The granodiorite is a rock intermediate between a granite and a quartz-diorite. With it, and often inseparable from it, are various types of gabbro-diorite. The "porphyrite" group is commonly termed the "greenstone series," and comprises various diabases and porphyrites that are now often largely uralitized. The relations of these rocks to the granodiorite are far from clear, and different successions have been advanced as a result of work in different regions. The most widely-accepted sequence of events in the Mesozoic eruptions commences with intrusions of gabbro-diorite and granodiorite, is continued by the extrusion of diabase and porphyrite, and is completed by further intrusions of granodiorite. As a result of contact metamorphism, the Mariposa slates, though only of Late Jurassic age, are, near contacts, altered into mica-schist and andalusite-schist.[c]

The most striking member of the Californian auriferous veins is the "Great Mother Lode," which is essentially a longitudinal series of quartz veins developed along a strike fault area for more than a hundred miles. Quartz is the dominant matrix, but calcite, dolomite, and ankerite also occur. The associates of the gold in the veins are various sulphides: pyrite, arsenopyrite, galena,

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[a] Bull. Geol. Soc. Am., VI, 1895, p. 225.

[b] Pre-Tertiary andesite.

[c] Forstner, Min. Sci. Press, 1908, p. 744.

chalcopyrite, tetrahedrite, and blende. Tellurides also occur. Gold has been noted as occurring in albite veinlets ramifying through a porphyrite.

To be associated with the Californian occurrences are the Southern Alaskan coastal mines. Of these, the Douglas Island deposits have been the most closely investigated. The country rock in the vicinity of the Alaska-Treadwell ore-deposit is, as in Victoria and often in California, a carbonaceous slate. The slate has been intruded by an albite-diorite dyke, consisting essentially of albite, with a little augite, hornblende, biotite, and a small quantity of a plagioclase felspar more basic than albite. Further crushing and metamorphism was followed by the intrusion of a diabase or gabbro (augite and plagioclase). The gabbro appears to have had no effect on the mineralisation, but a still later analcite-basalt dyke seems to have set mineralising solutions in circulation and to have filled two series of fissures in the albite-diorite. These series lie at right angles to each other at about 45° to the horizon. The vein-filling is quartz and calcite, and the associates of the gold are auriferous pyrites, chalcopyrite, mispickel, blende, and galena.

Eastern Australia.—The great chain of important goldfields developed along the Eastern Cordilleras of Australia—to use the term proposed many years ago by Murchison for this mountain range—are apparently all to be assigned to strongly-developed igneous intrusions of a general granodioritic facies. Recent geological work has thrown considerable light on the age of these intrusions. They are certainly older than Triassic times, and would appear to have reached their maximum development in the Carboniferous period; at least, so far as the main granodioritic intrusion is concerned. There is evidence of earlier igneous activity, indicated by the possibly Lower Devonian porphyrites of the Snowy River and Mitta Mitta Valley, East Gippsland, and there has been, subsequent to the deposition of the Permo-Carboniferous sedimentary beds, a widespread intrusion of more basic (dioritic) members. These last are exceedingly important from our present standpoint, and are certainly responsible for auriferous deposition on several fields (Mount Morgan, Gympie, Lucknow, Woods Point, Walhalla, &c.). The diorite dykes are perhaps most naturally to be considered as later magmatic segregations from the main, more acid magma. There is thus in this area a considerable similarity to the Californian province already outlined. The granodioritic and granitic intrusion is clearly a result of the action of the orogenic forces that have, in the course of geological ages, built up the mountain ranges of the eastern seaboard. The rocks and veins of Tasmania must be grouped with those of the mainland, since that island has only very recently been separated from Australia.

In southern New South Wales, Victoria, and Tasmania the acid igneous rocks show a relatively small exposure at the surface in auriferous areas, but further north, in Queensland, either from a greater development nearer the surface or from greater erosion, they bulk largely in the auriferous complex. Speaking generally, therefore, goldfields occur in the north (Croydon, Ravenswood, Charters Towers, &c.) in the igneous rocks; while in the south, as in Victoria and Tasmania, they occur in the overlying or adjacent sedimentary rocks. To this general rule there are notable exceptions. In Queensland both the famous Mount Morgan mine and the Gympie field are in the sedimentary rocks of the Gympie (Lower Carboniferous) series. Another division of the goldfields of the belt, and one dependent on the character of the ore-matrix, may also be made, inasmuch as some carry highly refractory auriferous sulphide-ores, while others yield only clean quartz with free gold. It will, on examination, be found that the former are restricted to the typical acid igneous rocks, while the latter lie within sedimentary, and often carbonaceous beds. Further, it may be seen, as at the Etheridge and Ravenswood, in Queensland, that where auriferous veins pass from granite or granodiorite into adjacent sedimentary rocks, the dense sulphide-ore of the former tends to give place in the latter to quartz with free gold. The veins of the Croydon goldfield in aplitic granite carry quartz with free gold and little pyrite; this is, however, not a real exception to the general rule, since both the country and the fissures contain large quantities of graphite. There is, therefore, reason to believe that no genetic distinction between the filling of the veins of the respective fields may be made, and that the difference arises from the segregative influence of the carbonaceous matter of sedimentary beds on pyrite and gold. In these beds the pyrite affects the country, leaving quartz and gold to be deposited in fissures.

The granite of the northern fields, as of Croydon, is of a curiously aplitic type; it is further characterised by the presence of considerable quantities of a graphite that possibly represents portions of Permo-Carboniferous coalfields caught up by intrusive magmas. Normal granite occurs, but is not common on the northern goldfields. Rocks of the granodioritic type may often be described, as from Charters Towers, with greater particularity as tonalite or quartz-mica-diorite.

In the southern regions the sedimentary beds of Ordovician and Silurian age form the normal locus of the auriferous veins, which have often been formed along the corrugations into which these beds have been folded, in this case giving rise to the "saddle reefs," peculiarly distinctive of Bendigo.

Of the goldfields in acid igneous rocks, Charters Towers is probably typical. Its veins, as already stated, lie in a complex of granitic and granodioritic rocks, through which, as may be seen from an inspection of the geological map attached (Fig. 103), there ramify numerous felsitic and dioritic and even more basic intrusions. It is probable that the serpentine area, as shown in the map, represents merely a weathered diorite or diabase. Close to the igneous rocks and intruded by them are slates and schists of probable Middle Devonian age. The main reefs of Charters Towers are the Brilliant and the Day Dawn. These are in depth highly pyritous.

The characters of two only of the numerous goldfields developed in sedimentary rocks may here be indicated.

Ballarat.—The rocks of this field are nearly vertical Ordovician slates and quartzites, and are intruded by granitic dykes which appear to be connected with the origin of the gold, and which are considered to be of later Palæozoic age. The period of auriferous deposition thus seems to be fairly well marked. The goldfield itself lies some little distance to the west of intrusive granitic rocks (quartz-monzonites of Lindgren). Tertiary basic dykes (limburgites) are also intrusive through the Silurian slates, but have no connection with auriferous deposition, and, indeed, are the intrusive representatives of the great Tertiary basaltic flows of Victoria.

The most notable features on the Ballarat East field are the "indicators"—narrow black pyritous bands striking with the country and bedded parallel or nearly so with it. They have generally been regarded as original, highly carbonaceous, pyritous bands interbedded with the country, but Gregory[a] has lately shown that they are not, as a rule, composed of pyrite and arsenopyrite, but rather of ferruginous chlorite. One, the "Pencil Mark," owes its dark colour to rutile. From the nature of the filling, and from his observation that the indicators do break across the bedding, Prof. Gregory maintains that they are filled fissures. This view is not generally accepted by local geologists.

The quartz veins of Ballarat are, on the whole, thin and irregular, and have been worked almost entirely in connection with the indicators, since these last have considerable continuity, and, where they cut the "flat makes" (horizontal floors) of quartz, are the cause of much local enrichment. Of late years, a considerable amount of profitable mining has been carried on in quartz veins developed along strike faults.

[a] Min. Jour., June 20, 1906.

The painstaking research work of Don[a] shows clearly that the country rock of Ballarat away from a vein is barren, and that it is only where pyrites, obviously introduced from the vein, occurs that the country rock carries any values in gold. He also points out the auriferous character of the pyrites of an acid eruptive (felsite-porphyry) dyke analysed by him, the highest analysis (with also the greatest amount of pyrites) yielding as much as 6·7 grains per ton. A genetic association of auriferous lode and acid dyke is suggested.[b]

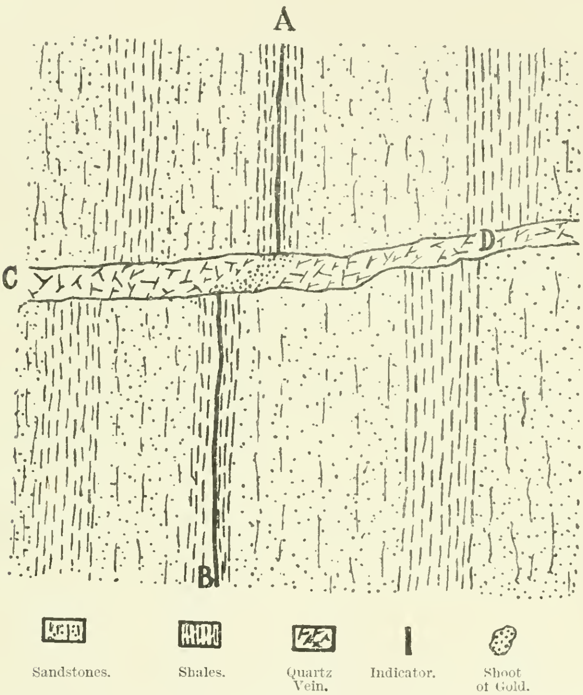

FIG. 66. SHOWING SHOOT OF GOLD AT INTERSECTION OF QUARTZ VEIN AND INDICATOR (*Rickard*).

Bendigo.—The veins of Bendigo are contained in Ordovician black clay-slates that have been compressed into a series of anticlines and synclines. The auriferous quartz occurs at the crest of a number of parallel anticlinals forming the well-known "saddle reefs," *i.e.*, veins with their greatest thickness at the crest of the anticlinal and with a dip away on either side, forming the "legs," which gradually thin out in depth and disappear. Beside the dip of the "legs," the quartz bodies have also the pitch of the anticlinal axis. Quartz is also formed along the corresponding syn-

[a] Trans., Amer. Inst. M.E., XXVII, 1897, p. 568.

[b] Loc. cit., p. 573.

clinal axes, but is not there notably auriferous. The folding of the clay-slates and sandstones is occasionally very sharp. The three principal anticlinals of Bendigo, the New Chum, Garden Gully, and the Hustler, are contained within a distance of 150 yards. Several "saddle reefs" may occur on the one anticlinal, one being superposed on the other at varying intervals in the sedimentary beds. Besides the quartz of the saddle reefs, there are also found irregular branches of auriferous quartz, in more or less obvious connection, however, with the characteristic form of quartz vein.

The quartz of the veins seems to be a simple vein-filling, growing probably with the folding of the sedimentary rocks. The gold is free, and is easily seen in the clear glassy quartz. Sufficient chlorite to give a greenish colour occasionally occurs embedded in the quartz. As at Ballarat, the usual sulphides are pyrite and arsenopyrite, with a little galena. Subsequent vein-filling has given carbonates of iron, lime, and magnesia. Albite occurs intergrown with quartz in drusy cavities.[a]

No direct connection with granitic intrusions has been noted on this field, but a granitic batholith (quartz-monzonite of Lindgren) occurs a little to the south of the auriferous area.

Ural Mountains.—The relations of the group of gold-quartz veins scattered along the eastern flanks of the Ural Mountains are not well defined, nor may either their geological age or that of their enclosing, generally granitic country be stated with any approach to accuracy. They may, however, be of Late Palæozoic age. The area presents so many features in common with those of the two preceding provinces, that it must, for the present at least, be grouped with them. There are the same indications of a widespread acid-magma, in this case, however, rather granitic than granodioritic, with which have been associated, as also in the two already-described provinces, numerous intrusions of more basic rocks. The igneous rocks therefore include granite, syenite, quartz-porphyry, felsite, porphyrites, diorite, diabase, gabbro, norite, and pyroxenite. In the north, and especially in the neighbourhood of Berezovsk, but also at Tcheliabinsk and Kotchkar, the gold-quartz veins form a network of stringers in microgranitic rocks that are either intrusive or massive. The typical microgranitic rock of Berezovsk has been termed "beresite." Gold-quartz veins also occur in the older schists and in diabasic and serpentinous rocks, the latter association being, perhaps, best marked toward the south of the auriferous region. While the country of the northern veins is generally acid, auriferous deposition is attributed by Purington[b]

[a] Lindgren, Econ. Geol., I, 1905, p. 163.
[b] Eng. Min. Jour., June 13, 1903, p. 894.

to the influence of intrusive basic rocks. Purington, indeed, considers the deposits of Berezovsk to be entirely analogous to those of the Alaska-Treadwell on Douglas Island, and, further, that the distribution of the gold-deposits is largely governed by that of the basic rocks.

The gold-bearing veins of Tcheliabinsk, according to Karpinsky,[a] lie in a country of highly dynamo-metamorphosed granite, in part a hornblende-granite. The vein-filling consists of completely decomposed country and of quartz, the latter occurring often as a stockwork.

The Berezovsk rocks are highly metamorphosed muscovite-granite schists and mica-schists traversed by numerous dykes of microgranite and of basic rocks. The acid intrusive rock, and not the schist, is the country of the gold, since across the micro-granites from wall to wall there extend numerous thin auriferous quartz veinlets. The associates of the gold are mainly sulphides, pyrite, chalcopyrite, aikinite ($Pb\ Cu\ Bi\ S_3$), chalcocite, and compact galena. Very frequently also the quartz contains long needles of a grey-green tourmaline, running at right angles to the walls. There also occur pseudomorphs of tourmaline after pyrites. It is suggested that the microgranite (aplite) dykes, which, by the way, recall very strongly the massive aplitic rock of Croydon, Queensland, may be genetically connected with the neighbouring granite massif of Lake Shartash.

The Kotchkar veins in Orenburg[b] are also in sheared and decomposed granite. The gold is associated with auriferous arseno-pyrite, which also impregnates the adjoining granite to a considerable extent.

Other Fields.—Further geological research may bring into the granitic or granodioritic group two widely-separated areas in which the relations of auriferous vein-filling are very obscure, viz., those of the Alps, in France, Piedmont, and the Tyrol, and those of the South Island of New Zealand, in Otago and Westland. Both are apparently to be attributed to Middle and Late Mesozoic mountain building, during which acid magmas were intruded into the rock complex. Tonalites (quartz-mica-diorites) are especially well developed along the Alpine fold ; they are generally disposed along a line to the south of that of the auriferous occurrences ; but here also the question is complicated by the intrusion of augite-porphyry and more basic rock, also of undetermined, and possibly of indeterminate age.

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[a] Guide des excursions du VII Congrés. Geolog. Internat., 1897, p. 30.

[b] Trans. Am. Inst. M.E., XXXIII, 1899, p. 24.

GENERAL CONSIDERATIONS.

From the foregoing facts, of necessity briefly detailed and outlined, we may reasonably make certain deductions. The almost invariable direct association of auriferous veins with igneous rocks, even when taken with the few cases that are not obviously so associated, indicates with some certainty that auriferous veins are formed by waters derived from, or, more often, set in circulation by the heat of igneous magmas and intrusions. That heat alone is insufficient to produce auriferous veins is clearly shown by the fact that they do not accompany every variety of igneous rock. Basalts, trachytes, and rhyolites are notoriously non-auriferous, and, indeed, the only volcanic rock strikingly gold-bearing is the andesitic type. Among plutonic rocks connected with gold-veins, there is a much greater range—granites, tonalites, diorites, and diabases furnishing goldfields. The diabases must, however, be regarded merely as vehicles of heat, since they are, as has been shown, operative only in pre-existing auriferous rocks, as in the Archæan schists. The diorites, again, are merely the plutonic forms of the auriferous andesites. There are thus left the tonalites and the granites. Some of these resemble the diabases in being merely heat carriers ; but others, as those of North Queensland, cannot so simply be explained. The salient fact, therefore, remains that the prominent goldfields of the world are associated with intermediate igneous rocks and with granites and tonalites. The granites and the tonalites may be for the moment neglected, since the data regarding them are too scanty to permit of deduction with the slightest approach to safety, and since the auriferous deposition exhibited in them may well be due to the basic rocks by which they are always intruded. There remain, therefore, closely connected with auriferous deposition, the Archæan schists and the andesites, and these, indeed, constitute the bulk of the world's auriferous rocks. The auriferous Archæan schists show, in the main, that they are of igneous origin, and they may often fairly safely be considered to represent ancient intermediate rocks—probably andesites. A clear distinction must here be made between the younger and older veins of the Archæan schists. The older veins have shared in the metamorphism of the schists, and no evidence of their origin remains, but it may well be considered to be due to solfataric action similar to that which has formed most of the Tertiary andesite veins. In short, we may have in the auriferous Archæan schists a prototype of the wide-spread auriferous Tertiary andesites. In another place the writer has endeavoured to establish an Archæan auriferous province (the "Erythræan") for the countries bordering on the Indian Ocean. This province is considered entirely analogous, for example, with the Cordilleran andesitic province of North America and Mexico; it forms part of an Archæan world-wide auriferous deposit, of which few exposures exist, but which, nevertheless, lies under many an auriferous region of younger age. It may, indeed, be possible in the future to establish a *direct* connection between the Archæan auriferous schists and some, at least, of the Tertiary andesitic goldfields, the gold of the latter having been derived by wandering solutions from the hidden veins of the former. Outside the Erythræan province, the old schists are best developed (as the Appalachian Province), in eastern North America. The recrudescence of auriferous activity in these schists, wherever penetrated by dioritic or diabasic dykes, is by no means one of the least striking features in the history of gold deposition.

The question now naturally arises: What is the relation between gold and the andesitic rocks? Some connection certainly does exist. It may be urged against the views set forth in this place that no actual proof has been adduced that the association is more than fortuitous, and, further, that the gold may have been brought into the andesites from unknown sources at unknown depths. But goldfields do not occur in the sedimentary rocks or even in the rhyolites or basalts that often surround, or occur with, the andesites, and, therefore, though it is merely an assumption that gold deposition is an andesitic function, it is not an unwarrantable assumption. Nevertheless, no direct answer to the above question may be given; the solution of the problem awaits further chemical research, probably, like other problems of ore-deposition, in the direction of the genesis of pyrite and other sulphides.

The poverty of basaltic regions has been explained[a] on the assumption that their occluded gases pass off as vapour, and are thus not available in vein formation. Indeed, it is stated that all surface flows are barren for this reason. But as will be abundantly shown when further considering the Tertiary andesites, these latter rocks are highly metalliferous, and yet they are not less superficial than basalts, trachytes, or rhyolites, all of which are devoid of auriferous deposits.

No less striking than the restriction of gold-veins to certain rocks is their discontinuity in geological time when broadly considered. There is the gap of all the geological table between the

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[a] Kemp, Trans. Am. Inst. M.E., XXXI, 1902, p. 169, p. 695.

Archæan schists and the Tertiary andesites—a gap but imperfectly bridged by the Permo-Carboniferous gold-veins of Eastern Australia and by the Middle Mesozoic lodes of California. With one exception, these intermediate deposits appear to have arisen from what may, perhaps, reasonably be termed in the present study an abnormal influence, viz., that of acidic magmas which may further, as has been suggested, have yielded auriferous solutions only with their less acid segregations.

SECONDARY AURIFEROUS DEPOSITS.

Due to Chemical Action at Depth.—Secondary auriferous deposits are those which may presumably be, or obviously are, due to the influence of chemical or mechanical agents acting on older or primary gold ores or gold solutions. Secondary deposits, being the result of subsequent action, are, therefore, generally to be found within the limits of the auriferous provinces already outlined and very often are confined to the same fissure or ore-channel that holds the primary deposit. From our knowledge of the general character of gold-veins in depth, it may perhaps be legitimately assumed that the normal primary form of deposition of gold is an auriferous sulphide or a chemically-allied gold-telluride, and, further, that the free gold of quartz-veins represents the products of decomposition of auriferous sulphides and tellurides. The propositions are self-evident on the great majority of goldfields, but there are, nevertheless, numerous, though perhaps only apparent exceptions. The most notable examples of clean quartz-veins carrying free gold to great depths are those of Bendigo and Ballarat, in Victoria. It has been shown that these are in sedimentary rocks adjacent to great granodioritic intrusions. Two alternative explanations have been advanced to account for the character of their contained gold. Either the free gold may be truly secondary and may be due to the action of deep-seated acid waters on sulphide or telluride ores, or, and more probably, the auriferous solutions that have deposited quartz and free gold in the sedimentary rocks were part of the same aqueous body that has deposited refractory auriferous sulphides in adjacent igneous rocks, the difference in the character of the deposit being due to the known segregative action of the carbonaceous matter of the sedimentary rocks, pyrite being deposited generally in the country adjacent to the fissure, leaving quartz and free gold to form veins by simple fissure-filling. In the second case, therefore, the deposit must be regarded as truly primary, using the word in the sense already defined. Additional evidence for regarding many of the deep-seated free-gold deposits of Eastern Australia as primary is afforded by the fact that where no natural precipitant is present in the sedimentary rocks, the auriferous deposit even in those may be sulphide-ore, and, further, that where carbonaceous matter is present in the igneous rocks, as at Croydon, free gold in clean quartz may result. At Mount Morgan, where the Gympie beds are sandstones and contain no carbonaceous matter, uprising solutions have deposited their metallic contents as sulphides, and, under the influence of mass action, their silica as a cement or replacement.

The Champion Reef of the Kolar goldfield, in India, furnishes another example of gold-quartz deposited at great depths. The evidence available renders it impossible to say whether its gold is truly secondary. Should its schistose country be admitted as having originally formed an auriferous andesitic complex, as has already been suggested, the secondary nature of the gold of the vein may also reasonably be assumed.

While free-gold of secondary origin is certainly not common in the deep zones below the reach of oxidising waters, some free-gold, such as that found at Kalgoorlie below the 2,000 feet level, is obviously derivative, arising from the action of deep-seated acid waters on sulphides or tellurides, or of tellurides on passing gold solutions. Deep-seated waters are probably generally alkaline, but it is obvious from a consideration of fumarolic vapours and solfataric waters that they may at given times and in certain places be decidedly acid. Maclaurin[a] on analysis found the hot waters (110° F.) of a lake 15 acres in extent, on White Island, New Zealand, to contain 5·47 per cent. of free hydrochloric acid, or more than one-sixth of that contained in ordinary commercial hydrochloric acid. In this connection the recent work of Lane,[b] showing that at great depths the waters of the Michigan copper area are essentially saturated chloride solutions, is of importance.

Exceedingly important secondary auriferous sulphide deposits are formed immediately below the zone of oxidation by descending solutions. It is probable that secondary deposits of gold-tellurides are deposited in the same way. It will be sufficient in the present place to indicate the existence of secondary auriferous sulphide and gold-telluride deposits; their characters and method of formation will be considered at length under the heading of "secondary enrichment."

Due to Chemical Action near the Surface.—The changes that take place in the chemical composition of gold-ores as they

[a] 41st Ann. Rep. Dominion Laboratory, New Zealand, 1908, p. 30.
[b] Amer. Geol., XXIV, 1904, p. 302.

are gradually subjected to the influence of oxidising waters, in the progress of the denudation of the overlying rock, are of the utmost economic importance. Briefly, the essential process for gold is one of liberation from auriferous sulphides. An immediate reduction to the metallic state is possible, but the normal result is either re-deposition as free gold in the zone of oxidation, or with sulphides at the top of the sulphide zone. For the associated base sulphides the change is to native metal, oxide, chloride, carbonate, or sulphate, the oxides of iron being as a rule especially abundant, and forming a ferruginous-red deposit that with quartz constitutes the "ironstone" of the Australian and the "gossan" of the Cornish miner. The depth of the oxidised zone, of course, varies considerably, and depends on the level of the permanent ground-water; it is usually, therefore, from 50 to 250 feet below the surface. In glaciated and boreal regions, it is usually shallow; in elevated desert regions, which yet receive a rainfall, it may be very deep. The economic aspect of the changes that take place in this zone are best considered in a later section, but there are certain points which must be taken here. A change in the character of gold ores as they pass upwards into the zone of oxidation is effected by the removal of the base matter, thus leaving the gold free. Though no direct proof of the existence of gold in vadose solutions has yet been offered, it is reasonably certain that when chemical changes are effected in the base associates of gold, some at least of the latter ordinarily passes into solution, and is carried elsewhere to be re-deposited, generally, indeed, to increase the bulk of already-deposited particles of gold, and to assume crystalline form wherever possible. The zone of oxidation is, therefore, for gold, also that of crystallization. It is only in propylitised andesitic country, or in the upper portions of gold-quartz veins, or, as we shall see later, in alluvial drifts, that crystallized gold is formed. It may be conceived that this restriction arises from the lack, in the zone of cementation, of free space necessary for the operation of the forces of crystallization, for, as we have seen, free gold may readily form in the deeper zones.

Due to Chemical Action at the Surface.—Experience has abundantly demonstrated a notable enrichment of gold veins at and near their outcrops, and it has been assumed that much of the gold taking part in the enrichment is probably transported in solution. It is evident that such solutions may pass from the vein-fissures, which often act as the drainage channels of the region, to the rock surface, and, finally, into overlying soils and gravels. In the soils they are speedily decomposed by carbonaceous matter; but in the gravels, which are composed for the most part of chemically inactive silica, metalliferous solutions may be carried considerable distances before parting with their metallic content. Where, however, they encounter a grain of a precipitant,or a cross-current of a precipitating solution, or suffer a physical change sufficiently great, deposition in the gravel will ensue. Gold may thus be deposited in alluvial gravels. Like mechanically-deposited gold, gold deposited from solution will be found on the down-stream side of the auriferous vein-fissure. The arguments for the chemical origin of alluvial gold have been in the main advanced by Australian geologists and chemists (C. S. Wilkinson,[a] Selwyn,[b] Uhlrich,[c] Daintree,[d] Skey,[e] J. Cosmo Newbery,[f] and others), and by Egleston[g] in America. They are, briefly: (*a*) Great masses of solid homogeneous gold comparable in size to nuggets are rare in veins; (*b*) the purity of alluvial gold is always greater than that of the gold of the neighbouring veins; (*c*) gold nuggets are often frosted with fine gold on their surfaces; (*d*) pyrites replacing organic matter in alluvial drifts is often auriferous; (*e*) laboratory experiments have shown that gold is readily soluble in reagents that may well be supposed to exist in nature. While no single one of the foregoing arguments is in itself conclusive, they, nevertheless, taken together, furnish strong grounds for the assumption of the transport of gold in solution. Masses of gold enclosing a considerable quantity of quartz, but withal more valuable than the largest nugget recorded, have been obtained from gold-quartz veins. A mass of golden quartz 630 pounds in weight and containing gold to the value of £12,000 was obtained in 1872 at the Hillend goldfield, New South Wales. The opponents of the hypothesis of the growth of gold *in situ* point, and with some considerable reason, to this and to similar, though smaller, masses of gold as competent to furnish, after the removal of the quartz by the battering action of stream pebbles, the nuggets of alluvial drifts.

It is universally admitted that the purity of alluvial gold is greater than that of the veins of the neighbourhood. This superiority in fineness is explained by the well-known fact that silver is more readily soluble in natural waters than gold, and is by them removed from the natural alloy, thus increasing its purity. This argument, while certainly valid, fails to explain the homogeneity of nuggets, which are, so far as has been ascertained, of even fineness throughout. Laboratory experience in "parting"

[a] Trans. Roy. Soc. Vict., VIII, 1866, p. 11.
[b] Geol. Mag., III, 1866, p. 457.
[c] Contrib. Min. Victoria, Melbourne, 1870.
[d] Rep. Geol. Ballan, Melbourne, 1866.
[e] Trans. N. Z. Inst., V, 1872, p. 377.
[f] Trans. Roy. Soc. Victoria, IX, 1867, p. 52.
[g] Trans. Amer. Inst. M.E., IX, 1881, p. 646.

silver from gold has indicated that unless the silver constitutes at least two-thirds of the bullion, the outside of the nugget will alone be attacked, and the depth of alloy affected by passing solutions is here considered to be too small to exercise an appreciable effect. Nevertheless, some attention must be directed in this respect towards the work of Liversidge, who found that the interior of nuggets is often spongy and at times even cavernous. It is possible that some part of the sponginess is due to the removal of silver. Further, a consideration of the fineness of the alluvial gold along the course of any given stream leads us to the conclusion that the greater purity of large masses, as nuggets, is not due to the solvent action of passing waters. It is found that the purity of alluvial gold is generally in inverse proportion to the size of the grain, and is consequently in direct proportion to the distance the gold has travelled down stream. This relation is simply explained by considering the greater surface presented to agents of solution by the further-travelled and consequently smaller grains. This fact has long been known, and was, indeed, pointed out by Pliny.[a] It was also known to Oveido, the companion of Colombus, and has been advanced by recent authorities.[b] It may be assumed, therefore, that solvents of silver could have exercised little effect in raising the fineness (in tenor) of the great masses of gold, seeing that so far as the facts go they show that such solvent action is operative to an appreciable extent only when the grains of gold become very small. In regions as Alaska and Siberia, where oxidation is scanty and acid waters are not abundant, meteoric waters may exercise little effect even on the surface of nuggets. The low tenor (750-800) of Klondike nuggets may be attributed in small part to this cause. The frosting of the surfaces of nuggets is attributed by the opponents of the chemical theory to the etching action of percolating waters on gold surfaces. As will be seen later, this assumption is opposed to the evidence and to the laws governing the solution of crystals. The validity of the fourth argument, viz., that the presence of auriferous pyrite replacing woody fibre in alluvial drifts indicates deposition from solution is generally admitted, but it is urged that it has no obvious bearing on the growth of metallic gold. Numerous examples of pyritous replacements of tree stems have been recorded from the alluvial drifts both of Victoria and of California. Many of these replacements are auriferous, and the gold is assumed to have been deposited from solution by the well-established reducing action of pyrite. Newbery also found gold in the ashes of timbers taken

[a] Hist. Nat., Lib. XXVIII, Cap. 21.

[b] Ross Browne, Eng. Min. Jour., Feb. 2, 1895.

from alluvial drifts. The bearing on the question at issue of the fifth argument, which makes an analogy between re-actions in nature and in the laboratory, is not admitted by the supporters of the mechanical hypothesis.

The foregoing, in brief, represented the position of the controversy in the early 'eighties, and the hypothesis of formation of nuggets from solutions in drifts was considered well established. The conclusions, rather than the work, of Liversidge have, however, done much to unsettle this position. Liversidge cut many nuggets into sections, etching with aqua-regia the flat surfaces. These showed, when thus treated, a well-defined crystalline structure, which appeared to be the more perfect as the quality of the gold improved. Nevertheless Liversidge concluded[a] that nuggets are derived entirely and directly from veins, and that "any small addition they may have derived from meteoric water" is quite immaterial and may be neglected. Apparently his difficulty in the acceptance of the hypothesis of the growth of gold *in situ* in gravels arose from his anticipation that nuggets, were they of meteoric growth, would show concentric or curvilaminar zones of growth arranged like the shells of an onion. Such concentric coatings, however, are probably only possible when growth takes place with abnormal rapidity. Two such nuggets from New Guinea have been described, showing distinct agate-like lines of growth, with no signs of crystalline structure,[b] but all others examined show more or less completely the crystalline character of Plate II, a character entirely in accordance with all that we know of the slow growth of crystalline bodies from dilute solutions. The internal homogeneous crystalline structure must certainly be considered an argument in favour of growth *in situ*. Evidence is accumulating in favour of this view. Definite examples of the deposition of gold *in situ* in gravels are still rare, but there can be no doubt that to this class belongs the crystallized gold of Kanowna, Western Australia, where tiny, yet bright and sharply-defined octahedral gold crystals occur in the so-called "pug" or ancient clayey gravel. They have obviously undergone no attrition such as they must have suffered had they been of detrital origin. It is interesting to note that Maitland[c] considers these crystals to be identical in origin with those found in the oxidised portions of adjacent and underlying veins, a view entirely in accord with that adopted in this treatise. An even more striking instance is recorded from the Klondike region of Canada.[d] In Miller Creek a well-

[a] Jour. Roy. Soc. N. S. W., XXVII, 1893, p. 343; Ib., XXXI, 1897, p. 79.
[b] Liversidge, Jour. Roy. Soc. N. S. W., XL, 1906, p. 161.
[c] Ann. Prog. Rep. Geol. Surv. W. A., 1899, p. 9.
[d] McConnell, Ann. Rep. Geol. Surv. Canada, XIV, 1901, p. 64B.

rounded quartz-pebble or boulder was found carrying on its upper surface numerous thin specks and scales of crystallized gold dendritically arranged. Spurr[a] quotes a somewhat similar case from the placers of Providence Hill, Plumas Co., California, where nearly perfect, and only slightly worn crystals of magnetite were covered by a thin film of gold. The sections of nuggets made by Liversidge show that nuggets are often spongy and cavernous, and may contain appreciable quantities of quartz, ferruginous oxides, and argillaceous matter. The specific gravity of a nugget of marked spongy character was only 15·21. Nuggets of gold from Klondike though only 750 fine showed, in general, the same characters as the purer Australian nuggets. In a later paper[b] the same authority, to whom we are indeed indebted for all our knowledge on the internal structure of nuggets, shows that apparently simple gold crystals, such as well-formed rhombic dodecahedra from New South Wales, on etching yield ample evidence that they are not internally homogeneous but are in reality highly complex, and are composed of a number of individuals.

From the present point of view, the most potent argument in favour of the growth of gold in gravels is one on which, for various reasons, no emphasis has previously been laid, viz., that by far the largest and best examples of crystallized gold have been obtained from alluvial drifts. (See Frontispiece.) The general absence of crystallized gold from the placers of California has led many to the inference that it never does so occur. Newberry (J. S.), for example, says: "Crystals are never found in placer-gold nor are sheets or threads." The evidence furnished by the placer gold of Klondike, the Urals, Victoria, Western Australia, and other fields is sufficient refutation of the foregoing statement. Wire-gold, according to Gordon,[c] was common at the surface in the early diggings of Otago, New Zealand, and was by the diggers considered to be grass-roots replaced by gold. The wires were often broadened to plates; they were smooth or striated and were occasionally dusted with small cubical crystals of gold. Of the many specimens of native crystallized gold examined by the writer during the past ten years, few derived from the oxidised portions of veins have approached either in size or in crystallographic perfection of the individual those obtained from placer deposits. The latter present an aspect entirely characteristic, indicated generally as a tendency towards isolation of the individual crystal, and, what is probably a corollary, towards the assumption of ideally simple cubical or octahedral

[a] 18th Ann. Rep. U.S. Geol. Surv., Pt. III, 1896-7, p. 378.
[b] Jour. Roy. Soc. N. S. W., XLI, 1907, p. 143.
[c] Trans. Amer. Inst. M.E., XXV, 1895, p. 294.

POLISHED AND ETCHED SECTIONS OF GOLD NUGGET, COOLGARDIE, WESTERN AUSTRALIA (*Liversidge*).
(Enlarged 2 diameters.)

forms. This facies is to be attributed to accretion of metal from an enveloping solution, a condition that is rarely possible in veins where regular crystal growth is further hindered by the influence of vein walls or of associated solid crystal precipitants (as galena or pyrite), which affect the local supersaturation of the auriferous solution in the neighbourhood of the growing crystal. The numerous solid angles of the gold crystals thus deposited, by counter-attraction within the solution, further operate to intercept the solid matter that would otherwise build up a single well-defined crystal. The general character of crystallized gold from veins is consequently that of an irregular mass showing numerous small, distorted, and, within crystallographic limits, unlike faces. Large specimens of crystallized gold, such as those described by the writer and others, do occur in veins, but they are so distorted either by flattening or by elongation, that they could not possibly withstand the abrasion to which they must certainly be subjected before finally coming to rest in gravels. Further, were the gold crystals of placers derived from veins they must be of the same character and of the same or less size. We have seen that they differ in character, and are greater in size. The occasional presence of small quantities of quartz enclosed in the interior of nuggets is not in itself an evidence of vein origin since it is conceivable that a nugget may in the course of its growth enclose grains of quartz. Where, however, the quartz so enclosed is sharp and angular, a detrital origin for the gold is indicated. Even where nuggets have not been entirely deposited from solutions, it is possible that they may owe their massive form to filling of interstices by gold attracted by mass-action from solution and deposited in cavities and crevices of detrital nuggets. Such accretion, from our knowledge of crystal growth, will probably take place in accordance with the direction of the crystallographic axes of already-formed crystals, and the new deposit may, to a limited extent, and until interfered with by the influence of adjacent crystals, be in crystallographic continuity with the older crystal. Close and exhaustive examination by assay of the variation in internal composition of gold nuggets would throw considerable light on the origin of nuggets, and is greatly to be desired.

The high gold tenor of certain pyrite deposits in the gravels of Southern Siberia, of British Columbia, and elsewhere, suggests the possibility of some of the placer gold of those regions having been derived directly from the decomposition of auriferous pyrite, itself probably of secondary origin.

It has been stated that sharp, well-defined, crystal edges are regarded as evidence of growth *in situ*; the converse, that rounded edges with curved faces may be taken to denote solution, is only partially true, since this result is also attained by attrition. Nevertheless, certain crystals have been observed whose rounded edges are too regular to be ascribed to pounding or rubbing, and these are perhaps to be considered attempts to approach the ideal sphere that theoretically results when isometric crystals are attacked by solvents.[a]

The final conclusions to which the writer has been brought with regard to the much-vexed question of the origin of alluvial gold are therefore that growth of gold on gold or on other nuclei is possible, and takes place wherever and whenever ionized or other auriferous solutions pass through gravels furnishing the conditions of precipitation ; and, further, that no real distinction in origin or method of formation may be made between the gold so deposited and that of the oxidised zones of gold veins, the differences above-noted being merely due to environment.

Secondary Auriferous Deposits Arising from Mechanical Action.—While, therefore, there remains but little doubt that some placer gold owes its origin to accretion from auriferous solutions percolating through gravels, it is nevertheless probable that by far the larger portion of the gold recovered from placers is of detrital origin, and has been derived directly from gold-quartz veins, and especially from those veins in which the gold is already coarse. Speaking generally, the richness of a placer deposit is governed rather by the physical conditions of deposition and, to a minor extent, by the character of the gold of the parent matrix, than by the tenor of that matrix. Where the geological history of any auriferous area has admitted of oft-repeated or long-continued erosion and consequent concentration of the heavy content of gravels, then the stream beds—modern and ancient—are of economic value. Thus the gold of the rich beaches of the Clutha River in New Zealand is derived from small and unimportant quartz-veins and lenticles in the quartz-schists of Central Otago. In the Klondike region, despite the extraordinary richness of the gravels, the parent gold-quartz veins of the local schists are apparently worthless. Many similar instances may be cited ; and in the majority of these the richness of the gravels cannot be explained by the assumption that the placers owe their value to the degradation of bonanza outcrops, for the formation of the placers has taken place in comparatively recent times, during which climatic conditions have not varied appreciably from those at present prevailing, and these, as in Alaska, British Columbia, and Siberia, are often inimical to outcrop enrichments. Tyrrell has calculated that the

[a] Fock, "Chemical Crystallography," London, 1895, p. 61.

gold of the Klondike gravels may be considered to be derived from 900 feet of eroded country, or a total quantity of 1·6 billion (English) tons of rock. Assuming the gravels to contain 10,000,000 ounces of gold, the average gold content of the schist removed has been only ·003 grain gold. On the other hand, exceedingly rich vein-deposits may give no shoadings, and therefore no hint of their existence. The bonanza outcrops of the Coromandel and Thames goldfields, in a country where conditions are peculiarly favourable to surface enrichment, yielded insignificant quantities of alluvial gold. On the eastern or Tokatea slopes of the mountain range at Coromandel, on which the rich Royal Oak and other veins outcropped, not a single colour could be obtained by panning, nor were nuggets found in the streams below. The famous Martha system of the Waihi mine, that has yielded nearly seven millions sterling from the uppermost 900 feet alone, gave no alluvial gold, although physical conditions were exceedingly favourable for concentration. In this case, however, there was no surface enrichment, and the gold of the veins is in a state of extremely fine division. The rainfall is heavy, and the gold in solution that would normally have formed a surface enrichment was carried into the surface waters and widely dispersed. The sheddings also from the famous Witwatersrand "banket" deposit were trifling in quantity. These instances are sufficient to show that the richness of a placer deposit is not, of necessity, dependent on the richness of the parent source.

Placers.—The gold-quartz of the outcrops of quartz-veins is freed from the parent body by erosion and passes either at once into a stream-bed or reaches the latter after a slow journey down the hill-slopes, where its progress towards the valley bottom is dependent on the supply of running water and on the "creep" of the hill-side. Where the slopes are flat a certain amount of gold concentration may take place in the soil of the hill-side below the vein outcrop by the readier removal of associated quartz. These deposits (*bergseifen*) are not of great economic value, and have been noted mainly in tropical countries (Borneo, &c.). Akin to them are the shallow surface deposits of dry desert countries where wind-action has removed the lighter grains of quartz. Both these types are in themselves of little economic importance, but are invaluable as indicating the near proximity of the parent vein.

Rivers erode their beds so long as their waters possess sufficient velocity to keep the river bottom clear of gravel. When this is no longer the case, and permanent deposition of material is the characteristic feature of any part of a river system, that part is said to have reached base level. Cessation of eroding activity obtains first in the lower part of a river course, but erosion may theoretically be continued in its headwaters and numerous branching and sub-branching tributaries until the whole country is reduced to base-level, and becomes so low, and the velocity of the streams is so far reduced, that erosion is no longer possible. This condition is, however, not of general occurrence in nature, for regions are rarely stationary, and their surface slowly rises or falls in respect to sea-level. In a region of depression base-level is naturally reached much sooner than would otherwise be the case. In a region of elevation, gradient is always being restored and the active life of the river prolonged. The general principles governing the life-history of rivers are of some importance from our present standpoint, since the gold and gravel are generally simultaneously deposited, and are subjected to the same natural laws.

Deposits of auriferous alluvial gravels are termed placers, alluvial drifts, or more simply, "alluvials." The first term is of Spanish origin, and is used mainly in America; the two latter obtain in Australia. Their gold is generally readily accessible to the individual miner, and is easily recovered by the simplest of means. They have, therefore, furnished a very large proportion of the world's gold supply, and for the same reason are the earliest of the gold deposits worked. Their richness, in California, Victoria, New Zealand, and the Klondike, has at times been extraordinary. Often in Victoria yields of 250 ounces gold per bucket of gravel have been obtained.

The upper portions of rivers form natural sluices, where, owing to the velocity of the stream, gravel deposits are rare, coarse, and thin. The earliest permanent deposit of gravel takes place when the gradient of a stream becomes sufficiently flat or the valley widens so that the waters of the stream are no longer confined. In the latter case, a "fan" results at the debouchure of the stream from the narrow into the broader valley or into the plains. They are especially characteristic of tropical and other rivers subject to periodic high floods. Rivers debouching from the Himalayas into the Gangetic and Brahmaputra plains show this feature especially well, gold and coarse gravel being deposited only within a short distance of the debouchure. Further out, sand, and still further, fine mud, are deposited. Owing to changes in the direction of rivers or in the level of river valleys, gravels may be covered by sands or clays, and those again by gravels. Since gold is deposited with gravels, there may therefore occur in the history of the alluvium of any given valley, two or more periods of auriferous deposition.

It may be stated as a general rule that the deposition of gold in gravels arises from a diminution in the velocity of the transporting waters. The diminution may be general, as in the case above-mentioned, or may be local. The latter occurs when the river crosses the strike of schistose or slaty strata, the upturned edges of which act as natural riffles, the gold being deposited in the crevices of the slate or schist. The down-stream side of a rocky bar is for the same reason a convenient lodging place for auriferous gravels, as also is the inner or concave side of a river bend. An uneven bottom is favourable to deposition, and a soft bottom is likely to retain more gold than a hard one.

A marked concentration of gold is observable towards the bottom of placer gravels, the richest deposits, as a rule, lying on "bed-rock." Where, however, conditions have permitted, without

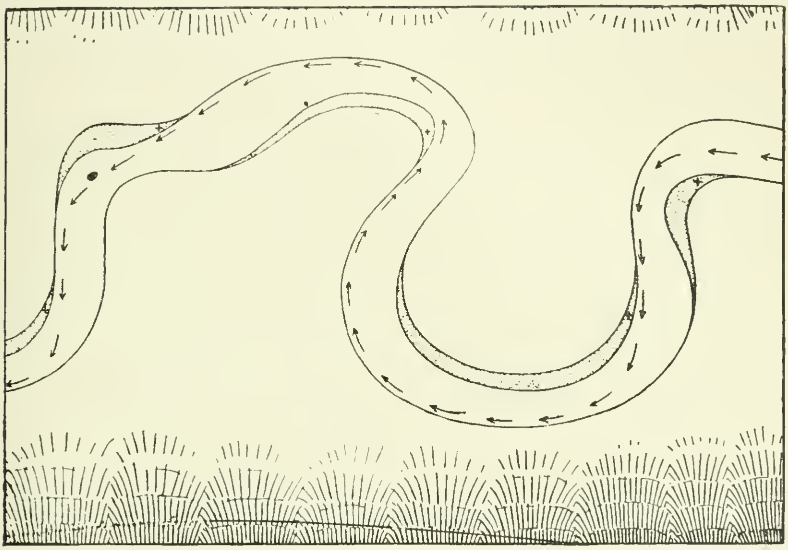

FIG. 67. SHOWING GRAVELS DEPOSITED BY A MEANDERING RIVER (*Spurr*).

prior scouring of the bed, deposition on clays or on cemented sands, the upper surfaces of these prevent the downward progress of gold, and are then known as "false bottoms."

The motion of a grain of gold in course of transport along a stream bed is neither forward horizontally due to the force of the stream current nor downwards vertically due to the force of gravity, but is in a direction compounded of the two.[a] Lateral currents may tend to deflect the falling grain sidewise, forming deposits on the beaches of the inner or concave side of the river. It has recently been shown that the course of stream-waters is

[a] Park, Bull. N.Z. Geol. Surv., No. 5, 1908, p. 36.

spiral when passing round river curves,[a] thus explaining the deposit on the inner side, since the lower part of the spiral flow is from the deep outer to the shallow inner bank. The stream itself combining a progressive with a lateral motion may thus be said to *screw* itself like a corkscrew round a bend. The fall of gold in gravel is not, of course, continuous, but takes place only on disturbance of the gravel. This is generally effected by the force of the stream current. It has recently been suggested[b] that the necessary disturbance of the gravel is effected during a downward "creep" of the valley gravels entirely comparable to that well known to occur on hill-sides. Where gravels are absent from a stream bed owing to scour, there also gold is wanting. Rocky potholes, contrary to the general belief, rarely contain gold. Coarse gold is certainly caught in them, but the continuous grinding of the stones generally to be found in these holes soon reduces it to powder, in which state it is readily carried away by the swirl of the waters.

Local enrichment of gravels may take place below the junction of two auriferous valleys, or, as is often the case, below the outcrop of gold-veins crossed by the stream. A general relation between the coarseness of gold grains and of gravel may be made out for most regions, fine gold occurring, as might be expected, with the finer gravel; it is possible that examination might establish a fairly constant ratio. For the same reason "black sand," containing magnetite, ilmenite, garnet, and other heavy minerals, is a common associate of gold in gravels.

Ideal rivers for the concentration of gold are those in which natural conditions approach most closely those of a long sluice; they therefore possess even, rapidly-flowing waters, have a regular gradient, and are at times subject to minor floods. These conditions are practically fulfilled only in temperate zones. In tropical countries subject to monsoons, where rivers are in high flood during a portion of the year, and are dry or nearly so during the remainder, the continuous concentration necessary to yield placer deposits of economic value is absent. Deposition of gold in these regions takes place only after the monsoon or rainy season, when the rivers are falling and when the boulders and pebbles on the surface of the gravels furnish convenient, but local, riffles. Under these conditions gold is deposited only in the tiny eddies formed by the passage of the falling flood waters over deposits of coarse gravel. It therefore occurs at the heads and tails of gravel banks and islands in the river-bed, and on the beaches

[a] Lodge, "Nature," Nov. 7, 1907, p. 7.

[b] Min. Sci. Press, Aug. 15, 1908.

of the inner sides of the river curves. The gold deposits are rarely more than a few inches below the surface of the gravel, and those formed at the close of a rainy season are scattered deep and wide by the monsoon floods of the ensuing season. Many economic investigations have failed from neglect to recognise the impossibility, under the foregoing conditions, of "bottom" concentration.

Surface concentration entirely akin to the above takes place locally and to a limited extent in many rivers in temperate regions, but in these rivers by far the greater portion of the gold is deposited on or near a "bottom," false or true, as a necessary consequence of the persistence, perhaps for centuries, of a stream in the same restricted channel.

Beach Sands.—Marine placers are the only other form of auriferous alluvial deposit requiring notice in this section. They are confined almost entirely to the shores of the Pacific Ocean, but their occurrence on the coasts of Nova Scotia, Ireland, and Portugal shows that the foregoing restriction is purely coincidental. They perhaps attain their greatest development on the west coast of the South Island of New Zealand, on the beaches of Oregon, and below Port Arthur on the Liau-Tung Peninsula. The richest beach sands known appear to have been those of the Gold Bluff, Klamath County, Oregon, where narrow beaches at the foot of overhanging bluffs serve as concentrating floors for the auriferous sands thrown within reach of the ocean waves by cliff falls. Concentration on these beaches takes place only when the surf strikes the shore line at an acute angle; when the surf beats at right angles gravel and sand are cast up. The process of concentration is simple: the strong surf casts up gold, gravel, heavy minerals, and sand, while the weaker and less rapidly flowing undertow removes only the sand and lighter stones. With the gold is generally associated much black sand. On the auriferous marine beaches of New Zealand pebbles or stones are absent, and the gold is contained entirely in "black sand." The distribution of beach sands, both in time and place, is erratic, the requisite degree of concentration being generally attained only after heavy storms. Once formed, beach deposits, when being worked for their gold content, are immediately removed beyond the reach of subsequent storms, since these, if coming from a slightly different direction, destroy the previously formed deposit. South-west gales are in New Zealand considered the most favourable for the production of rich layers of black sand. The gold of these deposits is invariably flaky; that of Oregon is often bi-concave with well-defined rims, due possibly to rolling edgewise when moving up and down the beach. The deposits of Oregon are continued north to Washington and south to California. Other notable beach placers are those of Carelmapu and Punta Arenas, Chili ; the shores of the Sea of Okhotsk ; at Unga Island, Nome, and Cape Yagtag, Alaska ; and on the northern coast of New South Wales. Those of Cape Yagtag are remarkable in that they carry garnet without the ordinary associates of gold in beach sands, viz., magnetite and ilmenite. In Oregon and New South Wales and at Nome, ancient auriferous beach sands are worked above present high water level. At Nome two such beaches may be traced.

Deep Leads.—The placer-deposits that have heretofore been described are of recent origin and lie at or near the surface. Auriferous gravels of greater age are liable to be subjected to all the vicissitudes of erosion or sedimentation attendant on orogenic movements in the given region. With depression of the region many hundreds of feet of sand and clay may be superposed on the gravels. In the two principal regions containing buried placers, viz., California and Victoria, the ordinary covering of alluvium has been capped by thick flows of basaltic lava, and to this capping the ancient gravels of California, at least, largely owe their preservation. Greatly depressed placers are, from their depth, and hence from the great bodies of water contained in them and in the superincumbent strata, generally economically inaccessible ; it is when they have, in the course of great earth-movements, been elevated above the permanent water-level of the country, that their gold becomes readily available to mining. The buried placers of California have been elevated to an average height above sea-level of 2,600 feet along the western flanks of the Sierra Nevada, and have shared in the late Tertiary uplift of that great range. In Victoria similar buried gravels are commonly termed "deep leads." Akin to those due to ancient fluviatile action are ancient lacustrine auriferous gravels, as those of the Blue Spur, New Zealand.

It will be evident that during regional depression and subsequent elevation, the drainage system of a country may be materially modified. The modification has been notable in California, where the existing streams have intersected the ancient buried channels almost at right angles, and have cut great gorges in them, the bed of the present stream being occasionally 1,500 feet below that of the ancient channel. In this way also great lengths of the course of the ancient rivers have been obliterated, and the adjacent country so eroded that the course of the ancient channel may now be traced only at intervals high up on the flanks of a mountain range. It may even follow a ridge, a feature of not uncommon occurrence when a basaltic lava flow has filled an ancient valley. In this case the lava has resisted denudation while the softer bed-rock of the valley sides has been worn away, leaving a lava-capped ridge, as shown in the accompanying section. (Fig. 68.) In the same way hill-tops of cemented or lava-topped gravel may be formed.

In Victoria the general direction of river drainage has not changed since the deposition of the deep leads, and the channels of modern streams are therefore either superimposed on the deep leads or are parallel to them. No great amount of elevation has taken place in Victoria, and the country has rather been subjected to a general north and south tilting, depressing the lower (northern) portions of the channels and raising the upper (southern) portions.

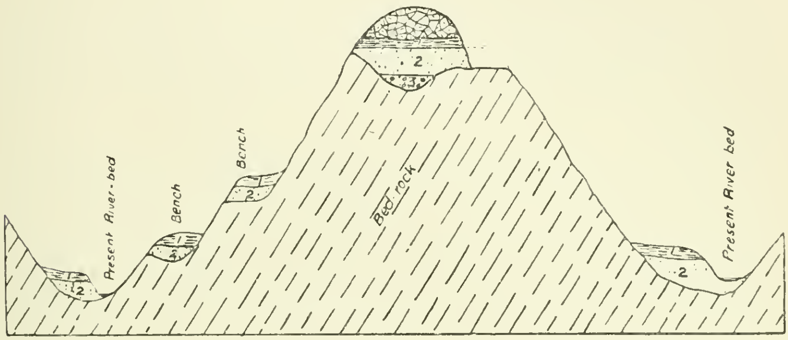

FIG. 68. IDEAL SECTION SHOWING RELATIVE POSITION OF "BENCHES" AND OF BURIED RIVER CHANNELS COVERED BY BASALT FLOW (*Hobson*).
1. Capping of clay and soil. 2. Auriferous gravels. 3. Blue lead.

The tilting has occasionally proceeded so far as locally to change the direction of fall of the bed-rock. On account of the absence of marked regional elevation, the ancient placers of Victoria fail to show the high-level "benches" (river terraces) so characteristic of the Californian deposits.

The gold of deep leads, as might be expected from analogy with the deposits of modern rivers, is not evenly distributed throughout the lead, either vertically or longitudinally. The deepest part of the lead is termed the "gutter," and normally pursues a sinuous course. The gutter is often the richest part of the lead, but the best runs of gold may nevertheless, as in existing streams, be contained in beaches high above the gutter. Buried "benches" are known along the course of deep leads, which also show all the branching into tributary streams displayed by modern placers. The boulders of the deep lead gravels of Victoria are, on the average, less than 6 inches in diameter. They may, however, range up to 3 feet, and, very rarely, to 12 feet. The general sequence of strata in a deep lead is gravel, sand, and clay, with often a carbonaceous layer overlying the clay ; this sequence may be repeated several times. The normal colour of the chief Californian leads is blue, from the presence of ferrous compounds. The colour changes to rusty brown on exposed surfaces. Cementation by ferruginous oxides is common in deep leads, the resultant indurated mass being termed a "cement." Notable enrichments occur in many deep leads below the junction of two streams and also below the intersection with auriferous zones or reefs.[a]

The principal deep leads of California lie on the western Sierra Nevada ranges, in Yuba, Sierra, Placer, and Nevada counties, in the region drained by the Feather, Yuba, and Bear Rivers. A deep lead on the eastern slopes of the Sierra Nevada has recently been described by Reid.[b] It crosses from Lake Tahoe to Washoe Lake. The general age of the Californian placers is Neocene (Miocene and Pliocene) ;[c] that of the Victorian deep gravels is late Pliocene.

Range in Geological Time of Placers.—A consideration of the range in geological time of auriferous alluvial deposits at once reveals a remarkable feature, viz., that all important placers are of Tertiary age, and that of these the majority are Recent, Pliocene, or Miocene in age. Few are Eocene and fewer still Cretaceous. Older than Cretaceous there are no undoubted examples of economically valuable deposits of placer gold. Possibly, however, an exception to this statement may be made in favour of the Permo-Carboniferous conglomerates of Tallawang in New South Wales. These have not been described of late years by any geologist, but on the evidence offered many years ago by Wilkinson there seems little doubt of the alluvial origin of the contained gold. Similar auriferous conglomerates were reported also many years ago, by Daintree, from Peak Downs, Queensland. Jurassic auriferous conglomerates have been described by Lindgren[d] from the Mariposa series near Mine Hill, Calaveras County, California, and Cretaceous (pre-Chico) placers by Dunn[e] from the Klamath range, Oregon ; but exception has been taken by Fairbanks[f] to the alluvial character of the gold, which is considered by him to be due in both cases to infiltration.

There are at least two great goldfields whose features of auriferous deposition must be considered in detail before this question

[a] Wilkinson, H. L., Trans. Inst. Min. Met., XVII, 1908, p. 210.
[b] Min. Sci. Press, Ap. 18, 1908, p. 524.
[c] Lindgren, Jour. Geol., IV, 1896, p. 881.
[d] Amer. Jour. Sci., XLVIII, 1894, p. 275.
[e] 12th Ann. Rep. State Mineral., Cal., 1894, p. 459.
[f] Eng. Min. Jour., Ap. 27, 1895, p. 389.

may be dismissed, and even before any validity may be given to the above statement, restricting the range in geological time of placer deposits. Both carry gold in conglomerates and both are of Archæan or at least Pre-Cambrian age. The contained gold of each has by various geologists been claimed as placer gold, and by other authorities has been described as due to infiltration. They are the famous Witwatersrand field of the Transvaal, and certain occurrences near the great Homestake mine in South Dakota.

Witwatersrand.—The great economic importance of the Witwatersrand goldfield has directed considerable attention towards this remarkable field, and several hypotheses have from time to time been advanced to account for the presence of gold within its "banket" or silica-cemented conglomerate beds. Two only of these hypotheses have stood the stress of time and agree with accumulated experience, viz., the placer hypothesis of contemporaneous deposition of gold and pebble, and the infiltration hypothesis of introduction of gold by solutions that have wandered through the gravels long subsequent to their deposition. The former is the older theory and has been excellently set forth by Becker,[a] and later, with modifications, by Gregory.[b] It is highly characteristic of the long discussion that has been carried on concerning this subject that there is little or no direct evidence in support of either hypothesis, and that the case for each rests almost entirely on the evidence against the opposing hypothesis.

The older "precipitation hypothesis" of Schenck, Stelzner, De Launay, and others, which assumed that the gold had been deposited from a sea containing metallic sulphides and gold when the conglomerates were still at the surface, has been revived by Voit,[c] but in a form so modified that it becomes essentially an infiltration hypothesis, differing only from the one generally advanced in that it is assumed that infiltration took place at the surface before the conglomerates were depressed. He assumes that solutions loaded with metallic sulphides and gold, analogous apparently to those of hot springs, were brought in great quantity to the surface at the periods of conglomerate deposition and that the metalliferous content found the requisite precipitant in the great amount of organic matter distributed along the then existing coast-line. To this hypothesis there are obvious objections, and these arise even from the valuable and suggestive evidence offered in the paper itself.

[a] 18th Ann. Rep. U.S. Geol. Survey, Pt. V, 1897, p. 160.

[b] Trans. Inst. Min. Met., XVI, 1907, p. 1.

[c] Min. Jour., Sept. 5, 1908, p. 296.

The advocates of the placer theory base their case on a supposed general resemblance of the deposit to modern placers. The resemblance is, however, not very marked, for the gold is exceedingly fine in grain, and, when sufficiently coarse to be visible to the naked eye, is often angular. Rounded grains, not only of gold, but also of pyrite, do occur, and are regarded as evidence in support of an alluvial origin.

The objections to the placer hypothesis are (*a*) the general fineness in grain of the gold—a fineness that in modern placers is paralleled only in beach sands, as those of the Snake River in Idaho, and of the west coast of the South Island of New Zealand; (*b*) the total absence of those nuggets and coarse grains that are characteristic features of all modern gravel placers; and (*c*) the absence of "black sands" (titanite, magnetite, and garnet), such as are found also in all modern beach-sand deposits where fine gold occurs. The rounded pyrite pebbles found in the banket are amply explained as concretions or as replacements from solution.

The infiltration hypothesis assumes that the gold was deposited with the siliceous cement that now binds together so strongly the quartz-pebbles of the banket. In its support is adduced (*a*) the general evenness in grade of the gold deposit; (*b*) the fineness of the gold; (*c*) the deposition of the gold on pyrite; (*d*) the general angularity and hackly nature of the gold grains; (*e*) the deposition of gold along cracks in the pebbles of the banket; and (*f*) the influence occasionally exercised by igneous dykes on the richness of the deposit.[a] As an argument against the infiltration theory it has been advanced that the overlying and underlying quartzites should also have been impregnated with gold, but it has been shown[b] that the quartzites at the time of auriferous impregnation may have been comparatively impermeable rocks and that the conglomerates of the vertical series alone were sufficiently porous to permit of the free passage of wandering solutions.

The validity of this objection is rapidly being impaired by gradually accumulating evidence showing that while gold is generally restricted to the conglomerate beds it nevertheless occurs in economic quantities in normal quartz-veins, in quartzites, in slaty schists, and in certain pyritous bands in the footwall of the Main Reef. These are, of course, not proofs of an infiltration origin for the whole of the gold of the Witwatersrand, but they at the least show that in the given cases the gold contained is not alluvial. A normal white quartz-vein intercalated in the footwall quartzite of the Main

[a] *e.g.*, Worcester Dyke, cited by Hammond, Trans. Amer. Inst. M.E., XXXI, 1901, p. 844.

[b] Maclaren, Trans. Inst. Min. Met., XVII, 1908, p. 50.

Reef has been worked successfully at the Rose Deep Mine ; at Kroomdraai similar gold-quartz veins occur in the schistose and pyritous hanging-wall of the Black Reef, a much higher horizon than that of the Main Reef. Patches of quartzite on the hanging-wall of the Main Reef contain appreciable quantities of gold ; as also do certain ferruginous schists in the footwall of the Black Reef. A well-defined dense pyritic quartzite underlies the Main Reef and is distant from it about 90 feet. This band has been opened up on many mines in the Central and Eastern Rand. Its tenor has at times been high ; this is especially the case when the band is very narrow, and in some cases (Cinderella Deep) a tenor of hundreds of pennyweights gold per ton has been reached.[a] The width of the pyritic band at times reaches 25 feet ; at that width it is not, however, workable at a profit. The foregoing facts are therefore ample evidence that infiltration of gold is not restricted to conglomerate bands, and that it has taken place elsewhere when conditions have been favourable.

The absence of "verticals" or fissures by which auriferous solutions may obviously have risen to the conglomerate beds is urged as an objection to impregnation. The absence, however, of an undoubted precipitant of gold within the conglomerate points rather to a general deposition arising from physical changes in the solution than to one from chemical reaction. But in any case, deposition, either of silica or of gold, can hardly have taken place in narrow fissures in which the solutions are conceived to be still highly heated and to be travelling with comparative rapidity. Moreover these fissures, representing as they did the planes of structural weakness, are precisely those that would be occupied by later extrusions of igneous matter, of course with complete obliteration of the original characters of the walls. The absence of well-defined ore-shoots has also been urged against the infiltration theory.[b] Ore-shoots are, however, essentially a result of local changes in the saturation of metalliferous solutions or are brought about by local conditions ; they must necessarily be absent where conditions are fairly uniform over wide areas. Nevertheless there is a tendency in depth for the gold of the banket-reefs to aggregate to shoots.

With the data at present at hand, the gold of the Witwatersrand banket may certainly be most conveniently considered to be due to infiltration. It is possible, though there is no evidence whatever for the assumption, that the banket originally contained placer gold, which has been dissolved and redeposited elsewhere in the conglomerate. In such a case, however, there would have been, in

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[a] Voit, loc. cit. sup.

[b] Gregory, loc. cit.

some places at least, local aggregations of gold to nugget size, and it has already been shown that nuggets or masses of gold are unknown, at least at depth, where there has been no possibility of secondary free-gold enrichment. In any case, on such an assumption, the hypothesis becomes essentially one of infiltration, when it is scarcely profitable to enquire as to the original form of the gold taken into solution.

By analogy, moreover, with other auriferous occurrences in the Transvaal, and especially with those of the Lydenburg district, the Witwatersrand gold may reasonably be referred to the same agents that have obviously been effective in the latter cases, viz., the diabasic masses (or rather their advanced, contemporaneous, or consequent, heated solutions) that intrude through the conglomerate "reefs" of the Rand, or overlie, as sills, the flat-lying reefs of the Pilgrim's Rest field.

South Dakota.—The auriferous Cambrian conglomerates of the neighbourhood of the great Homestake Mine in South Dakota have long been considered[a] to owe their gold to alluvial deposition. There are, however, in the immediate vicinity widespread impregnations of secondary silica that carry gold. These are nearly always connected with the so-called "verticals," or vertical fissures that pass down into the underlying Algonkian schists, and that have obviously served as channels for the uprising metalliferous solutions. Emmons,[b] who has conducted the most recent geological examination of this area, and who is pre-eminently well qualified to judge, has concluded from the waterworn character of some of the gold and from its concentration near bed-rock, that some at least of the gold of the conglomerate is of placer origin, but that the enrichment of the deposit to one of economic value is due entirely to the work of secondary auriferous solutions, which are also responsible for the pyrite with which the auriferous portions of the conglomerate are invariably associated. The pyrite is often found occupying fissures and cavities in the pebbles. Clear evidence of local secondary enrichment is afforded by the presence of films of gold in the laminations of the schist and in crevices from 3 to 10 feet below the base of the conglomerate.

Nullagine, Western Australia.—The Nullagine auriferous conglomerates of the Pilbara field, Western Australia, closely resemble those of the Witwatersrand, but in addition to the gold contained in the siliceous matrix between the pebbles, gold is also found in thin white quartz-veins that are parallel to the bedding

[a] Devereux, Trans. Amer. Inst. M.E., X, 1889, p. 465.

[b] Emmons, S. F., Prof. Papers U.S. Geol. Surv., No. 26, 1904, p. 99.

planes. The veins are much richer in gold than the siliceous cement, and there is thus evidence to support the view that the gold of the latter is due to infiltration.

It is noteworthy that these ancient Cambrian or Pre-Cambrian conglomerates are all highly silicified and pyritised. They all, it would appear, owe their gold to infiltration rather than to contemporaneous deposition. The question therefore arises as to the reason for the restriction of undoubted placer deposits to the Tertiary period. It is not conceivable that conditions of denudation different to those in existence at the present day prevailed in the Palæozoic and Mesozoic periods. The strata of these periods contain numerous conglomerate beds that are situated in the vicinity of older auriferous regions. Conglomerates of Gondwana (Permo-Triassic) age are largely developed in India, Eastern Australia, South Africa, and the Argentine. They are, it is true, for the most part of glacial origin, but such an origin does not preclude the possibility of gold deposits, for the rewash of recently deposited glacial matter has yielded auriferous deposits of economic value. It is therefore probable that wherever Palæozoic or Mesozoic conglomerates were formed in the degradation of an auriferous area, they contained alluvial gold distributed in "leads" precisely analogous to those already described from Victoria and California. It is believed that these ancient gravels have all, in the course of orogenic movements, been depressed below the ground-water level, and into the region of the alkaline deep-seated waters. Here the gold has been dissolved and removed, probably to be re-deposited as free gold in clean quartz in adjacent rocks, or possibly to pass to the sea, not again to be concentrated in economic degree for long geological ages. Should, however, the gold grains, prior to the introduction of a solvent, be enclosed in silica (acid siliceous solutions being assumed to have no effect on gold), the placer-gold may be preserved for an indefinite time. Hence we have the original gold of the Homestake Cambrian occurrences, and possibly also the faintly auriferous conglomerates of France and England. But such a preservation would appear to be exceptional, and ancient conglomerates are on the whole devoid of gold. It is further noteworthy that rich ancient gravels, as those of California and Victoria, occupy regions that have not suffered a notable depression. Admitting the foregoing speculation we have therefore a complete cycle of auriferous transference, from deep-seated vein to surface placer, and from depressed placer to vein.

SOURCE AND TRANSPORT OF GOLD.

Source of Gold.—In the investigation of auriferous deposits no feature stands out in greater relief than the constant association of the primary goldfields with igneous rocks, and it therefore becomes necessary to examine the evidence available for the occurrence of gold as an original constituent of an igneous magma. As a rule the evidence offered is valueless, from the impossibility of establishing definite criteria of authigenesis for gold and rock, and in many instances that have been advanced the gold with its associated pyrite has certainly been subsequently introduced into the cooling or cooled igneous rock by percolating solutions. There are, however, certain cases that do not obviously fall within the above category. They have been described by Merrill,[a] Schultze,[b] Möricke,[c] Blake,[d] Helmhacker,[e] Jacquet,[f] Scheibe,[g] Brock,[h] Catharinet,[i] and others. With the exception of those noted by Helmhacker from diorite and serpentine rocks in the Urals, and by Scheibe in an olivine rock from Damara Land, South Africa, all the foregoing are from acid rocks, that described by Merrill being in a normal biotite-granite from Sonora, Mexico, while Möricke's specimens showed native gold in pearlstone (obsidian) from Guanaco, Chile, as skeleton crystals in the glass and as inclusions in perfectly fresh plagioclase and sanidine crystals and in spherulites. Jacquet records the occurrence of free gold in the microcline of a quartz-microcline rock impregnated with hæmatite. Brock reports gold from porphyries in British Columbia ; Catharinet's examples are also from the same region, but in pegmatites.

Two instances at least of the occurrence of gold in economic quantities within acidic dyke rocks are known, but in both cases it may be clearly shown that the gold is of later origin. Both are fully described elsewhere in this volume and need only be mentioned here. The first is that of Berezovsk, Ural Mountains, where the

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[a] Amer. Jour. Sci., I, 1896, p. 309.
[b] H. Kunz, "Chile," 1890, p. 78.
[c] Tscherm. Min. Petrog. Mittheil. XII, 1891, p. 195.
[d] Trans. Amer. Inst. M.E., XXVI, 1896, p. 290.
[e] Oesterr. Zeit. für Berg- und Hütt., XXVIII, 1880, p. 97.
[f] Mem. Geol. Surv. N.S.W., No. 5, 1894.
[g] Zeit. Deutsch. Geol. Gesell., XL, 1888, p. 611.
[h] Eng. Min. Jour., 1904, p. 511.
[i] Eng. Min. Jour., 1905, p. 127.

gold occurs in thin veinlets in microgranite (beresite), and the second is that of Omai in British Guiana, where, however, the gold occurs not solely in thin stringers of quartz in an aplite dyke, but also scattered through the mass of the aplite. The dyke is decomposed to great depth, but where fresh contains notable quantities of auriferous pyrite, the decomposition of which has furnished the free gold of the upper zones.

Despite the foregoing, however, the occurrence of free gold as an original constituent of unaltered igneous magmas cannot be

Fig. 69. Thin Section showing Free Gold in Diorite from Mashonaland (*Spurr*). × 25; *f.* felspar; *q.* quartz; *e.* epidote; *h.* hornblende; *m.* magnetite; *g.* gold.

considered fully proven. The gold may have been caught up from veins or sediments by an intruding magma, or the granitic rock may itself be metamorphic and its gold derived from veins enclosed within the original rock. That apparently igneous acidic crystalline rocks may, in exceptional cases, be really of metamorphic origin, the present writer, reasoning from analogy with certain diorites of metamorphic origin,[a] fully believes. Further, the presence of orthoclase and albite in many normal auriferous quartz-veins (Bendigo, California, Cripple Creek, &c.) may suggest an explanation

[a] Maclaren, Rec. Geol. Surv. India, XXXIV, 1906, p. 112.

for the free gold in the quartz-microcline rock of Jacquet,[a] viz., that the rock matrix is essentially an aqueous deposit. It is interesting to note that Liversidge[b] records the presence of gold in certain European and Australian meteorites (siderolites).

The auriferous tonalite- or quartz-diorite-gneiss of the Ayrshire mine, Lomagunda, Rhodesia, has been described by J. E. Spurr.[c] The rock lies between hornblende and chloritic schists, and is only 100 feet distant from a granite mass. It was at first considered to be a true diorite, but is a fresh fine-grained diorite-gneiss, composed chiefly of felspar and grey hornblende. Quartz, biotite, magnetite, and epidote also occur. The gold is most closely connected with the hornblende and magnetite, but also occurs rarely as inclusions in the quartz and felspar. The rock follows a fairly distinct bedding, and the gold may, on the whole, be reasonably regarded as derivative from veinlets in an older, presumably igneous rock now highly metamorphosed. Somewhat similar biotite-gneisses containing pyrites are recorded by Lacroix[d] from the Mundraty River, Madagascar.

The close connection between igneous rocks and auriferous regions may have been brought about in either or both of two ways: The gold may have been brought near the surface and within the reach of meteoric waters by inclusion within an ascending magma. Considerable weight was given to this view by the work of Becker and others on the country of the Comstock Lode, all tending towards the conclusion that the gold resided in the ferro-magnesian silicates. Don, on the contrary, has shown, for the igneous districts examined by him, that gold does not necessarily reside in the ferro-magnesian silicates. He has further shown that, for the given districts, the amount of gold present in the country rock is, as a general rule, directly proportional to the amount of pyrite present, and also that the amount of pyrite decreases inversely as the distance from the vein-fissure. Since the pyrite may be considered to be entirely secondary and to have been introduced by percolating waters, we are thus brought to the second view, viz., that auriferous solutions have been introduced by uprising waters that have a connection with igneous masses. Until detailed and extended analyses of fresh igneous rock and of igneous emanations have been made, the problem will remain a matter for pure speculation. In the absence of definite data, it is here assumed that the auriferous content of many waters,

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[a] Loc. cit. sup.

[b] Jour. Roy. Soc. N.S.W., XXVI, 1902, p. xxiv.

[c] Eng. Min. Jour., Oct. 3, 1903.

[d] C. R. Acad. Sci. Paris, CXXXII, 1901, pp. 180-182.

and especially of those which are set in circulation by intrusive igneous rocks, as by the Pre-Cambrian diabases, is derived from emanations from intrusive magmas, the emanations being finally dissolved in percolating waters and by them carried into vein-fissures. From whatever side the question is approached, primary auriferous deposits may be regarded as phenomena dependent on the extrusion of igneous magmas, and further as having an origin indissolubly bound up with that of metalliferous sulphides or of the chemically related tellurides. Work throwing light on the origin of pyrite is, therefore, to be welcomed as assisting enquiry into the genetic relations of gold.

Transport of Gold.—The gold in vein waters may most reasonably be regarded as ionized and balanced either as auro-silicanion, as thio-auranion, or as telluro-auranion; in the first case the deposition products are silica and free gold; in the second case, free gold and sulphides, or possibly sulphides (including gold-sulphide) alone; and in the final case, gold-tellurides. The first combination is considered by the writer to be the probable form in all those veins in which free gold is found studding clean quartz. Even in many pyritous veins, deposition of pyrite, quartz, and gold has been contemporaneous. In such cases the gold would appear to have been held by both the first-mentioned ions and to have been freed on deposition.

Since gold has never been definitely isolated from or recognised in underground waters all speculations on the manner in which it is dissolved and transported must necessarily be tentative. There are, however, several established solvents of gold that may well play important parts in the transport of gold in nature. Of these the chief, in the deeper zones at least, are the alkaline sulphides, if any value is to be placed on the widespread association of base sulphide and gold. The same importance cannot, for various reasons, be given to the solvent action of alkaline silicates, and it has elsewhere been shown that colloidal gold solutions, the third form in which gold may be transported underground, requiring, as they do, pure water and neutral conditions, are of doubtful occurrence. In this connection the experiments of Doelter[a] are instructive. He found that gold was somewhat readily soluble in an 8 per cent. solution of sodium carbonate with sodium silicate and an excess of carbonic acid. Transport of gold as an alkaline auro-silicate may thus be admitted. It has been seen that tellurides of gold are of common occurrence, and from the general chemical analogy between sulphides and tellurides, the latter may be considered to have been also transported in alkaline solution. In regions affected by meteoric waters possible natural solvents appear to

[a] Tscherm. Min. Mittheil., XI, 1890, p. 329.

be fairly numerous. Stokes[a] shows that gold is readily soluble, at a temperature of 200° C., in solutions of ferric chloride and cupric chloride, the gold forming a chloride. The percentage of gold dissolved increases with the temperature and with the concentration of the solution. Ferric sulphate also dissolves gold, but only in the presence of a chloride. That, however, the process of solution by ferric salts is not a simple reaction at normal temperatures and pressures is shown by the experiments of Don,[b] who failed even with strong solutions (from 1 to 20 grains per litre) to dissolve either metallic gold or auriferous sulphides. The ready solubility of gold in alkaline sulphides has been demonstrated by various chemists.[c] Skey further thought that gold was soluble in hydrogen sulphide, and it is probable that this reagent, though perhaps rather indirectly, in alkaline combination, than directly, does exercise a notable effect. All these reagents occur in natural waters, and that some solvent action does take place is indicated by the presence of gold in the sinter of sulphurous springs in Nevada and New Zealand.[d] As long ago as 1877, Liversidge[e] found gold in recently-formed pyrite that had been deposited on twigs in hot springs near Lake Taupo, New Zealand.

Waters containing free chlorine, or compounds that may furnish free chlorine, are always competent to dissolve gold. The not improbable combination in nature of an acid, manganese di-oxide, and an alkaline chloride, would therefore fulfil the conditions requisite for the solution of gold.[f]

The existence of gold in sea-water had long been suspected before its occurrence was qualitatively proved by Sonstadt,[g] whose further quantitative determination showed results roughly estimated at less than 1 grain gold per ton. Quantitative determinations have also been made by Liversidge, Don, and others, showing results always less than 1 grain per ton. The presence of gold in the waters of the ocean being thus established, it has been suggested that the gold of fissure-veins in sedimentary rocks has been derived from sea-water carried down during the course of deposition of the sediments, and from them has been removed into the fissures by

[a] Econ. Geol., I, 1906. p. 650.

[b] Trans. Am. Inst. M.E., XXVII, 1898, p. 598.

[c] Skey, Trans. N.Z. Inst., III, 1870, p. 216; Egleston, Trans. Am. Inst. M.E., IX, 1880-1, p. 639; Becker, Am. Jour. Sci., XXXIII, 1887, p. 207; Liversidge, Proc. Roy. Soc. N.S.W., XXVII, 1893, p. 303.

[d] Becker, Mon. U.S. Geol. Surv., XIII, 1888, p. 344; Maclaren, Geol. Mag., 1906, p. 511.

[e] Jour. Roy. Soc. N.S.W., XI, 1877, p. 262.

[f] Don, Trans. Am. Inst. M.E., XXVII, 1897, p. 564; Pearce, ibid., XXII, 1893, p. 739; Rickard, T. A., ibid., XXVI, 1896, p. 978.

[g] Chem. News, XXV, 1872, pp. 196, 231, 241.

lateral secretion. There is little to be said for this assumption. On the other hand, it is reasonable to assume that a proportion of the steam ejected from maritime volcanoes has been derived from the adjacent seas. In such cases the contained gold is deposited within the rock, either in fissures or vents, or in the rock-mass itself. Notable quantities of gold may thus have been introduced into the solid portion of the outer crust.

Lenher's experiments,[a] showing that gold is soluble in sulphuric, phosphoric, and other acids if a compound, as manganese di-oxide, capable of liberating oxygen be present, are of great importance as affecting the solution of gold in the upper zones of veins that lie within the reach of oxidising waters. Van Hise has clearly shown that ferric and other *-ic* salts are abundantly produced in the zone of weathering by the action of descending solutions on the minerals of the deeper zone, as pyrite. Their solvent action becomes, therefore, of considerable importance when considering, as will later be done in detail, the problems of secondary enrichment.

Epitomising briefly the course pursued by gold from its hypothetical magmatic host, it may be said that in the deeper zones transport upwards is effected by alkaline sulphides or tellurides and alkaline silicates ; in the vadose zone or zone of weathering, as the surface of the land is gradually lowered by erosion, the free gold, gold-telluride, or possible gold-sulphide of the uppermost portions of the deep zone is attacked by acid chloride waters and by them is carried either upward to or near the actual outcrop, depositing their content as free gold, or downward to the permanent ground water-level, where the gold is deposited with base sulphides.

Dispersion of Gold in Nature.—The dispersion of gold is effected both by mechanical and by chemical agencies. Water, either liquid or solid, acting at the earth's surface is the chief of the former. In rapidly-flowing streams with hard rock bottoms with or without pot holes, coarse gold is in the course of time triturated to fine flaky powder, in which condition it is transported with ease even at or near the surface of the stream waters, and comes to rest only with the finest of sediments. In certain rivers the fine "float" gold is so abundant that its capture by "fly-catching" tables has proved a profitable avocation. Such gold may pass to the sea to be deposited in fine muds, or on the sand or gravel beaches along which it is swept by tide or current. In either case it is almost certain that the ultimate fate of the gold is solution in sea-water.

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[a] Jour. Amer. Chem. Soc., XXVI, 1904, p. 550.

In tropical regions, subject to violent and short-lived floods, rivers and streams are, in general, agents of dispersion rather than of concentration of gold. Throughout India, a country typical of these conditions, from the Himalayas to Cape Comorin, small quantities of gold (rarely more than ½-grain gold per ton) may be obtained wherever coarse gravels are found ; yet in all that extensive area no placer aggregations of economic value are found or are likely to be found.

In high latitudes or at high altitudes glaciers exercise a minor dispersive effect. They wear down the outcrops of lodes that have possibly undergone "secondary enrichment" prior to the period of glaciation, and so scatter fragments of auriferous quartz through a great mass of morainic matter.

Coastal erosion attacking an exposed "deep lead" or a gold-quartz vein, may destroy the aggregation of the gold and disperse it widely through sands. Examples of the latter case are not uncommon.

No evidence is at present available indicating a natural precipitation of gold from sea-water, and the sea must, on the whole, and so far as chemical action is concerned, be regarded as an agent solely of dispersion.

Underground waters, by virtue of their heat or of their contained salts, may act as a dispersing agent. It has been shown that alkaline sulphides in the deep regions and *-ic* salts in the vadose zone are ready solvents of gold, and it is quite conceivable that re-deposition of gold from these and other wandering solvents may result in a more widely-distributed deposit than the original from which the gold was derived.

It has already been remarked as a noteworthy fact that, so far as our knowledge goes, extensive auriferous alluvial deposits are confined to Tertiary strata that have not yet been depressed to any considerable depth beneath the earth's surface. It cannot be conceived that the agencies of denudation, erosion, and deposition during the Palæozoic and Mesozoic periods differed materially either in character or in degree from those now in operation. The conclusions arrived at therefore have been that auriferous alluvial gravels *were* deposited, but that from the necessarily porous nature of the gravels or conglomerates, such beds when depressed below ground-water level afforded ideal conditions for the leaching action of deep-seated solutions, which have carried the gold to be deposited elsewhere, possibly in a notable state of aggregation in fissures, possibly widely diffused in percolating waters.

Another method of dispersion of gold is finally admitted. It is purely hypothetical, but yet is sufficiently reasonable. It is assumed that igneous magmas may eat their way toward the earth's surface. In such cases any gold formerly contained and concentrated in the rock so absorbed is in the course of time distributed throughout the magma.

The assays of Wagoner,[a] on rocks far removed from known metalliferous deposits, show how widely spread are gold and silver at the outer surface of the earth's crust. His researches appear to have been conducted with the extreme care necessary in these assays where litharge, which is apt to contain unsuspected quantities of gold, is used. The figures given below are in milligrams per metric ton; the rocks assayed are mainly Californian.

	Au.	Ag.		Au.	Ag.
Granite	104	7,660	Sandstone	24	450
Do.	137	1,220	Do.	21	320
Do.	115	940	Basalt	26	547
Syenite, Nevada	720	15,430	Diabase	76	7,440
Granite, Nevada	1,130	5,590	Marble	5	212
Sandstone	39	540	Marble, Carrara	8·63	201

It is probable that the wide distribution of gold above indicated is closely connected with that of pyrite.

[a] Trans. Amer. Inst. M.E., XXXI. 1901, p. 808.

DEPOSITION AND CONCENTRATION OF GOLD.

Precipitants of Gold.—In whatever form and by whatever means gold is transported, it is deposited either as free gold or as a telluride of gold. It is, as has already been indicated, at present impossible to say whether deposition as a sulphide also takes place. The amount of free energy shown by the complex ions of gold indicates ready reduction of the element, and the precipitants of gold are consequently numerous. They may be gaseous, as sulphuretted hydrogen, liquid, as a solution of ferrous sulphate, or solid, as numerous sulphides and as gold itself; again, a physical modification of auriferous solutions may induce precipitation. Of the active physical factors, decrease of temperature and decrease of pressure are the most potent; minor physical agents are those involved in a modification of the degree of dilution of an auriferous solution, and in the change from the colloidal to the crystalline state.

The chief of the chemical agents of precipitation is probably the base-metal sulphide group. These act mainly below the ground-water level, and there is very often a fairly definite relation between the occurrence of gold and of the base sulphide, which is generally pyrite or chalcopyrite. Thus Don[a] shows for the Victorian rocks that where sulphides are abundant the total amount of gold is likely to be great, and that when a small quantity of pyrite is present, gold also is lacking. The same relations also hold for many Californian gold-quartz veins.[b] In these cases it is believed that the gold has been carried in solution as an alkaline sulphide, and the same cause that induced the precipitation of the base sulphide has induced that of the free gold. Skey,[c] Liversidge,[d] and others, have shown that nearly all natural base metallic sulphides will precipitate gold, at least, from auric chloride solutions. This reaction suggests a prior deposition in nature of the base sulphides, which then act as a precipitant for gold. According to Skey, one part of pyrite will precipitate more than eight parts of gold. Nevertheless, it must be pointed out that while laboratory experiments have shown that deposition of gold from solution in these cases takes place as a shining metallic film on the pyrite, no gilded pyrite or other sulphide is known in nature.

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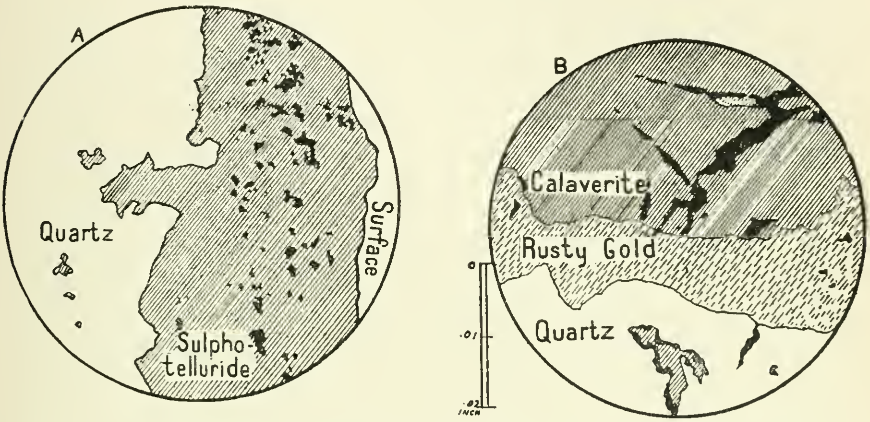
[a] Trans. Amer. Inst. M.E., XXVII, 1898, p. 567.

[b] Lindgren, 17th Ann. Rep. U.S. Geol. Surv., II, 1896, p. 182.

[c] Trans. N.Z. Inst., III, 1870, p. 225.

[d] Proc. Roy. Soc. N.S.W., XXVII, 1893, p. 303.

The recent work of Lenher and Hall,[a] on the reducing power of tellurides of gold, is of great interest when considering the distribution of free gold in gold-telluride veins and ore-channels. They found that the natural tellurides of gold, silver, and mercury (calaverite, krennerite, sylvanite, nagyagite, hessite, and coloradoite) readily reduce metallic gold from its solutions. While most of the free gold of Kalgoorlie, for example, is undoubtedly derived from the decomposition of the tellurides by vadose waters, there are occasional occurrences of free gold at considerable depths which are rather to be attributed to the reducing power of tellurides on



FIGS. 70 AND 71. SHOWING RELATIONS OF GOLD, TELLURIDE-ORE, AND QUARTZ AT (A) GOLDFIELD, NEVADA, AND (B) KALGOORLIE, WESTERN AUSTRALIA (*Sharwood*).

ascending solutions containing gold. It is conceivable that this action may be of considerable economic importance.

Selenium and selenides precipitate gold in the same manner as tellurides ; in both cases time is an important factor in obtaining complete precipitation.

In the zone of oxidation *-ous* salts and oxides are potent precipitating agents. The most notable of these are ferrous sulphate and ferrous chloride. Stokes[b] claims that the chemical action varies with the temperature, and that the reactions are, as shown below, reversible.

$$Au\ Cl_3 + 3\ Fe\ Cl_2 \rightleftarrows Au + 3\ Fe\ Cl_3.$$

With a falling temperature the result is shown on the right-hand side of the equation ; with a rising temperature the tendency to revert to the salts shown on the left-hand side is followed.

[a] Jour. Am. Chem. Soc., XXIV, 1902, p. 918.
[b] Econ. Geol., I, 1906, p. 650.

Ferrous sulphate is often abundant in the waters of the oxidised zone. The old disused workings of the Cambria mine, Thames Goldfield, New Zealand, at times contain stalactites of ferrous sulphate (green vitriol) 3 feet in length. It is to be noted that according to Moissan[a] exceedingly dilute solutions of gold in complex media are not precipitable by ferrous salts or by sulphurous acid.

A most important reducing agent is organic matter. Its association with gold has long been noted, and is described in detail elsewhere in various sections of this treatise. In placer deposits the wire gold found at the surface is commonly ascribed to the reducing action of grass roots, since the wires often assume a similar form. The occurrence of auriferous pyrite replacing woody matter in alluvial drifts has already been mentioned. The deposition of gold is here perhaps not directly dependent on the carbonaceous matter but on the pyrite itself reduced by the woody tissues.

Numerous instances are on record of gold in the ash or in the pyrite of coal or coaly matter. The ash of the pyritous coal of Batu Belaman (Assem Assem, Tanah-Laut, Borneo) contains gold.[b] Coaly matter intercalated in the quartzites of the Witwatersrand occasionally carries high tenors in gold, some, indeed, from the Buffelsdoorn mine, Klerksdorp, assaying as high as 800 ounces per ton, so that the ash was coloured purple by the gold. The gold was exceedingly fine, but on close examination it was found to be scattered through the coal. It was only, however, in the immediate neighbourhood of a diabase dyke that the coal contained gold; elsewhere in the mine it was barren.[c]

A notable instance also occurs in California, where, in the so-called "pocket" region in Tuolumne County, north of Sonora, pockets of gold are developed only where a silicified porphyry dyke crosses a carbonaceous band of slate.[d] Gold is also reported from the coal of Gippsland, Victoria. Some 65 miles south-west from the goldfield of Deadwood, South Dakota, are the Cambria coal seams. The coke of this coal is stated to contain between 1 and 2 dwts. gold, assays occasionally showing 3 dwts. The coal is used in smelting the gold-ores of Deadwood.[e]

The most remarkable instances of the influence of carbonaceous matter on auriferous deposition are furnished by the Eastern

[a] "Traité de Chimie Minerale," Paris, 1906, V, 602.

[b] Jaarb. Mijnw. Ned. O. Ind., 1885, II, p. 114.

[c] Stephens, Aust. Min. Stand., Sept. 8, 1904.

[d] Min. Sci. Press, June 6, 1908; see also 12th Ann. Rep. State Min. Cal., p. 299.

[e] Chenhall, Proc. Inst. C.E., CXXXIX, 1900, p. 326.

Australian goldfields of Ballarat and Gympie. In the former case auriferous deposition is common and abundant where vertical carbonaceous "indicator" bands are intersected by flat "floors" of quartz. The indicators are occasionally highly pyritous, and, according to Gregory, at times contain rutile. Deposition of gold here, as in many other cases, may therefore be primarily due to the presence of sulphides, themselves due to the influence of carbonaceous matter. It is not probable that solid carbonaceous matter plays an active and primary part in auriferous deposition; it acts rather by the liberation of hydrocarbons (liquid or gaseous) which form the actual reducers. Again it, or its products, may produce *-ous* salts, which are then the immediate precipitants of gold. That carbonaceous shale is a ready reducer in nature has been abundantly proved by Rickard[a] and others.

At the Gympie goldfield quartz-veins intersect bedded Permo-Carboniferous strata, but it is only where they cross carbonaceous shales that they are notably auriferous. At Croydon, in Queensland, abundance of graphite in the "pug" of the veins is considered a most favourable indication of high tenors in the gold-quartz. The gold-quartz lenses of the eastern side of the Gadag goldfield in India, follow for several miles a narrow carbonaceous argillite band. Instances of the potent reducing effect of carbonaceous matter in veins might be multiplied indefinitely, but sufficient has been said to indicate its extreme importance in the formation of gold-deposits of economic value.

Some little light is thrown on the deposition of gold by a general consideration of the gangues and minerals with which it is commonly associated. How numerous these are has recently been shown by Merrill, whose list[b] contains 48 members, each showing a different association of gold. It may here once again be emphasized that, notwithstanding this long list, to two alone, viz., to quartz and to base sulphides, may a genetic association be attributed. The "indicator" minerals so largely relied upon on various fields have a purely local value, and no general deductions, based on their presence or absence, may be drawn for other fields. On a given field, any or some of the following minerals may be valuable indicators: calcite, graphite, chlorite, serpentine, native arsenic, stibnite, galena, tetradymite, chalcopyrite, chalcocite, pyrite, pyrrhotite, pyrargyrite, proustite, and others.

Concentration of Gold in Nature.—Since the degree of aggregation of gold is of vital importance from an economic point of view, it is necessary to briefly review the causes that have formed

[a] Trans. Amer. Inst. M.E., XXVI, 1897, p. 978.
[b] Eng. Min. Jour., May 25, 1905, p. 922.

not only the notable bonanzas that have from time to time been found, but also those minor aggregations that furnish so much of the world's present supply of gold. The possible sources from which the gold of any deposit may have been derived are: (*a*) Emanations from igneous magmas; (*b*) disseminations throughout igneous rocks; (*c*) pre-existing auriferous veins; and (*d*) deposits mechanically or chemically formed in sedimentary rocks. Some, or all of these may have been affected by the leaching action of the waters that are gathered within a single fissure. Since the motion of loaded waters in fissures is mainly upward, and since deposition of their metallic content may take place with the diminution of heat and pressure that obtains as they near the surface, the general effect of motion in upward-moving deep-seated waters is towards deposition of their metallic content on the sides of the fissure. For gold, precipitation takes place either in the mass of baser sulphides or as tellurides. With long-continued passage of solutions the auriferous sulphides may readily be conceived to grow in bulk, but, to the growth of gold-tellurides in like fashion, the evidence available offers certain objections, which may, nevertheless, be inapplicable to the natural conditions of telluride deposition, of which we are profoundly ignorant. Lenher and Hall[a] have shown that the natural tellurides of gold are capable of readily reducing gold from its solutions. Hence, while the association of free gold and gold-telluride is readily accounted for, there is reason to believe that accretion of gold-telluride to gold-telluride does not take place. Telluride aggregations are perhaps to be ascribed rather to the long-continued mingling at the given spot, or in the given fissure, of solutions containing, respectively, gold and a telluride compound. In such fashion there may be formed notable concentrations, both of auriferous sulphides and of gold-tellurides. The two are often associated. At Kalgoorlie, after a steady decrease in value from the secondarily enriched telluride zone at the base of the vadose region, a notable and probably primary enrichment has been noted in certain mines at the 2,000-foot level.

The agents of concentration acting on the surface of the earth are fluviatile, æolian, and marine. Of these, the first is important, the two last insignificant. Their relative values have already been indicated, and need not be here further discussed.

Local factors often tend to produce bonanzas. These will be treated separately as inducing secondary enrichment and as forming shoots.

Secondary Enrichment.—The aggregation of gold with regard to its matrix may be increased either by the removal of a

[a] Jour. Am. Chem. Soc., XXIV, 1902, p. 355; Ibid., p. 918.

portion of the matrix or by an actual addition of gold. The first is a relative, the second an actual enrichment. The first is operative in the vadose zone or the zone of weathering, where complex minerals are decomposed and the resultant salts removed either in solution or in mechanical suspension in running water. Notable enrichments may thus occur at the outcrops of veins, especially where their contained gold is coarse. When the primary gold is fine, as in the case of the great Martha lode of the Waihi mine, the outcrop gold is not less readily removed by chemical than by mechanical agents.

The great proportion of the work of secondary enrichment is performed by solutions percolating in the vadose zone. These may be divided, according to the nature of their work and its result, into two divisions : (*a*) Ascending solutions depositing free gold as near the outcrop of the vein as possible ; (*b*) descending solutions, which by interaction with the solid and liquid contents of the fissures of the deeper zone deposit auriferous sulphides and gold-tellurides at or near the base of the vadose zone. For both divisions the initial process of solution of gold is the same. We have already considered the various possible natural gold-solvents, and also the precipitants of the vadose zone, and they need not here be recapitulated. It remains but to trace the course of the gold solutions. Free gold may conceivably be dissolved within the vadose zone, but the general source is the upper sulphide and telluride horizon, which erosion and the consequent lowering of the ground-water level brings within the reach of oxidising waters. When the course of the loaded waters is upward the gold may be precipitated in the free state by one of its numerous precipitants, or, as is probably generally the case, the contained gold is withdrawn from solution by mass-action exercised by grains or crystals of free gold. Thus are grown those gold crystals, which, as we have seen, are characteristic of the vadose zone as well as of alluvial gravels, and thus are formed the notable masses of gold that have been found in the gossan of the deposit, as at Mount Morgan, or at the intersections of fissures, as in the "propylite" of the Thames and other andesitic goldfields. This action, though perhaps most notable at the immediate outcrop of veins, since there it represents the sum of the products of many such operations, yet takes place throughout the whole of the zone of weathering, which may, indeed, range to many hundreds of feet in depth. At moderate depths it is generally accompanied by the formation of siliceous veins or replacements ; these last are lacking at the immediate outcrop.

In the second division of secondary enrichments, where the ultimate course of the gold-bearing waters is downward to the top of the sulphide and telluride zone, the possible reactions are much more complex. In the zone of weathering the sulphides are oxidised ultimately to oxides and sulphates generally in the following order in time: arsenopyrite, pyrite, chalcopyrite, blende, galena, and chalcocite, the first-mentioned being the most readily attacked. Chlorides and carbonates are also formed in the zone of weathering. When these reach the sulphide zone on the downward journey and come into contact with the reducing waters of that zone, their metallic content is deposited in a variety of ways. Organic matter below the ground-water level has, as we have seen in the case of the carbonaceous bands of Bendigo and Gympie, exercised a notable effect in this direction.[a] Sulphates and sulphites are probably also reduced to sulphides by *-ous* salts, such as ferrous silicates.[b] Perhaps the most important agent in the formation of metallic sulphides in this zone is sulphuretted hydrogen, which is of wide distribution in underground waters. Alkaline sulphides may also be operative.

However formed, the resultant mineral sulphide contains all or some of the gold contained with it in the solution. At the top of the sulphide zone there is thus a notable secondary enrichment, both of sulphide and of gold. Thus we have in a typical gold vein: (*a*) a surface oxidised zone characterised by free gold, (*b*) a narrow zone of enriched auriferous sulphides, and (*c*) a belt of great depth of original lean auriferous sulphides. The contact between the first two zones is often well defined; that between the two last is rarely so.

It is believed that a telluride zone of secondary enrichment may be formed in a manner somewhat analogous to that of the enriched sulphide zone. For the existence of such a zone there is abundant evidence both at Kalgoorlie, Western Australia, and at Cripple Creek, Colorado, the two most important telluride areas at present worked.

The apparent comparative insusceptibility, in the oxidised zone, of gold to solvents, the accumulation of gold in that zone as the vein is slowly worn away by erosion, the removal of much of the vein-matter by decomposition and weathering leaving cavities and vughs, and the constant reinforcement of its gold contents from the enriched sulphide zone, all tend to render the tenor of a given vein in the oxidised zone greatly higher than in the primary lean sulphide zone far below. Notable exceptions to this rule, arising from special conditions, are known (Waihi, &c.), and have been indicated elsewhere in this volume. Owing probably to slowness of oxidation in boreal regions, as Alaska, British

[a] See also Jenney, Trans. Amer. Inst. M.E., XXXIII, 1903, p. 445.

[b] Van Hise, Mon. U.S. Geol. Surv., XLVII, 1902, p. 1112.

Columbia, Siberia, &c., secondary enrichments are there very rare, even the pyrite in surface gravels showing no tendency to oxidation and consequent liberation of its contained gold.

Shoots.—Local enrichments or aggregations of gold are called "shoots," "chimneys," "bonanzas," "pockets," or "pay-streaks," according to their general shape. Ore-deposits vary at times in tenor and in shape with remarkable suddenness. The study of the conditions governing their formation is one of extreme difficulty, since, in the course of time, many changes, physical and chemical, may have taken place in the adjacent country, all tending to obliterate the essential features in existence at the period of formation of the ore-shoot. It is characteristic of shoots within a vein that they possess not only the dip of the vein, but a pitch to one side or the other within the vein itself. In given veins a general parallelism of successive shoots may often be observed. Shoots may be rudely divided into three classes, according to their probable method of origin or to the causes that have affected their deposition :—

(1) Shoots due to structural features in fissure or in country.
(2) Shoots due to the influence of wall rocks.
(3) Shoots due to the influence of descending waters.

No sharp division may be made between these, since more than one, or all three, may have been combined to form a given shoot. Other causes beside those given may operate, and the history of any shoot may be traced only on the field on which it occurs, and then only when in possession of abundant geological data derived from that field.

Where ore-bodies are formed by simple filling of fissures, their shape is naturally dependent on the conditions that have directed or modified the formation of the fissures. Since fissures are generally also fault-lines, the irregularities of the walls are so opposed by dislocation that the subsequent ore-body presents a succession of swellings and pinchings. This takes place not only vertically, but also, to a more limited extent, laterally. Faulting along a fissure may therefore mean the local discontinuity of the ore-body subsequently formed. The openings of a fissure due to fracture and dislocation are greatly enlarged and modified by the solvent action of passing waters. Solution may be simple or may be accompanied by metasomatic replacement. An ore-body, therefore, tends to widen on passing from a less to a more soluble rock. The mass of metal is often greater in wider parts of the ore-body owing to the greater amount of solution contained within the wider cavity, but no general statement may be made under this head. Often the narrower portions of an ore-body are much the richer, and in these cases it may be observed that the total quantity of gold contained within the ore-body at selected horizons is fairly constant, but that in the wider portions it is merely distributed through a greater mass of gangue.

Successive movements along the same fault-line may re-open a mineral-filled fissure and permit of the further deposition of ore. This process may be repeated until a notable aggregation results. The walls of a main fault-fissure may be so deeply affected by movement that adjacent bands of numerous minor parallel and interlacing fissures may form in the country, thus affording a ready passage for mineral-bearing waters and abundant opportunity for replacement of the brecciated country by ore. Interlacing stringers (stockworks), especially in propylite regions as those of Transylvania, Colorado, and New Zealand, are favourable to ore-deposition, probably because opportunity is afforded for the intermingling of solutions containing the metallic salt and the precipitant respectively.

The line of intersection of fractures or fissures is always a possible locus of an ore-body. Since these may meet in any line at any angle from the horizontal or from the vertical, any given disposition of ore-body may result. Local variations, either towards poverty or richness, may arise in shoots of this character, from the fact that the precipitating or the metalliferous solution may have egress and may be intermingled with the waters of the other channel only at given points along the line of intersection. A remarkable instance of the secondary development of an ore-shoot along the line of intersection of two fissures is afforded by the "chimney" of the Bassick mine, Colorado, where igneous matter has taken advantage of the line of weakness so formed to the surface, and has welled up along it, shattering the walls and forming a pipe elliptical in plan of brecciated material. The ore-body consisted of the central portion of the breccia, this portion apparently remaining the channel for ascending solutions.

A remarkable form of ore-body is furnished by the "saddle-reefs" of Victoria and Nova Scotia, where ore-bodies are developed at given horizons within the rocks at the crests of anticlinal folds, or more rarely at the bottoms of synclines. Minor flexures carrying ore-bodies may also be developed on the sides of the main folds, and these, as in Nova Scotia, may carry shoots. The shoots of the Champion Reef, India, perhaps the most notable worked in the history of gold-mining, are apparently due to combined vertical and longitudinal compressions, the resultant of which is midway between horizontal and vertical and is in the strike of the vein. Along the resultant line, therefore, there have been opened channels for the passage of the auriferous waters, and along the same line the already-formed quartz-vein has been folded over to form the rolls characteristic of the Champion Reef. As might be expected, the Kolar shoots, like those of many other veins in other parts of the world, are parallel in "pitch," which is here understood as the dip of the shoot within the plane of the vein. In fairly steep veins it is probable that the direction and the velocity of flow of metalliferous waters are important factors in governing the "pitch" of an ore-shoot formed by the intermingling of waters from intersecting fissures. In this case the position finally occupied by the gold grain lies along the line resultant from the combination of the motions imparted to the grain by the moving waters and by gravity respectively. Even in a slowly-moving current a fine particle of gold may be carried a considerable distance before coming to rest. In other cases, as on the Maldon goldfield, Victoria, the pitch of auriferous shoots is dependent on the dip of a given stratum and the underlie of the vein, since it is only along the intersection of bed and vein that shoots are developed.[a]

We have seen that ore-shoots may be due to the influence of wall-rocks, and those due to the action of carbonaceous rocks have also been indicated with sufficient detail. In readily soluble rocks, as limestones, traversed by fissures through which auriferous silica-bearing solutions are passing, widespread metasomatic replacement adjacent to the fissures may result. When metasomatism is accompanied by auriferous deposition, as has been the case, *e.g.*, at Pilgrims's Rest, Transvaal, and Tintic, Utah, the ore-body may assume considerable economic importance. Again, in the northern goldfields of Western Australia, the peculiar banded hæmatite-magnetite-quartz rocks of the Archæan schists are auriferous only where they are intersected by transverse fissures. Finally, a wall-rock may, on leaching, furnish the metalliferous contents of the veins by which it is traversed. The propylitic rocks of the Tertiary andesites may thus have furnished some portion of the gold of their stringers; this assumption is based on analyses of the country of the Comstock Lode, and of similar rocks, but it is doubtful whether much of the evidence offered a quarter of a century ago is now admissible.

A further cause of ore-shoots is the precipitation from downward-moving solutions that takes place at the top of the sulphide zone. Their formation has been fully indicated under secondary enrichment. As already seen, shoots of this type are more or less horizontal in disposition, and extend only to comparatively shallow depths below the zone of oxidation.

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[a] Moon, Rep. Mines Dept. Victoria, 1895.

PART II.

The Geographical Distribution of Gold.

EUROPE.

The auriferous deposits of Europe comprise three great groups and a number of minor occurrences, the latter not being obviously related to each other or to the main groups. Two of the groups, viz., those of the Ural mountain chain and of the Hungarian Miocene andesitic lavas and tuffs possess considerable economic value ; the third, or Alpine group, which ranges from Carinthia through the Austrian Tyrol and the Italian Alps to the Pyrenees and the Cantabrian Alps, is of minor importance.

The gold-veins of the Urals are apparently dependent for their origin on late Palæozoic igneous activity, though it is not clear whether they are to be ascribed to acid or to basic magmas ; most probably to the latter, though, as at Berezovsk and at Kotchkar, they occur in micrograntic and granitic country. It is possible, however, that, as in California and in Eastern Australia, they are all to be referred to a single protracted period, during which magmatic differentiation produced both acid and basic rocks. On the other hand, the relations of the Hungarian occurrences (of which the principal fields are Schemnitz, Kremnitz, Nagybanya, and those of the Transylvanian Alps) are very clear, and auriferous impregnation is there certainly dependent on the extrusion in Miocene time of dacites and normal andesites. The third or Alpine group contains numerous sporadic occurrences along the belt above indicated. These are all in the Permo-Carboniferous schistose rocks of the Alpine uplift, and in some cases, at least, would appear to have arisen from dioritic or diabasic intrusions. It is noteworthy, however, that tonalite rocks have been extruded on the eastern and southern side of the schistose rocks.[a] The Italian gold-quartz veins have proved the most important of the group.

Of isolated occurrences, the gold of the North Wales area in Middle Cambrian strata is perhaps connected with diorites and dia-

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[a] De Launay, Comptes Rend. Congrès Geol. Internat., 1906, p 586.

basic rocks, as also is that of Norway in metamorphic rocks. The Carboniferous conglomerates of Western Europe appear in places to be slightly auriferous, but no guess may be hazarded as to whether their contained gold is due to impregnation or is in point of deposition contemporaneous with that of the conglomerate.

ENGLAND.

Cornwall.—Of the production of gold in Cornwall and Devon in early times there are no records, but that from time to time the

FIG. 72. AURIFEROUS LOCALITIES IN GREAT BRITAIN AND IRELAND.

gold mines of these counties were considered sufficiently remunerative to be worked is evidenced by the numerous writs and grants of Henry III, and of his successors down to Elizabeth. With all these, however, not a single ounce of gold is recorded as having been obtained. In 1564 a patent or monopoly was granted to William Humphreys, Cornelius Devos, Daniel Hochstetter, and Thomas Thurland, to seek for gold, silver, and quicksilver in certain counties in England, Wales, and Ireland within the Pale. This patent was confirmed and amplified by James I, and became the charter of the Mines Royal Company, which existed and claimed the right to all royal metals until after the middle of the nineteenth century. It does not appear, however, that their operations at any time met with any degree of success. In the early part of the last century, gold was obtained in small quantities at Ladock by Sir Christopher Hawkins. A specimen presented by him to the Royal Geological Society of Cornwall was enclosed in a quartz-matrix.

In 1753, certain tin-streamers in the parish of Creed, near Grampound, met with some grains of gold, and "in one stone a vein of gold as thick as a goose quill was found." Shortly after, gold was discovered in blue sandy slate at Luny in the parish of St. Ewe. A little gold-ore is reported to have been obtained in 1846, at Wheal Samson, in St. Teath. In 1852 gold was discovered in quartz-veins at Davidstowe, North Cornwall.

Borlase mentions that he had seen a nugget from the parish of Creed, near Grampound, weighing 15 dwts. 3 grains. Gold was also found in the Crow Hill stream works at Trewarda, at Kenwyn, and at Llanlivery, near Lostwithiel. In the British Natural History Museum there is exhibited a small water-worn nugget from Wendron, near Helston. Gold is also reported from Cornwall in the matrix from a cross-course in Huel Sparnon, and in the gossan of the Nargiles mine. Forbes records the presence of gold in the argentiferous tetrahedrite, chalcopyrite, and galena of a lode at Bound's Cliff, near St. Teath.

Native gold has been found in most of the Cornish tin-streams flowing to the south. Of these the Carnon stream, at the head of Restronget creek in the Falmouth estuary, has perhaps yielded the most specimens. Small nuggets are not uncommon there, and one found at Carnon is reported to have weighed more than 10 guineas, and was probably about 2 ounces in weight. The gold is generally found associated with stream-tin. Analysis of several grains from St. Austell Moor, the largest of which was only 2·1 grains in weight, gave Forbes the following result: Gold, 90·12; silver, 9·05; and silica and iron, 0·83 per cent. The specific gravity of the gold was 15·62. Gold from Ladock, analysed by Church, proved to be slightly finer in quality than the above: Gold, 92·34; silver, 6·06; and silica, 1·60 per cent.

Devon.—In this county the existence of gold has been known or assumed for many centuries. In the beginning of the nineteenth century, a miner named Wellington is reported to have found gold at Sheepstor on South Dartmoor. At different times he brought to a silversmith at Plymouth quantities which in the aggregate were valued at about £40. The principal auriferous locality in

Devon is at North Molton. Here, in 1852, the gossan ores of the Britannia and Poltimore mines were discovered to be payably auriferous. This discovery, coming immediately after the world-wide excitement and unrest caused by the discovery of the Californian diggings, attracted an extraordinary amount of interest. The first trial of the gossan yielded 26½ ozs. from 20 tons of ore, and the average yield of further trials of 50 and 75 tons was 6 dwts. per ton. The gold was of very good quality, and was said to be worth nearly £4. 4s. per ounce. The total value of the gold produced from the Poltimore mines up to November 2nd, 1853, was £581. 5s. 1d.

The North Molton auriferous copper lodes are situated in an area of Devonian rocks, some distance away from an exposed contact with the overlying Carboniferous sandstones. Both the Devonian and Carboniferous strata are very highly inclined, being at times even vertical, and the lodes appear to dip with the country. The chief auriferous gossan-lode is from 4 to 10 feet wide, and dips to the north. There is considerable evidence of this mine having been worked, probably for copper, in very remote times. The auriferous gossan is a friable ironstone, highly mineralised, and containing copper. It is brown on the western side of the Mole and reddish on the eastern bank. The latter portion of the vein is reputed to be twice as valuable as the former, assays giving 17 dwts. and 8 dwts. gold respectively. The Britannia mine is three-quarters of a mile north of the Poltimore. Gold was found there, in grains and small plates, prior to 1822. It likewise carries a gossan ore, which is more siliceous than that of the Poltimore. These gossans arise from the decomposition of slightly auriferous metallic sulphides, mainly iron-pyrites. In a specimen from North Molton, in the British Museum, small particles of gold are clearly visible in the brown and somewhat siliceous ironstone.

Cumberland.—Gold is said to have been formerly recovered from the rich copper-ore of Goldscope, Keswick, Cumberland, but no specimens have been obtained in modern times.

Somerset.—Gold has been recorded from the Carboniferous Limestone near Bristol. Appreciable quantities of both gold and silver have been found in the limestone at Whalton, near Clevedon. One sample on assay contained 94 grains of silver and another nearly 1 ounce of silver ; while both returned 3 to 5 grains of gold per ton. In the absence of proof of the absolute purity of the fluxes used (and especially of the litharge), these results must be received with some degree of caution.

Gloucester.—During 1907 the discovery of auriferous conglomerates was reported from Gloucester (Forest of Dean), 1¼ miles south-west by south of Mitcheldean, where siliceous pebbly conglomerates were found to carry about 6 grains gold per ton. Their present importance is, however, negligible.[a]

WALES.

Of the early Roman gold-workings in Wales there are no authentic remains, but it has generally been supposed that the old workings of Ogofau, near the village of Pumpsant, some 12 miles west of Llandovery, are evidences of Roman occupation and of their search for gold. The name Ogofau or Gogofau is probably Ogofawr, designating a large cave or large disused workings, Ogo being a generic term for such old excavations. At this spot, numerous remains of Roman pottery, ornaments, and baths have been found. Some of the ornaments are of gold, and show considerable artistic skill. Grooved stones, on which the crushing of the quartz was performed, also occur in the neighbourhood. The workings are extensive, and have evidently been opened first along the cap of the lodes. When these open cuts became too deep for easy working, levels 170 feet long, 6 feet high, and 5 to 6 feet wide, were driven through the country to cut the lode. The upper level communicated with the opencast workings by a rise, and the lower and upper levels were similarly connected. The workings are in Lower Silurian rocks, which here dip slightly to the northward. The lodes are of quartz, and vary both in dip and strike. The quartz is massive and somewhat opaque, showing in places a tendency to form interpenetrating growths of crystals. The accompanying minerals are iron-pyrites, in cubes and pyritohedra, and a little galena. A white sericitic mica and inclusions of slate are not uncommon. The slates when fine-grained are very dark and very fissile, and through them run occasional thin veins of greenish blue serpentinous mineral. Gold was first noted at Ogofau in modern times by Sir W. Warington Smyth and Dr. Percy, though Sir Roderick Murchison had some years previously submitted the quartz to assay without result. The Ogofau veins were worked for a short time (during 1889 to 1891) by the South Wales Gold Mining Company, but the results were extremely discouraging, the total return of gold being only 4 ozs. 19 dwts. The mine was soon abandoned, but work was resumed about 1903, and the veins have since been further opened up by private enterprise. A small 5-stamp battery was erected to deal with the ore, and in 1905-1906, some 800 tons of quartz and ancient tailings were crushed for a yield of 92 ounces of gold. In 1907 the mine passed into the possession of a small company.

[a] Cullis and Richardson, Proc. Cottesw. Nat. F. C., XVI, 1907, p. 81.

North Wales.—The auriferous veins of Merionethshire, in North Wales, appear to have been discovered in 1843, the occurrence of gold in that county being reported to the 1844 meeting of the British Association for the Advancement of Science. In 1846 an attempt was made to raise capital to work the gold-mines, but, owing to the ridicule cast on the project, the attempt resulted in failure. Early in 1847 the Vigra, Clogau, Tyddyn-gwladys, and Dol-y-frwynog lodes were opened up. The last mentioned yielded a little gold during 1847, but, being in places 12 feet wide with good copper-ore, it was worked almost entirely for the latter metal.

Before January, 1849, the first extensive trials of Welsh auriferous veins had been made at Cwm Eisen, and 7 lbs. of gold of the approximate value of £350 had been obtained from 10¾ tons of concentrates, the produce of 300 tons of ore. Gold-mining operations were at this time much hindered by the claims of the Mines Royal Corporation, to which, as we have already seen, the Crown had granted, by patents of Elizabeth, its royal prerogative in Wales. The matter was finally settled by the Crown requiring a royalty of 5 per cent. on private property and of 10 per cent. on Crown land. In 1853, a great impetus was given to gold-mining in Wales by the introduction of the Berdan machine for gold-recovery. It came at the height of the excitement caused by the gold discoveries in California, and created a mild boom, of which the usual advantage was taken by unscrupulous persons. At that time, gold was reported from all parts of England and Wales, nearly all the alleged discoveries being, of course, fictitious. The gold mines worked during this boom were all about the upper waters of the Afon Mawddach, in the vicinity of the Rhaiddr Mawddach.

On August 16th, 1853, gold was discovered at the Prince of Wales mine (later the Voel mine), about half a mile west of the junction of the Mawddach with the Afon Wen, and in the same week a similar discovery in an old dump was made at Vigra (Clogau ?) by Messrs. Goodman and Parry, of Dolgelly. In 1854, a single piece of stone worth £25 was crushed from Clogau, and two years later 100 lbs. of quartz from the same mine yielded 14½ ounces of gold. It was not, however, until 1860, that the St. David's lode of the Clogau mine gave any indication of the presence of rich bonanzas. On May 21st, 1860, a mass of 15 cwt. of gold-quartz of the estimated value of £500 to £600 was broken down. During the first half-year of 1861, 983 ounces of the value of £3,664 were obtained. This rich discovery naturally stimulated enterprise in the vicinity; and in 1863 the Clogau, Cefn Coch, Dol-y-frwynog, and Cwm Eisen mines were being vigorously worked, and visible gold was obtained at Garth-gell, Cambrian, Cae-Mawr, Prince of Wales, Moel Offryn, Glasdir, Tyddyn-gwladys, and Ganllwyd mines. In April, 1862, gold was met with *in situ* in the Berthllwyd mine, near Tyn-y-groes, and a crushing of 332½ tons from the adjacent Welsh Gold Mining Company's mines gave a yield of 282½ ounces of gold. The gold

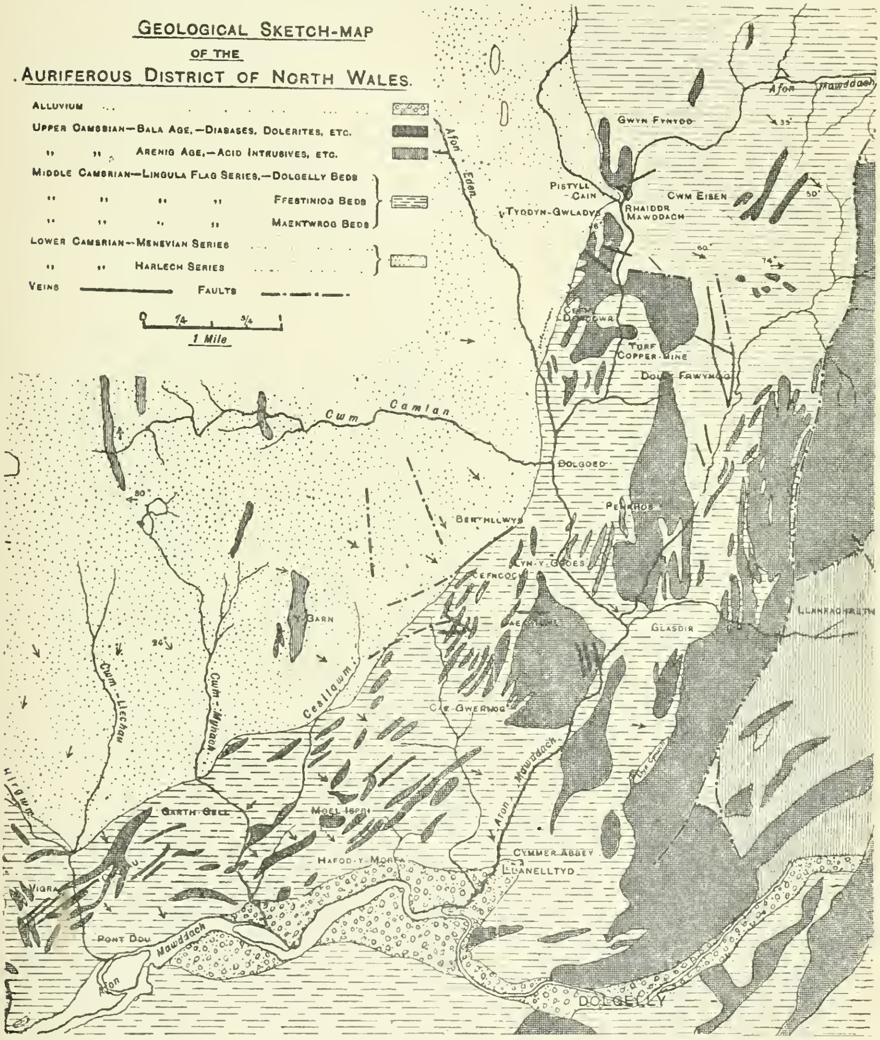

FIG. 73. GEOLOGY OF THE AURIFEROUS AREA OF THE MAWDDACH VALLEY, NORTH WALES.

of the Gwyn-fynydd lode, which yielded so handsomely a quarter of a century later, was discovered early in 1864 by Capt. Griffith Williams, but the discovery was kept secret until February 23rd, 1864. In 1865, the Clogau mine paid £22,575 in dividends and had in little more than three years produced gold to the value of £43,783.

After 1866, gold-mining languished for nearly 20 years, and there is little of importance to note in that period. The Vigra and Clogau mines had worked out their bonanzas, and in 1868 produced only 490 ounces of gold. In 1870, the total yield from Wales was only 191 ounces, of which Gwyn-fynydd contributed 165 ounces. During the following year not a single ounce of gold was produced.

The following table shows the yield of gold from Wales from 1861-1906 inclusive :—

Year.	Gold Ore.		Gold. Crude Ounces.			Value of Gold.		
	Tons.	Cwts.	Ozs.	Dwts.	Grs.	£	s.	d.
1861	——		2,886	3	0	10,816	17	0
1862	803	14	5,299	1	12	20,390	15	5
1863	385	15	552	12	19	1,747	0	0
1864	2,336	10	2,887	0	0	9,991	0	0
1865	4,280	15	1,664	11	0	6,408	10	0*
1866	2,928	0	742	16	10	2,859	7	10*
1867	3,241	4	1,520	6	21	5,853	3	5*
1868	1,191	10	435	14	23	1,677	12	9*
1870	——		191	0	0	735	7	0*
1874	——		385	0	12	1,477	6	11*
1875	——		548	1	21	2,105	17	6
1876	——		288	18	6	1,119	10	9
1877	——		139	4	13	536	0	4*
1878	——		697	12	16	2,825	8	6
1879	2	0	447	7	21	1,790	0	0
1880	——		5	0	0	19	5	0
1882	——		226	0	0	863	0	0
1883	869	0	66	0	0	254	2	0*
1885	35	0	3	10	0	13	9	6*
1887	0	17	58	0	0	209	0	0
1888	3,844	0	8,745	0	0	29,982	0	0
1889	6,226	0	3,890	0	0	13,277	0	0
1890	575	0	206	0	0	675	0	0
1891	14,067	0	4,002	7	0	13,700	0	0
1892	9,990	0	2,835	0	0	10,511	0	0
1893	4,489	0	2,309	0	0	8,619	0	0
1894	6,603	0	4,235	0	0	14,811	0	0
1895	13,266	0	6,600	0	0	18,528	0	0
1896	2,765	0	1,352	10	0	5,035	0	0
1897	4,517	0	2,032	0	0	7,185	0	0
1898	703	10	395	0	0	1,299	0	0
1899	3,047	0	3,327	0	0	12,086	0	0
1900	20,802	0	14,004	0	0	52,147	0	0
1901	16,374	0	6,225	0	0	22,042	0	0
1902	29,953	0	4,181	0	0	14,570	0	0
1903	28,600	0	5,495	0	0	19,308	0	0
1904	23,203	0	19,655	0	0	73,925	0	0
1905	15,981	0	5,797	0	0	21,222	0	0
1906	17,384	0	1,871	0	0	6,569	0	0
	†222,389	10	116,197	19	8	£417,183	13	11

* Estimated, at £3. 17s. per ounce of crude gold.
† From 1888 to 1906 inclusive.

In 1881, a low-level tunnel was driven to intersect the St. David's lode (Clogau mine); shortly afterwards a small pocket of 225 ounces was obtained. Nothing of importance was recorded from the district until 1888, when a rich shoot was discovered in the Gwyn-fynydd lode. The Morgan Company was floated to work this mine, which, in two years, produced over £35,000 worth of gold. After the exhaustion of the shoot, the company suspended operations; but a new company was formed, and carried on operations for many years, with varying success. The two most important mines, the Clogau and the Gwyn-fynydd, were then united as the St. David's Gold and Copper Mines, Ltd.

The recent yields of the two principal lodes near Dolgelly are shown in the subjoined table :—

	Gwyn Mines.		St. David's, Dolgelly.	
	Tons.	Ounces.	Tons.	Ounces.
1901	726	622	15,517	5,537½
1902	12,239	1,079	17,711	3,054
1903	11,461	2,868	17,128	2,595
1904	8,819	1,238	14,384	18,417
1905	2	188	15,538	5,550
1906	703	83	16,153	1,728

In addition to the foregoing, Cefn Coch mines for the years 1901-1903 produced 90½ ounces gold from 58¾ tons; and Ffridd Coch, 43 ounces from 76¼ tons during 1901-1902.[a] Small yields have also been obtained from Borth Valley mines (27 ounces), and from the Arenig mines, Bala (2 ounces).

It will be seen that at times the returns have been so large as to admit of a handsome profit. The net profit of the St. David's Gold and Copper Mines, Ltd., for the year 1900, was £39,729, which admitted of the payments of dividends at the rate of 60 per cent. on the capital. While the gross receipts for that year were £51,344. 4s. 10d., the total expenses were only £8,423. 9s. 7d., or 8s. 7¾d., per ton. The royalties paid to the Crown were £2,038. 7s. 7d., or at the rate of 2s. 1d. per ton of ore crushed. The extremely low mining and milling costs have therefore permitted of the payment of substantial dividends.

The rocks of the auriferous area of North Wales may be grouped as follows :—

Upper Cambrian or Ordovician	Bala Series	Castell-carn-Dochan Slates.
	Bala Age	Felstone-porphyries and felspathic ashes.
	Arenig Age	Igneous intrusive rocks.
Middle Cambrian	Lingula-flag Series	Dolgelly Beds.
		Ffestiniog Beds.
		Maentwrog Beds.
Lower Cambrian	Menevian Series.	
	Harlech Series	Harlech Grits.

[a] Home Office Rep. Mines and Quarries, 1902. Part III.

Neither in the Harlech grits nor in the Menevian beds are metalliferous veins developed, and the general horizon of the auriferous veins of North Wales is that of the Lingula-flags. These are divided into three groups. The lowest, the Maentwrog, rests in this area directly and without unconformity on the Menevian beds, and like them, dips south-east and east at angles varying from 45° near Barmouth to 10° near Gwyn-fynydd. They are fossiliferous at Tyddyn-gwladys and Cwm Eisen. The most productive auriferous lodes in these beds include the Gwyn-fynydd, Cwm Eisen, Cefn-dewddwr, Ganllwyd, Berthllwyd, Cefn Coch, Voel, and Clogau. The contact of the Maentwrog and the underlying Menevian beds is, especially in the Llechau and Mynach valleys, clearly traceable on the surface, the Menevian beds showing a barren surface, while the slates of the Maentwrog beds yield a fair soil that supports an abundant vegetation. The rocks of the Maentwrog beds are, on the whole, grey and dark-coloured slates, sometimes highly ferruginous, associated with occasional bands of sandstone.

The Ffestiniog beds, which conformably overlie the Maentwrog beds, are developed from Moel-Hafod-Owen through Glasdir to Penmaenpool. The auriferous veins on this horizon are those at Dol-y-frwynog and at Glasdir. The Ffestiniog beds in this neighbourhood have been very considerably altered by dynamic stress, occasioned possibly by the extrusion of the great neighbouring igneous mass of Rhobell Fawr. The ordinary slaty rocks of the Lingula-flags give place to a hard, massive rock, indistinguishable in many cases from the intrusive felspathic igneous rocks of the area. In places, it contains a large quantity of talc, becoming a talcose schist, weathering along fissure-planes to a somewhat kaolinic clay.

Igneous rocks are well developed in the auriferous area, the intrusions, especially north of the Mawddach river, between the Barmouth estuary and Llanelltyd, running parallel with the strike of the lower beds of the Lingula-flag series. They occasionally occupy fault-lines, furnishing a remarkable instance midway between Tyn-y-groes and the Clogau mine, where the large Cefn Coch quartz-lode occupies for some distance the plane of contact between the Menevian and Maentwrog beds; further south-west, the fissure, which runs into the head of the Mynach valley, has been filled by intrusive diabase, which at times again gives place to quartz. No less than 150 diabasic intrusions, varying from a few feet to nearly a mile in length, have been mapped in this area by the officers of the Geological Survey. Many of the dyke-rocks are light in colour, and exhibit the imperfect crystallization due to rapid cooling. Some are calcareous, showing effervescence on treatment with acid. They are, as far as may be gathered from hand specimens, dolerites and diabases.

These North Wales gold mines are, with the exception of Castell-carn-Dochan, disposed along the northern and western slopes of the watershed of the Afon Mawddach, a stream flowing into St. George's Channel. The auriferous belt extends from near Pontddu, midway between Barmouth and Dolgelly, in an easterly direction to a mile beyond the falls at Rhaiddr Mawddach. The two most productive lodes are located one at each end of the already proved auriferous belt—the Clogau on the south-west and the Gwyn-fynydd on the north-east. The Clogau mine is situated some distance from Pontddu up the Cwm-llechau valley. Midway between Pontddu and the mine is the crushing-mill, the ore being conveyed by an aerial tramway from the mouth of the main level. The mountainous nature of the country permits of the lode being worked level-free, and at the same time furnishes abundant fall for the use of the water of the Llechau as a source of motive-power. The St. David's lode lies, as already stated, in the Middle Cambrian slaty rocks (Lingula-flags), a short distance south of their line of surface-contact with the coarse greenish-grey underlying Lower Cambrian or Menevian grits and sandstones. The vein, which has a nearly east and west strike, parallel with the line of contact mentioned, is almost perpendicular, any dip being towards the north. It varies in width from 2 to 9 feet, but it is much split in places, forming occasionally large horses. The matrix of the vein is quartz, somewhat white and chalcedonic in appearance, especially near and at the surface. Calcite is not uncommon, and occasionally contains gold. Of the sulphide ores found at depth, blende is by far the most abundant, but iron pyrites, pyrrhotite, chalcopyrite, and arsenopyrite also occur in quantity. Tetradymite, the silvery white telluride of bismuth, and a somewhat uncommon associate of gold, is met with at Clogau. The gold itself is occasionally in the clean white quartz, where it is shotty, but is more often associated with blende or with a darker veinstone, the darker hue being probably due to the contemporaneous deposition of sulphides in a state of extremely fine division. The values are disposed generally in shoots and pockets.

The Gwyn-fynydd mine lies a short distance above Rhaiddr Mawddach; like the Clogau it has the advantage of an ample supply of water under a good head, and also is worked level-free. This mine was originally opened as a lead mine, but in 1870 a small rich pocket of gold-ore was discovered a few feet below the surface, portions yielding at the rate of 7 to 16 ounces to the ton. The auriferous character of the lode was first discovered in

1864. The Gwyn-fynydd lode, like the St. David's, from which it is distant about 8 miles, is close to the contact between the Maentwrog slates and the Menevian sandstones. The former, in this area, dip to the east at angles varying from 10° to 60°. The latter also dip in the same direction, but at much lower angles. The lode strikes east and west, dipping to the north at about 80°. It branches in several places, forming numerous small horses of slate. As a natural consequence, its width varies considerably, 2 feet and 20 feet being perhaps the extreme limits. The matrix of the gold is a white and opaque quartz. In places it is much mineralised, the most abundant sulphide being blende ; but pyrite, mispickel, galena, and chalcopyrite are also present. The gold here is, as a rule, much finer in grain than that from Clogau ; indeed, in some cases, it is so finely divided that it imparts a yellow stain to the stone, with which it is obviously of contemporaneous origin. In other cases, the gold is of subsequent deposition, occurring in vughs in blende, and infiltrating the somewhat cavernous quartz. In the latter case, the gold is often leaflike and wiry. Since the discovery, in 1888, of the rich shoot, which has been traced for more than 300 feet, this lode has yielded consistently, and for many years it furnished the greater proportion of the Welsh gold-yield.

In the vicinity of Gwyn-fynydd, mines that have yielded good specimens, but have never been sufficiently rich in gold to pay for working expenses, are the Cwm Eisen (Cwm-heisian), Dol-y-frwynog, Cefn-dewddwr, and Tyddyn-gwladys. Of these, as we have already seen, Cwm Eisen and Dol-y-frwynog, were among the earliest worked, and though never yielding a profit, the gold produced from them has been considerable. Cwm Eisen, in the early days of gold mining, yielded two large returns, of 170 ounces from 300 tons and 148 ounces from 157½ tons respectively. The quartz is on the whole rather clear, and the invariable associate of the gold is zinc-blende, the latter being sometimes contemporaneous and sometimes prior in point of deposition. Galena and pyrites also occur in quantity.

The Dol-y-frwynog mine, about a mile east of Cwm Eisen, has produced some very rich ore. The gold here is fine, at times staining the quartz. It is also found associated with blende and with pyrites. The main lode averages about 5 feet in width, strikes west-north-west and east-south-east, and dips towards the north at about 40°. At a depth of 200 feet, very rich ore was met with in this mine. The Tyddyn-gwladys silver-lead mine has yielded a small quantity of gold, as also has the Cefn-dewddwr. Both are situated almost at the junction of the Menevian and the Maentwrog beds.

On the west of the river Mawddach, below its junction with the river Eden, gold has been obtained in small quantities from lodes at Ganllwyd, Coed-cy-fair, Berthllwyd, Goitref, Cae-gwernog, Cefn Coch, and Cae-mawr. These are either in the Maentwrog beds or, as in the case of Cefn Coch, are at the contact with the underlying Menevian beds. East of the Mawddach, and across the valley from the foregoing are Penrhos, Tyn-y-Penrhos, and Glasdir. The last is situated opposite the Tyn-y-Groes hotel, and a short distance up the Afon Pabi. The country here is of bedded slate (Festiniog beds) striking about north-east and south-west, and dipping south-eastward. The ore-body is not a defined vein, but appears to be an impregnation of the country-rock along a line of faulting, and is contained between two fairly well-defined walls, which are usually slickensided. The auriferous pyrites (pyrite and chalcopyrite) is distributed in irregular patches throughout the ore-body. The general tenor of the ore-body is about 1·1 per cent. of copper, with a very small proportion of gold, less than 1 ounce per ton of concentrates.

The only other lodes to be noted in this area are those included in the Voel mines near Llanelltyd, where they occupy planes of contact between diabase and slates, the igneous rock in one case forming the hanging-wall and the slates the foot-wall of the vein. The auriferous quartz is generally stained with green chloritic matter, and is associated with zinc-blende, here the usual "indicator" for gold. The gold is sometimes contained in the quartz, but is more often deposited on the accompanying blende.

The only noteworthy auriferous occurrence outside the watershed of the river Mawddach is that of Castell-carn-Dochan, about five miles from Bala, and two miles from the small village of Llanuwchllyn. The main auriferous vein strikes north-east and south-west, dips southward, and is composed of extremely clean quartz, completely free, as a rule, from sulphide ores. The gold occurs in specks disseminated throughout the quartz. The lodes are in soft, black, shaly rocks, dipping eastward at about 45°, very near their junction with the felspathic ash-beds and lavas which form the summit of Castell-carn-Dochan. Complete reduction works were erected in 1864, and up to the end of 1865 about 3,500 tons had been treated for a yield of 1,606 ounces. The lode has since been worked spasmodically, in 1889 yielding 12½ ounces from 50 tons, and, during the years 1895 to 1898 inclusive, 393 ounces of gold from 2,638 tons crushed.

The gold or electrum of the Welsh auriferous region, when met with *in situ*, is scattered throughout the quartz matrix, or occurs deposited on blende or pyrites in vughs and cavities. It rarely shows any approach to crystallization. The following are average percentage analyses of vein gold from Clogau :—

No. of Sample.		Gold.		Silver.		Quartz.		Loss.
1	..	90·16	..	9·26	..	0·32	..	0·26
2	..	89·83	..	9·24	..	0·74	..	0·19

These samples represent a value of £3. 16s. to £3. 16s. 6d. per ounce.

The alluvial gold of the river Mawddach is found mainly in the bed of the stream, but a fair prospect may be washed in many places from the soil on the slopes of the valley. The gold occurs in small flattened grains, often coated with a hæmatitic film, and is associated with galena, blende, titanic iron ore, marcasite, and pyrite. Its specific gravity is low, namely, 15·79, due, however, not so much to impurities as to the presence of numerous small air cavities. As a general rule, the Mawddach alluvial gold is worth about 5s. per ounce more than vein gold. It is also lighter in colour than the Clogau gold, owing to the admixture, in the latter, of copper with the ordinarily prevailing silver.

The earliest recorded attempt to obtain gold from the sands of the river Mawddach was that of Mr. Frederick Walpole and Sir Augustus Webster, who obtained an appreciable quantity in the summer of 1852. In 1870, owing to the unprecedented lowness of the river Mawddach, several Australians and Californians worked its bed with good results. One sample of about 1 ounce weight was taken to Liverpool and there assayed at the rate of 23¾ carats (nearly 990 fine). Above Gwyn-fynydd no nuggets have been found, but they occur along the whole course of the river Mawddach from Rhaiddr Mawddach to Cymmer Abbey, the gold gradually becoming finer as the latter place is approached.

An analysis of the alluvial gold of the river Mawddach made by Forbes gave the following results :—

Gold.		Silver.		Iron.		Quartz.		Loss.		Specific Gravity.
84·89	..	13·99	..	0·34	..	0·43	..	0·35	..	15·79

It will be noted that this analysis shows a much lower value than those of the vein gold from Clogau cited above. This is due to the fact that none of the alluvial gold of the river Mawddach is derived from the Clogau lode, but in all probability arises from the degradation of the Gwyn-fynydd or neighbouring lodes, the gold of which is worth much less than that from Clogau, 8 miles to the south-east. A fruitless attempt has in recent years been made to dredge the gravels of the Mawddach.

SCOTLAND.

The earliest recorded notice of the occurrence of gold in Scotland is found in a grant (1153 A.D.) to the Abbey of Dunfermline of a tithe of all the gold which should accrue to David I from Fife and Fothrif, and Gilbert de Moravia is said to have discovered gold at Duriness (Durness), in the north-west of Sutherland, in 1245.

With the discovery of the gold mines of Crawford Moor in the reign of James IV (1488 to 1513), we pass, however, from the region of speculation to that of fact, for in the Treasurer's accounts for 1511, 1512, and 1513, are found many payments to Sir James Pettigrew for working the gold mines of that region. In 1524, it was enacted that the gold from Crawford Moor should be minted at the Cunyie House (the Scottish Mint). The Albany medal, struck in the same year, was made from gold found on Crawford Moor, as no doubt was much of the coinage of that period.

In July, 1526, a lease of all the mines of gold, silver, and other metals was granted for 43 years to certain Germans and Dutchmen, Joachim Hochstetter, Gerard Sterk, Antony de Nikets, and others. To the same grantees, a license to coin was issued in the following year. But the results could not have been encouraging, for in 1531 a payment is recorded to "the Dutchmen quhill cam here for the myndis, at their departing hamewart." In 1535, a commission was appointed to enquire into the workings of the gold mines, with the result that miners were imported from Lorraine in 1539. From 1570 to 1583 licenses to work the gold mines of Scotland were successively assigned to Arnold von Bronchhorst, to Abraham Peterson (or Greybeard), and to Eustachius Roche (1583). The royalty demanded varied from 6 to 7 ounces per 100 ounces obtained, and the remainder was to be brought to the Cunyie House, where £22 Scots was paid for the ounce of fine gold and 40 shillings Scots for the ounce of fine silver. About 1578, there appeared on the scene one Sir Bevis Bulmer, a man destined to play a great part in the development and working of the Crawford Moor deposits. The scenes of his operations lay principally on Mannock Moor and Wanlock Water in Nithsdale, and on Friar's Moor and Crawford Moor, and the district in the Leadhills. He worked the deposits very systematically, constructing head-races and tail-races, and appears to have been fairly successful. The largest nuggets of pure gold recorded by him are of 6 ounces and 5 ounces weight respectively. They were found within 2 feet of the moss at Lang Cleuch Head.

In 1593, James VI granted the gold mines of Glengonnar to Thomas Foullis, a goldsmith, and a burgess of Edinburgh.

In 1603, a sum of £200 was granted to Sir Bevis Bulmer, and in 1604, £300 to George Bowes, to search for gold and other metals on Crawford Moor. Bowes reported the discovery of an auriferous vein, but later was doubtful of it being so. He gave up his work in 1604. After Bowes's retirement, little appears to have been done till 1616, when a grant of the Scottish mines was made to Stephen Atkinson, an Englishman and a refiner in the Mint of the Tower of London. The operations were apparently unsuccessful, for in 1621 a lease was granted to John Hendlie, physician, for a period of 21 years, and another in 1631, for 7 years, to James, Marquis of Hamilton. In 1649, grants are recorded in favour of Sir James Hope in respect of the Crawford Moor mines.

At the present time, it is, of course, impossible to estimate with any approach to accuracy the quantity of gold yielded by the Crawford Moor placer deposits during the sixteenth and seventeenth centuries. Pennant, on what authority it does not appear, says, "In the reigns of James IV and James V, vast wealth was procured in the Leadhills, from the gold found in the sands washed from the mountains; in the reign of the latter not less than £300,000 sterling." Dr. Lauder Lindsay places the yield still higher, namely, £500,000, but his authorities for this high sum are equally obscure. Bowes himself, speaking of the total produce of the Crawford Moor district, during his own and part of the preceding generation, places the yield at £100,000 sterling, and even this amount is probably overstating rather than understating the amount.

Lanarkshire.—The district of Leadhills, southern Lanarkshire, lies about 44 miles south-east by south from Glasgow. The auriferous area lies almost entirely in rocks of Lower Silurian age—of Llandovery, Caradoc-Llandeilo, and Arenig time. The surface-contact line of the Llandovery and the older underlying Caradoc-Llandeilo beds runs approximately north-east and south-west, parallel with, and some little distance to the north of the Potrail Water.

The oldest rocks in the district are pillowy diabase-lavas which, with the overlying radiolarian cherts, are exposed in rapidly-recurring folds wherever denudation has proceeded sufficiently far to remove the younger rocks. The folds are generally isoclinal, and relief is often obtained by the development of thrust-planes. Overlying the radiolarian chert (Lower Llandeilo) is a well-defined but thin band of black shale—the Glenkiln shales (Upper Llandeilo). Overlying the Glenkiln shales, at a short interval, and without any stratigraphical break, are the Hartfell shales (Caradoc), which at the Leadhills occasionally give place to coarse grey-wackes, grits, and conglomerates. It is in these arenaceous sediments alone that the metalliferous (galena) veins of the Leadhills are developed. As these veins approach the black shales, either laterally or in depth, they gradually become poorer, and finally, with contact, the galena disappears from the vein.

The gold of the Leadhills area is found in the streams, into which it has been washed from a gravelly clay, locally known as "till," which lies on the slopes of the hills. It generally occurs as fine dust, but small nuggets have from time to time been observed. The largest on record weighed 27 ounces; it is said to have been discovered about 1502, and, being larger than the Wicklow nugget of 22 ounces, is therefore the heaviest recorded British nugget. Gold-washing as an industry has been abandoned at Leadhills for many years, such gold as has been obtained during the last century having been collected for the purpose of making jewellery for wedding-presents, &c., to the ground landlords. The gold from Wanlockhead is of the average quality of British gold, the following being an assay: Gold, 86·60; silver, 12·39; copper and iron, 0·35; loss, 0·66. The specific gravity is 16·50.

Gold has also been found *in situ* in the Leadhills district. In 1803, Prof. Traill recorded gold from a vein of quartz at Wanlockhead, and in the Edinburgh Museum of Science and Art there is a specimen of clean, slightly water-worn, white quartz, containing gold which shows a tendency to wiriness. A specimen of auriferous quartz in the Edinburgh Museum of Science and Art, from Wingate burn, Leadhills, shows somewhat wiry gold, is but little water-worn, and is associated with a clean, milky-white quartz. Another specimen from Stake burn, Wanlockhead, in the same museum, shows native gold disseminated throughout limonite and quartz.

Sutherland.—Though, as far back as 1853, a nugget weighing 1½ ounces is recorded as having been picked up in 1840 in the Kildonan stream, and though, as we have already seen, gold was reputed to have been obtained in 1245 by Gilbert de Moravia at Durness (a few miles south-east of Cape Wrath), it was not known to occur in any considerable quantity in Sutherland until November, 1868, when the re-discovery of gold was made in Kildonan burn, a small tributary of the Ullie. Following up the discovery, gold was found in the neighbouring burns, and a rush to the neighbourhood took place. At one time, in 1869, no less than 400 men were employed at the diggings. That the work was remunerative for the time being, is evidenced by the continued payment during a year of the license-fee for each digger of £1 per month, in addition to the royalty of 10 per cent. demanded by the Government. During the short period that these gravels were worked after the discovery of their auriferous character, royalty was paid on £3,000 worth of gold ; but as the temptation to conceal the greater portion of the gold discovered must have been almost irresistible, it is possible, as estimated by Dr. Joass, that the total amount recovered was not less than £12,000.

About the same time, gold was discovered, but in smaller quantities, in the Allt-Smeoral, or Gordon-bush burn, and in the Uisge Duibh or Blackwater, two streams falling into the head of Loch Brora. These were, however, worked for a very short time, since the license-fees obtained did not by any means compensate for the damage occasioned by the diggers to pastoral interests by driving sheep away from the sheltered valley to the bleak moorland. Digging was therefore prohibited in the Brora district from January 1st, 1870, and has never since been resumed.

The goldfields of Sutherland are therefore restricted to two main localities—to the tributary streams flowing from the north into the Ullie or Helmsdale, and to the two streams, already mentioned, flowing into Loch Brora. All the former have their sources in the highlands running along the boundary between the counties of Sutherland and Caithness. The auriferous streams, are, in order from the mouth of the Helmsdale upward, the Allt Torrish, Allt Breacich, Allt Duibh, Kildonan, Allt Ant' Fionnaraidh, Suisgill, and Kinbrace (Cn Preas). The Craggie, flowing from the west into the Ullie, has also yielded alluvial gold.

The whole country through which these streams run is typical moorland, with heather-clad lower hills and with extensive marshy ground at the sources of the streams in the high lands. The valleys of the streams have been cut down rapidly, and are narrow and fairly straight. Alluvial flats of any size are wanting along their course, and it is only in the main stream, the Ullie or Helmsdale, that such are developed.

The rocks of the district have been mapped by the officers of the Geological Survey, and are, in the main, granites and schists. The auriferous district proper is almost wholly in schistose rocks, which have been divided into quartz-schists, flaser mica-schists, and granulitic biotite-schists, clearly representing original sandstones and shales, probably of Lower Silurian age. The upper portion of the Kildonan, and the main part of the Suisgill, lie in these rocks. Overlying the metamorphic schists, and rendering it at all times difficult, and in some cases impossible, to map out the boundaries of the rocks, is a heavy deposit of glacial drift, overlain in its turn by thick beds of peat.

SUISGILL AND GOLD BURN, KILDONAN, SUTHERLAND.

CEFN COCH AND EDEN VALLEY, NORTH WALES.

BRITISH AURIFEROUS LOCALITIES.

The gold is found as small grains in the beds of the streams, and in the gravel banks along their courses. It is naturally most abundant in the coarser gravels, and in the crevices afforded by the upturned edges of the flaggy schists, across the strike of which the streams run; but it appears to be also disseminated throughout the drift. Although most abundant in the lower courses of the streams, it is not found there alone, but occurs in the heads of the burns, clearly demonstrating either long-continued denudation, or more probably, a concentration of the gold in the drift which caps all but the highest hills. The grains of gold are generally flattened, and, except in the case of the larger nuggets, present very little evidence of rolling or attrition by the action of water. The heaviest nugget discovered here weighed 2 ounces 17 dwts. Generally speaking, the gold becomes finer from north-west to south-east, indicating perhaps a north-western origin for the gold of this area. The alluvial gold of Kinbrace burn is coarse and shotty, as also, but in a less degree, is that of the Suisgill, while Kildonan gold farther to the south-east is very much finer than either of the above. The richest deposits yet found have been in the Gold burn, a stream flowing from the east into the Suisgill. Here, indeed, several colours or specks of gold may be obtained from nearly every dish.

The matrix of the gold is to be sought for in the quartz-veins in the local schists, and possibly in similar veins in the granites to the north-west; but in the latter case only where they are adjacent to, or intersect the schists. An examination of the beds of the streams disclosed several quartz-veins, apparently striking and dipping with the country.

The two auriferous localities at Loch Brora are the Allt Smeoral, or the Gordon-bush burn, and the Uisge Duibh, or Blackwater. The former flows from the north into the loch about ¾-mile from its head. The rocks are Lower Silurian flaggy quartzites and micaceous schists dipping south-eastward from 40° to 60°. Granite-dykes and quartz-veins are common in the upper waters of the Allt Smeoral. The gold is found in the bottom-stratum of coarse grit lying on the rock, both in the terraces and in the flats of the stream, and is overlain by a deposit of reddish clay and sand, much of which has been obviously derived from the neighbouring Old Red Sandstone area.

The Uisge Duibh, or Blackwater, flows into the head of Loch Brora, in the upper part of its course, over Lower Silurian rocks precisely similar in composition to those noted above, and through an alluvial flat for more than two miles of its lower course. A short distance above its junction with the Brora river, two miles from the

Loch, gold has been found. Here the burn runs across the strike of the rocks, which dip south-eastward at angles of about 20°. The micaceous schists and quartzites are seamed by numerous narrow dykes of granite. The gold occurs in a bluish sandy clay, together with rolled fragments of red granite and quartz, and is somewhat coarse in character. There is, however, little alluvium in the stream after it leaves the valley plain formed by the filling of Loch Brora.

Other Scottish Occurrences.—The other Scottish localities in which gold has been discovered may be grouped into two divisions:—

(*a*). Occurrences which may be associated with the Leadhills alluvial deposits. These are, in addition to the streams already mentioned as flowing from the high land in the vicinity of Leadhills (Shortcleuch, Leadburn, Elvan, Langcleuch, Glengonnar, Wanlock), those in valleys flowing into the Tweed (Manor Water, Meggat, Yarrow, and Glengaber), and those flowing into the Annan (Moffat Water and Dobbs Linn). All the above occurrences are alluvial, but auriferous pyrites is recorded from Torbockhill, near Annan. This on analysis yielded 4 dwts. of gold and 10 ounces of silver per ton. The auriferous pyrites was taken from an old working called "the cave," which was worked in the eighteenth century by Germans.

(*b*). Perthshire occurrences (Breadalbane area), about Loch Tay and the headwaters of the Tay. According to Lauder Lindsay, a nugget found here in former times weighed 2 ounces. He also records gold in its matrix from Tyndrum, at the head of Strathfillan, western Perthshire, where argentiferous galena occurs in mica-slate near its junction with quartzite. In 1861, James Tennant found gold in quartz, associated with iron-pyrites at Taymouth. Gold has also been recorded by various observers from other parts of Perthshire: from galena veins at Lochearnhead, where arsenical pyrites has yielded at the rate of 6 ounces to the ton, and where particles of native gold have been found in the gossan; Glen Lednoch; Ardvorlich, south side of Loch Earn, in mining for argentiferous galena; Cornebruchill, on the southern side of Loch Tay, opposite Ben Lawers; Glenturret; Glenalmond; and Glenquaich, near Loch Freuchie. There is in the British Natural History Museum a nugget of 1,010 grains from Turrerich, Glenquaich, Breadalbane. It is of a brassy-yellow colour, and is apparently of very poor quality. It contains about one-third of its weight of quartz. The gold is extremely cavernous, and shows a tendency to crystallization, though no distinct crystal-faces are to be seen.

Small quantities of alluvial gold have been recorded from tributaries of the Dee at Braemar and Invercauld, and in the sea-sand of the coast near Aberdeen.

In 1869, gold-dust in small quantity was found in the alluvium of the headwaters of the Erricht and Nairn rivers in Inverness; gold was also washed from the granites there by Dr. Bryce in 1870.

IRELAND.

There is no actual knowledge of the discovery or working of gold-deposits in Ireland before 1765. Gerald Boate, in his Natural History of Ireland, written in 1652, mentions the occurrence of alluvial gold in the Mayola (Miola) river, which flows into Lough Neagh through a portion of Londonderry county.

It would appear that the first well-authenticated discovery of gold in Ireland was made about 1765, a small nugget being obtained in the Ballinvalley brook, which flows into the Aughrim river, near its junction with the Ovoca. Five years later another small nugget was found in the same stream by a boy while fishing, but it was not until September, 1795, that it became generally known that the gravels of this stream (then called the Aughatinavought, but afterwards called by Mr. Thomas Weaver the Ballinvalley or Gold-mine river) were more or less auriferous throughout its whole course. A rush to the spot naturally followed, and in a very short time a great concourse of peasants were engaged in the arduous and unaccustomed work of gold-washing, using the crudest of appliances. In October, 1795, when the news of the discovery came to the ears of the authorities, a strong force of Kildare militia was sent to turn away the peasants, who, driven from Ballinvalley and Ballinasiloge, the richest spots on the Aughatinavought, flocked to the neighbouring streams, but these apparently did not prove as rich as that first exploited, for work in them ceased after a time.

Government operations were conducted on these gravels until May, 1798, when the works were destroyed by the rebels, and the workings were deserted for more than two years. During the period of working, the directors had obtained 555 ounces 17 dwts. 22¼ grains of gold, valued at £2,146. 15s. The cost was £1,815. 16s. 5d., and thus the produce of the undertaking defrayed all expenses, and left a surplus in hand. Streaming operations, carried on in 1801 in the branches of the Gold-mine river and in adjacent streams, yielded 388 ounces 6 dwts. 16¾ grains, valued at £1,528. 12s. 11½d., so that the total quantity of gold recovered by the Government operations was 944 ounces 4 dwts. 15 grains, of the value of £3,675. 7s. 11½d. The workings were abandoned in 1803.

In 1840, Messrs. Crockford & Co. obtained the rights to the auriferous deposits and worked them energetically for a period of nearly 4 months, during which time they obtained no less than £1,800 worth of gold, including one nugget of 11 ounces and another of 4 ounces 12 dwts. 12 grains. It seems curious that, notwithstanding this apparently profitable return, the enterprise should have been abandoned so quickly; and further that, if we except more or less surreptitious working by the peasants, no attempt was made to recover the gold of the Gold-mine river until 1862, when the Carysfort Mining Company leased the gold-royalties. This company appears to have devoted its attention rather to the discovery of auriferous veins in the neighbourhood, than to the working of the stream gravels; but its operations in the former respect were no more successful than were those of Messrs. King, Weaver, and Mills in the early years of the century. The company ceased active work in 1865, having obtained only £203. 5s. worth of gold. Since that time, with the exception of some desultory streaming by Mr. Acheson from 1876 to 1879, no work has been done on these gravels.

The total yield of the Ovoca gravels since 1795 is estimated at from 7,440 to 9,390 ounces, of a value between £28,855 and £36,185; but the estimated amount bulks very largely in these totals and the amount recovered is possibly much less than that stated.[a]

Though, so far as is yet known, no other auriferous deposits of economic value occur in Ireland, the presence of gold has been detected in various places, both in veins and in alluvial sands. Under the latter head are the sands of the Glendun river, county Antrim, which enters the sea at Cushendun, and flows from the flanks of Slieve-an-Orra; the sands of the Dodder river above Rathfarnham, which yielded the two small nuggets picked up many years ago on Stephen's Green, Dublin; Balliscorney Gap, county Dublin; and the "black sand" deposit near Greystones, county Wicklow. This last deposit appears to have resulted from the concentration, by wind and by wave-action, of the heavier constituents of the drift-sands that are here exposed on the beach. It extends along the beach for several hundreds of feet and was, when examined, several inches in thickness. It contained 21·5 per cent. of magnetic material (magnetite, chromite, and ilmenite), together with red and brown hæmatite, iron pyrites, rutile, cassiterite, and garnets. On washing and panning 7½lbs. of black sand, 37 colours of very finely divided gold were left in the dish. Indeed, "gold was found in small quantities in all the specimens of black sand taken from the beach."[b]

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[a] Kinahan, Jour. Roy. Geol. Soc. Ireland, VI, 1882, p. 147.

[b] Idem, loc. cit., p. 113.

Gold *in situ* has also been reported from Bray Head, county Wicklow; from the gossan of the Dhurode copper-lode, Carrigacat, county Cork; and from the pyrites and gossan of the mineral lodes in the Ballymurtagh, Cronebane, and Connary mines in the Vale of Ovoca, several miles to the north of the Gold-mine river. The pyrites-lodes of the last-mentioned district have long been known to carry a small quantity of gold.

From the foregoing, it will therefore be apparent that the only Irish occurrence requiring description in this place is that of the Gold-mine and adjacent valleys in Wicklow.

The Gold-mine river flows into the Aughrim river at Woodenbridge, immediately above the junction of the Aughrim with the Ovoca. Its sources are on the southern and eastern slopes of Croghan Kinshelagh mountain, the highest eminence in the vicinity. For the greater part of its course it flows through a miniature ravine, with steep, well-wooded sides. These narrow trench-like valleys in the slaty rocks are characteristic, not only of the tributary streams, but also of the main rivers—the Aughrim and the Ovoca. About ¾-mile above the confluence of the Gold-mine river with the Aughrim, the former is augmented in volume by the Eastern stream, also auriferous. All the other auriferous streams lie to the west of the Gold-mine river, and are tributaries of the Aughrim. They are the Ballintemple, a mile above Woodenbridge; the Clone; and the Coolbawn, which flows also from the slopes of Croghan Kinshelagh, but to the north-west. Gold in small quantities has also been reported from the Ballythomas stream, still further to the west.

All these streams run through an area of Lower Silurian (or Cambro-Silurian) grey, green, and dark slates, sandy shales, and grits, belonging probably both to the Caradoc and to the Llandeilo beds. They have, in this district, a general north-east to south-west strike and a dip south-eastward of 70° to 80°. To the west and north-west of the Gold-mines river, and forming the high lands of the Croghan Kinshelagh (1,987 feet), Monateigue (1,892 feet), and Ballycoog (1,169 feet) hills, occurs a great development of plutonic and volcanic rocks. Both appear at the surface with outcrops elongated in a general north-easterly and south-westerly direction. The plutonic rocks occur as narrow dykes or masses, and are essentially microgranites. The volcanic rocks are developed farther to the north-east than the microgranites, but preserve in the outline of their exposures the same general north-east to south-west elongation noted in the case of the microgranites. They are mainly epidiorites, quartz- and augite-diorites, and dolerites.

The gold of the Croghan Kinshelagh area is in all cases found in the gravels in the beds of the streams. Since the river-valleys are, in Wicklow, extremely narrow and deep, it follows that concentration of the gravels has been restricted, at any rate, since the initiation of the present valley-system, to the well-defined lines represented by the present courses of the streams.

The black sand associated with the gold is composed mainly of magnetite, ilmenite, hæmatite and iron-pyrites, but cassiterite, galena, wolfram, molybdenite, gold, copper-pyrites, and oxides of manganese also occur in the sand. The gold of the gravels is generally in fine grains, presenting evidences of considerable attrition, especially in the lower portions of the streams. Mr. Thomas Weaver, however, noted gold "crystallized in octahedrons, and also in elongated garnet dodecahedrons," and "frosted" or crystallized gold has been remarked by various observers from the upper portions of the valleys.

The heaviest nugget found in Wicklow was picked up by a party of peasants, in or about September, 1795, and weighed 22 ounces. Fifteen other nuggets from Wicklow, ranging in weight from 4 ounces 8 dwts. to 1 dwt. 4 grains, are on record.

The following are various assays of Wicklow gold :—

No. of Sample.	Gold.	Silver.	Iron.	Copper.	Silica.	Totals.
1	94·06	5·94	..	..	..	100·00
2	90·62	7·82	..	1·56	..	100·00
3	92·32	6·17	0·78	..	..	99·27
4	91·01	8·85	..	..	0·14	100·00
5	89·00	8·10	2·10	Trace	..	99·20

The richest deposit appears to have occurred in the upper course of the Western auriferous stream (also called the Ballinvalley stream) about ½-mile below Ballinagore bridge. Here, at the Red Hole, and for some 1,200 feet below, the most remunerative results were obtained by the peasants, by Messrs. King, Weaver, and Mills, and by all later workers. At Lyra, the junction of the Eastern and Western streams, a rich deposit was found containing much coarse gold. Below Lyra, and as far as Rostigah, the gravels of the main stream were productive ; but below Rostigah, they became too poor, and the overburden proved too heavy to work.

The Ballintemple brook, flowing into the Aughrim from the north-western flank of Croghan Kinshelagh, was worked by Messrs. Crockford and Company, and subsequently by the Carysfort Mining Company, in both cases yielding gold, both fine and coarse.

In the Coolbawn stream, flowing northward to the Aughrim from Croghan Kinshelagh, Mr. Thomas Weaver found a 2½-ounce nugget—the largest discovered outside the Ballinvalley stream.

The source of the alluvial gold was probably in the immediate vicinity of Croghan Kinshelagh, the present auriferous deposit representing the concentrates of a pyritous lode that has suffered degradation. For this view some corroboration is afforded by assays of quartz from a vein 8 inches wide, and in the immediate vicinity of the old Government workings, that assayed at the rate of 4 dwts. of gold to the ton.

General.—In reviewing the geological distribution of the known auriferous veins of Great Britain (Merioneth, Leadhills, &c.), the most striking feature is their more or less intimate connection with the diabasic intrusions of the older palæozoic rocks. Further, in the case of the alluvial auriferous deposits of Sutherland and Wicklow, where the parent-veins have not been located, the available evidence leads to the inference that those veins also are, or have been, located in Lower Silurian areas, with which are generally associated diabasic igneous rocks.[a]

The total yield of gold in Great Britain and Ireland may, with the exception of that from the Leadhills, be computed with sufficient approach to accuracy to give a considerable degree of value to the estimation. The yield for each country has already been dealt with under its respective heading, and the total is as follows :—

	£
England : North Molton	581
Wales : since 1844	417,183
Scotland : Leadhills	100,000
Sutherland (1868-1869)	3,000
Ireland	28,855
Total to 1906	£549,619

PORTUGAL.

The auriferous alluvial gravels of Portugal were worked successively by the Phœnicians, Romans, and Arabs. The richer deposits were in all probability exhausted long before the Christian era, but nevertheless sufficient gold remains at the present day to afford a scanty subsistence to a few washers. The gravels lie along the course of the Tagus and its tributaries, and more particularly at Santarem, Almeira, Alvega, and Rosmaninhal. The Elga, the boundary stream between the province of Beira in Portugal and Caceres in Spain, is

[a] For a detailed description of British gold occurrences, together with a complete bibliography, see Maclaren, Trans. Inst. M.E., XXV, 1902-3, pp. 435, *et seq.*

probably the most productive. Near Monfortinho, a small village on its course, the auriferous beds are from 12 to 18 feet thick, with a pay-streak of from 1½ to 6 feet in thickness. The overburden is of clay. The pay-streak carries gold to the amount of from a few grains to 2½ dwts. per metric ton, but the average tenor of the whole vertical series is probably not more than 7 grains per ton.[a]

In Northern Portugal, in the Provinces of Minho and Traz-os-Montes, quartz-antimonite (stibnite) veins carry gold in gneiss and palæozoic slates, near granite contacts. The principal district lies on the Lower Douro at Vallongo, about six miles east-north-east of Oporto. This district is some 42 miles long and 7 miles wide. Its gold-production is small, being little more than a kilo (32·15 ozs.) per annum.[b]

The important antimony deposits of the Traz-os-Montes carry, in addition to stibnite, auriferous chalcopyrite and pyrite in a quartz matrix. The outcrops of these veins furnished to the ancients a considerable amount of free gold, liberated, of course, by the weathering of the sulphides. Auriferous quartz, generally associated with copper and iron pyrites, exists in the districts of Coimbra, Evora, Beja, Foro, and Porto. The poor chalcopyrite veins of La Sierra da Caviera, 6 miles south of Grandola, itself south-east of Lisbon, contain 1 to 3 dwts. gold and 1½ to 10 ounces silver per ton.[c]

Marine placers are said to occur on the coast near Adica, between the mouth of the Tagus and Cape Espichel.[d]

The following table shows the official return of gold from Portugal during recent years[e] :—

	Kg.	Value Milreis.	Value Sterling.
1900	2·6	1,728	£384
1901	2·0	1,730	384
1902	2·0	1,760	392
1903	1·3	1,043	232
1904	1·3	940	210
1905	4·2	2,275	506
1906	29·0	18,429	4,096

[a] Breidenbach, Zeit. für prakt. Geol., 1893, p. 250.

[b] Ahlburg, Zeit. für prakt. Geol., XV, 1907, p. 204.

[c] Min. Jour., November 30, 1907.

[d] Leonhard, Top. Min., 1843, p. 245.

[e] Dipl. and Consular Reports.

[f] It is not clear whether the gold obtained from antimony concentrates is included in these figures.

SPAIN.

Both Strabo[a] and Pliny[b] give detailed accounts of the ancient gold washings of Spain, the latter describing with great particularity the methods of undermining the rock and of washing off the surface soil and overburden by the system known to modern placer miners as "hushing" or "booming." Incidentally he mentions the haphazard nature of ancient mining: "Nor yet even then are they sure of gold, nor indeed were they by any means certain that there was any to be found when they first began to excavate, it being quite sufficient as an inducement to undergo such perils and to incur such vast expense to entertain the hope that they shall obtain what they so eagerly desire." Spain was the richest gold country known to Pliny, and for the possession of its placers many wars were waged. According to the same historian, the annual yield of Spanish gold was 20,000 pounds. As each Roman pound was equivalent to perhaps 10 ounces troy, this quantity may represent 200,000 ounces troy. At one time no less than 60,000 slaves were employed; their sufferings were paralleled only by those inflicted many centuries later by the Spaniards themselves on the unfortunate inhabitants of the New World.

In the northern provinces of Asturias and Leon the remains of the Roman workings may still be traced, and the canals or races by which the water was brought to command the gravels are still visible. Some idea of the scale on which these workings were performed may be gained from the fact that water was conducted to the alluvial gravels by channels aggregating 100 miles in length. These deposits appear to have been exhausted before the commencement of the Christian era and washing therein has been carried on only spasmodically during the last 2,000 years.

The auriferous occurrences of Spain form two groups, one in the north in the provinces of Leon and Asturias, and the other in the south in Granada. The northern area lies along the flanks of the Cantabrian Mountains (Sierra Cantabrica) west of a line drawn from the town of Leon, in the province of the same name, to Oveido, in the province of Asturias. Its westward extension is marked by the western boundaries of the above-mentioned provinces, and its southern by the railway line connecting Villafranca and Astorga. The principal auriferous streams of the region are the Sil, Duerna, and Eria, together with the Burbia, Ancares, and Qua, principal tributaries of the Sil. The auriferous region has a total length north and south of some 80 miles, and is

[a] Lib. II, cap. II, par. 38.

[b] Lib. XXXIII, cap. 21.

40 miles in breadth. The rocks of the Cantabrian Mountains are Palæozoic (Silurian) slates and schists much intruded by granite. A great number of quartz veins occur in these rocks and are obviously the source of the alluvial gold. The only quartz mines that have recently been worked in the Leon province are those in the ferruginous mica-schist of Menival. The valuable deposits, however, appear to be auriferous gravels, which may occasionally, when developed as high-level terraces, attain an extraordinary thickness (900 feet); their average thickness may be assumed to be some 30 to 60 feet. They are disposed along the streams on both slopes of the Sierra Cantabrica, but are best developed in the Rio Sil, where the remains of the aqueducts of the Romans are especially numerous. The average tenor of these gravels, according to Breidenbach,[a] who made numerous assays from Navalgas, La Pol, Allanda, Nieves, Palacios-Sil, Paramos-Sil, Cuevas-Sil, and Salientinos, was nearly 2 dwts. (3 grammes) per ton! None of the gold-quartz veins yielded results higher than 2 dwts. (3·22 grammes) per metric ton, and the majority gave only some 9 or 10 grains to the metric ton. It is therefore fairly clear that the northern Spanish gold-quartz veins are of little present economic value, and that the Romans, or even their predecessors, the Phœnicians and the Carthaginians, have long ago exhausted any secondary enrichments that may have been formed at their outcrops. Little information is available as to the tenor of the placer deposits, though serious attempts have from time to time been made to work these. In 1887 the Rio Sil and Leon Mining Company operated on the Duerna river. They found the beds to consist essentially of 180 feet of poor gravel overlying a richer pay-streak that rested on bed-rock. It was found that the Romans had already worked patches of the pay-streak by stripping the over-burden by "booming." The company sank several trial pits to bed-rock, which was reached at depths of from 16 to 28 feet, of which 9 to 16 feet were over-burden and 7 to 12 feet were pay-dirt.

According to Jones[b] the average yield from the trial pits by panning was about 18 grains per ton. A nugget weighing 26 grains was obtained, while another with crushed quartz crystals attached weighed 23 dwts. 13 grains. The company ceased work owing to uncertainty of tenure and to claims for compensation for damage done by the débris that was swept down the streams from the alluvial workings. The cultivators living on the lower reaches of the Rio Sil further succeeded in obtaining a legal injunction against working. Desultory washing is carried on during a few weeks in the

[a] Zeit. für prakt. Geol., I, 1893, p. 18.

[b] Trans. Inst. M.E., XX, 1900, p. 427.

summer by local washers, who use the batea. Their earnings are, however, insignificant, ranging, under exceptionally fortunate conditions, from 5 to 10 pesetas (4s. to 8s.) per head per day.[a]

The southern auriferous occurrences of Spain lie along the banks of the Darro and Genil streams on the northern slopes of the Sierra Nevada in Granada. The Sierra Nevada is made up principally of gneiss, schists (micaceous, hornblendic, and chloritic), and granulites. The gravels are Pliocene or Pleistocene in age, and are composed of coarse gravel containing at times large boulders. Beds of clay are often interstratified with the gravel. All the rocks represented in the gravels are to be found *in situ* in the Sierra Nevada. Boulders of mica-schist are occasionally met with containing gold-quartz veins. A tough, highly ferruginous clay, containing much sericitic mica, was largely washed for gold by the ancients. Their workings extended to more than 1,000 feet above the present bed of the Genil. The tenor of the Granada deposits varied from less than a grain to 7½ grains per cubic metre. These deposits are interesting as furnishing the only example of modern "hydraulicing" that has been practised on a large scale in Europe. The head-race is nearly 11 miles (16 km.) long, of which more than 4 miles are run through tunnels. The available head thus gained was about 550 feet. On the way to the point of attack, the water was carried across a valley by an iron pipe-siphon 25 inches in diameter and 2,600 feet long. No details are available as to the results from this hydraulic installation.[b]

The following table shows the amount of gold obtained in Spain during recent years :—[c]

	Metric Tons.	Pesetas.	Sterling.
1900	1,300	39,000	£1,560
1901	1,595	47,850	1,914
1902	1,764	52,920	2,117
1903	2,681	92,025	3,681
1904	..	..	..
1905	..	..	..
1906	..	..	..

Elsewhere in Spain gold in minute quantities has been reported from the Sierra da Gaudarrama, near San Ildefonsa, in Segovia; from Membris in Cacerés ; from Culera in Gerona, on the south side

[a] Sowerby, Jour. Soc. Arts, XXXIII., 1884, p. 359.

[b] Bourdariat, Bull. Soc. Belge de Geol., VII, 1894, p. 50.

[c] Estadistica Minera de Espana, Madrid, 1901–1905.

of the Pyrenees ; from La Nava de Jadraque in Guadaljara ; from Las Hurdes, Caceres, and Escambrax ; and from Peñaflor in Seville.[a]

FRANCE.

Numerous streams in France are reported to be gold-bearing. These are mainly in the departments of Ariège, Garonne, Tarn, and Herault, where the streams flow northward from the Pyrenees ; and in the departments of Ardennes and Meurthe-et-Moselle in the north, very near the German frontier.[b]

The southern deposits have been worked spasmodically since Roman times. The wealth of the French rivers was highly esteemed by Strabo, Diodorus, and other ancient writers. Some of the streams, as the Ariège (Aurigera), indeed, owe their names to the presence of gold.[c] The Ariège is auriferous between Foix and Pamiers, and nuggets weighing ½ oz. have been found in its sands.[d] The source of the gold appears to be in the Pyrenees. At La Caunette, however, in the north of the Department of Aude, are numerous small pyritous quartz veins, in mica-schists and gneiss, that are occasionally auriferous to the extent of ½ oz. to 1 oz. per ton. These and similar veins may have furnished some portion of the alluvial gold of the neighbouring streams.[e]

In the Erieux stream, Dep. de l'Ardeche, there was found a nugget of gold weighing 17¼ ounces (537 grammes). Fairly large plates of gold have also been obtained near La Voulte on the right bank of the Rhone. The Rhone elsewhere, as on the left bank at La Roche-de-Glun, and near Givors, &c., carries auriferous gravels that were formerly washed for gold.

Ancient alluvial deposits have possibly furnished the gold of a Carboniferous conglomerate near Bessiéges, in the Department of Gard, in the Cevennes, where gold occurs in minute quantities in the quartzose pebbles of the Millstone Grit.[f] Laur[g] records the

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[a] Navarro, Act. Soc. Españ. Hist. Nat., II, July, 1893 ; III, Feb., 1894 ; Paillette, Bull. Soc. Geol., 2, IX, 1852, p. 482 ; Antissier, Bull. Soc. Ind. Min., St. Etienne, XIII, 1884, p. 125 ; Nogués, Ib., XIV, 1885, p. 931 ; Id.. Compt. Rend. Acad. Sci., XCVIII, 1884, p. 760.

[b] Dewalque, Ann. Soc. Geol. Belg., XXIII, 1895, p. 43.

[c] Caraven-Cachin, Bull. Soc. d'Hist. Nat. Toulouse, XXXIV, 1901, p. 66.

[d] Loc. cit., p. 70.

[e] Bernard, Annales des Mines, Ser. 9, XI, 1897, p. 602.

[f] Simonin, Compt. Rend. Acad. Sci., LXII, 1886, p. 1042.

[g] Compt. Rend. Acad. Sci., Paris, CXLII, 1906, p. 1410.

presence of gold in the Trias (Keuper), from which an assay of a sandy dolomite (near Raucourt, Dep. de Meurthe-et-Moselle) yielded as much as $1\frac{1}{4}$ ounces per ton of rock, while other assays from greater depths gave 4 dwts. and $2\frac{1}{2}$ dwts. per ton !

The only gold-vein of importance worked in France in former times was that of La Gardette in the department of Isère, near Bourg d'Oisans, east-south-east of Grenoble. It has been known since Greek and Roman times, and has since then been worked in desultory fashion. At times its yield has given rise to considerable excitement, and this was particularly the case in the years 1733, 1781, and 1841. The gold occurs in a quartz-vein traversing a gneiss which is overlain unconformably by dolomitic beds. The gneiss

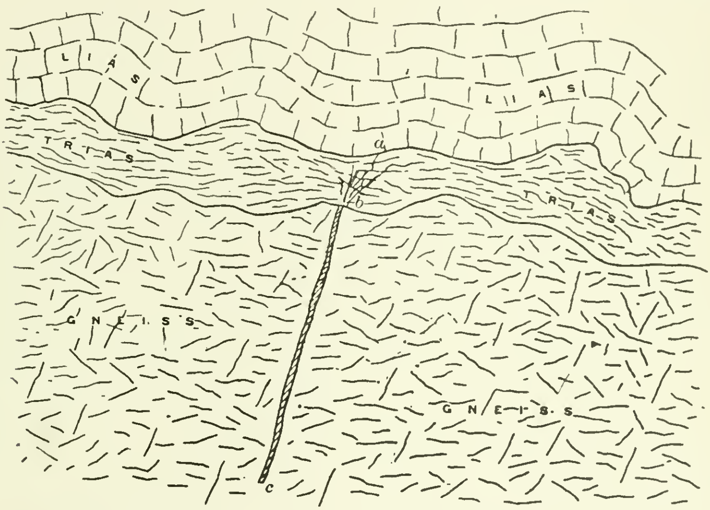

Fig. 74. Cross-section, showing La Gardette Lode (*c*, *b*, *a*) (*Rickard*).

is part of a series of schistose rocks that has apparently suffered metamorphism in Permo-Carboniferous times. The vein ceases abruptly at the old eroded surface of the gneiss. Its strike is nearly due east and west, and it is exceedingly well defined. The gangue is a remarkably banded, ribboned, and laminated quartz. The walls of the veins are well slickensided. Galena, and copper and iron pyrites accompany the gold, the first being the most favourable for the occurrence of gold. According to Rickard[a] the infilling of the fissure was later than Triassic times, and is possibly to be associated with the intrusion of an amygdaloidal diabase which occurs in the neighbourhood. The yield of the La Gardette mine has on the whole been insignificant since its upper

[a] Trans. Am. Inst. M.E., XXI, 1892, p. 84.

enriched portions have been exhausted. The total vertical depth explored exceeds 400 feet.

Four deposits containing gold are now being worked in France: (1) La Lucette, near Laval, Department de Mayenne ; (2) La Belliere par Montrevault, St. Pierre Montlimart, Department de Maine et Loire ; (3) Le Chatelet, Department de Creuse ; (4) and at Carcassone, Department d'Aude.

In December, 1904, the first gold-mill (10-stamp) in France was put in operation at La Lucette mine, near Laval, in the Department of Mayenne. The mine is mainly worked for antimony, and produces some 150 tons regulus per month. The gangue is quartz with auriferous mispickel. The daily production of gold in 1905 was some 32 ounces (1 kilo), in the form of concentrates carrying 3 or 4 kilos gold per ton. The production from La Lucette mine for 1905 was 6,759 tons ore, worth £10,158 (253,945 francs). Seventy-five tons of very rich ore were treated for a yield of more than 2 ounces per ton. During 1907 these mines yielded gold to the value of £42,015 (1,050,380 francs), or more than double that of the preceding year.[a]

At La Belliere, in the Vendée, an ancient Roman quartz mine carrying auriferous mispickel, is worked.[b] The Le Chatelet mines produced during the month of December, 1907, 180 tons (metric) ore that yielded 915·7 ounces (28·483 kilos) gold worth £3,873 (96,843·55 francs). In addition to the foregoing, about 250 ounces (8 kg.) were obtained by cyaniding. The Le Chatelet installation contains the first cyanide mill erected in France for the treatment of native gold ores. The Montrevault and Carcassone mines yield somewhat less than Le Chatelet. At Martigné-Ferchaud, Department of Ille-et-Vilaine (Brittany), gold-bearing antimonite veins similar to those of La Lucette are being worked. Free gold is rare. The antimonite carries about 9 grammes per metric ton, while associated-arsenopyrite has a tenor of 8 grammes. The ore occurs in irregular quartz veinlets in a greenstone (diorite or diabase) dyke intrusive through clay-slates of Ordovician age.[c]

For the seven years from 1896 to 1902 inclusive, the average annual gold production of France was worth a little less than £30,000 stg. In 1906, 41,400 metric tons ore were treated for a yield of 24,267·6 ounces (756 kg.) gold, worth £35,529 only.[d] The total gold yield of France in the beginning of 1908 was about 3,700 ounces per month.

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[a] Echo des Mines, May 4, 1908.

[b] Strap, Eng. Min. Jour., Feb. 9, 1905, p. 280.

[c] Stutzer, Zeit. für. prakt. Geol., XV, 1907, p. 219.

[d] Statist. de l'Ind. Minérale en France, &c., pour l'année 1906.

SWITZERLAND.

The older fundamental rocks of the Alpine chain contain sporadic pyritous occurrences which are occasionally auriferous. On the south side of the Simplon, not far from the Swiss boundary village of Gondo, are the most noteworthy of the Swiss gold occurrences. Auriferous veins occur here in the region of the eastern slopes of Monte Rosa. They closely resemble those of the Val d'Anzasca on the Italian side. The country of the veins is essentially an antigorite-gneiss. The vein fissures traversing the gneiss strike N. 25° W., and dip at steep angles to the north-east.

Some ten more or less parallel veins occur in an auriferous zone about 1,100 yards (a kilometre) in width. They are oxidised to depths of from 60 to 150 feet, and have there been worked open-cast by the ancients. Below the oxidised zone the gangue is made up of country and quartz. The main veins are crossed by cupriferous stringers. The richer workable portions are pockets from 13 to 66 feet (4 to 20 m.) long and rarely more than 1 foot (30 cm.) wide. The gangue is quartz and calcite ; the ore, pyrite and chalcopyrite with subordinate galena and blende. Free gold is no longer met with. The average value of the better ore in the Camozetta vein is about 1 ounce (30 grammes) per ton, but it may reach some 2½ ounces per ton. The period of maximum production of these veins appears to have been between 1820 and 1830. Some were worked as early as 1810. In later years they were worked vigorously in 1871, and again from 1894 to 1896.[a]

In the Canton of Ticino, between Lake Maggiore and Lake Lugano, auriferous occurrences have been met with at Astano, Novaggio, and Tesserete. South-east of Astano in the Val Tresa are traces of old gold mines. These old workings have fallen in, but so far as may be seen, the veins on which work had been done are some 6 feet in width. The gangue is quartz and carries arsenopyrite, pyrite, blende, galena, and stibnite. The ores are ground in Piedmontese mills and yield from 1 to 2 ounces gold and 4 to 5 ounces silver per ton. Similar veins were found in 1878 between Novaggio and Miglieglia, some 2½ miles east of Astano. In the Monte Cenere gneiss in the north of Lugano, 2½ miles from Tesserete in Val Capriasca, and on the eastern slope of Monte Beglio, is an auriferous lenticular pyritous lode, the lenses of which attain a maximum thickness of some 8 inches only. The pyrite and arsenopyrite of the vein, as well as the quartz, contain gold.

Auriferous löllingite veins have been worked near Vernayaz at the foot of the Dent du Midi, Valais Canton. The deposit is in

[a] Schmidt, C., Zeit. für prakt. Geol., 1903, p. 205.

gneiss, but only a few yards from the contact with Permian sandstones. It has a thickness in its richest portion of some 6 feet and a length of 150 to 300 feet. The gangue is mainly calcite, and the ore löllingite.[a]

The Calanda auriferous veins, lying west of the Rhine Valley between Chur and Mayenfeld in the Grisons Canton, are perhaps the best known of the Swiss occurrences. The veins occur on the southwest end of the Calanda mountains, west of Felsberg. The lower part of the Dogger (Inferior Oolite) Beds is there developed as a quartzose, sericitic, and calcareous clay slate, about 50 feet thick. This bed is traversed by veins, stringers, and lenses of quartz and calcite, having no predominant direction of strike. The sandy slates of the series are impregnated with pyrite and arsenopyrite. Native gold is found in the veins as dust, or in fine dendritic aggregates and small octahedral crystals. These mines were especially productive from 1809 to 1813, and were again worked vigorously from 1856 to 1861. The tenor of the ore is about ½ ounce per ton (metric). The largest piece of free gold found weighed 4 ounces (125 grammes).[b]

Alluvial gold, apparently derived from the above or from similar occurrences, is found along the Rhine between Chur and Mayenfeld. The Aare was worked for gold between Olten and Klingnau, from 1834 to 1839, when the washers are said to have earned from 2 to 3 francs (1s. 8d. to 2s. 6d.) per day.

Gold has been found in the Reuss and other tributaries of the Rhine, and in the Emmen, a tributary of the Aare, but nowhere do these deposits appear to be of present economic importance.

ITALY.

The ancient gold mines and deposits of northern Piedmont are mentioned by Pliny[c] as lying near the village of the Ictimuli in the Vercellian territory. He refers to a decree forbidding the employment of more than 5,000 slaves in these mines. The mines are mentioned also by Strabo,[d] who describes the friction that had arisen even in those days between the miners and the cultivators, the latter complaining of loss of water and of damage to the soil from the débris swept down the streams from the mines.

In modern days all, or nearly all, the southward flowing tributaries of the Po carry alluvial gold in small grains and spangles. The principal streams are the Malone, Elvo, Orco, Cervo,

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[a] Schmidt C., Handworterbuch der Schweiz. Volkwirtsch. Sozialpol. und Verwalt., Basel, 1907, p. 150.

[b] Schmidt, C., loc. cit., p. 50.

[c] Hist. Nat., Lib. XXXIII, 21.

[d] Book IV, cap. vi., par. 7.

Dorea-balta, Sesia, and Ticino, in Turin, and the Adda, Serio, and Oglio, in Milan. These are but little worked at the present time, although in 1894 a dredge was placed on the Ticino by a French company. It excavated during that year 1,100 cubic metres of gravel for 15·6 ounces (485 grammes), or $5\frac{1}{4}$ grains per cubic yard. Alluvial gold also occurs in the Orbo, and in the Val Corsente on the northern slopes of the Ligurian Apennines on the north of Genoa.

Fig. 75. Auriferous Occurrences of Piedmont, Northern Italy.

The auriferous veins of Italy lie mainly in the Western Alps, west and north-west of Lake Maggiore. The principal valleys are the Upper Sesia, Toppa, Anzasca, Antrona, and Antigorio. The fineness of the alluvial gold is about 920.[a] In these valleys the veins ordinarily occur as thin pyritous seams in Permo-Carboniferous quartzites, mica-schists, and gneiss.[b] The gold occurs generally with the pyrite, and is rarely free. The associates of the auriferous pyrites are normally chalcopyrite, mispickel, grey copper-ore, galena, and

[a] Jervis, "Dell 'Oro in Natura," Turin, 1881, pp. 68–71.

[b] De Launay, Comptes Rend. Congrès Geol. Internat., 1906, p. 586.

blende. The auriferous pyrite lodes in the Val Antrona, in the vicinity of Monte Rosa, show on analysis tenors of 16 to 20 dwts. (21 to 31 grammes) gold per ton, but of this only from ½ to 1 dwt. is recoverable by amalgamation.[a]

The two main districts are, however, those of Val Toppa and Pestarena. In the first locality Upper Palæozoic talcose schists form the country, and through them straggle irregular pyritous bodies with many secondary ramifications. At Pestarena on the other hand, there are true veins disposed fanwise. Two have been distinguished, dipping with the stratification of the mica-schists. Both are cut by a transverse vein and are enriched at the junctions.

An English company has for many years carried on mining operations in the Anzasca valley, working mainly on the Peschiera lode at Pestarena. At Val Toppa the tenor of the ore is 9 dwts. per ton; at Pestarena 11 dwts. per ton. Everywhere the gold occurs entirely in the pyrites, the quartz being barren. At Battiggio (Cani) veins occur in mica-schists, but after having been worked extensively, in the eighteenth century, these have now been abandoned owing to the large percentage of arsenic contained in them, and also owing to their low gold tenor.

The veins of the Val d'Anzasca appear on the whole to have been the most productive of Italian gold mines in the past. The principal were those of Peschiera (Pestarena), and Cavone. The last reached its maximum production as long ago as 1790, when, in two years, some £23,000 gold was produced.[b] The name Pestarena is itself indicative of the great number of small Piedmontese crushing (*pestáre*) mills in the neighbourhood. The annual production of these mines for the period immediately prior to 1827 was about 119 metric pounds gold, worth, say, £17,810 (Lire 445,300), of which, however, only some 12 to 15 per cent. was profit.

The Pestarena United Mines included Peschiera, Kint, Stabioli, Cani (Battiggio), and also Carboniera d'Alberto (Val Toppa). The value of the Peschiera bullion was £3. 8s. 1½d., and its fineness 754. Work on these mines was suspended in 1900. They had during the later years of operation produced as follows:—[c]

	Long tons crushed.	Crude Ounces Gold.	Value. Sterling.	Annual Profit or Loss.
Oct., 1896, to			£	£
Dec., 1897	6,929	10,884	37,053	+ 10,551
1898	5,270	6,386	21,192	— 3,363
1899	5,210	3,477	10,357	— 5,904
1900	2,734	1,362	3,791	— 5,783

[a] Lenieque, Bull. de la Soc. de l' Indust. Min., May, 1907.

[b] Fantonetti, "Le Miniere Metalliche dell'Ossole in Piemonte," Milan, 1836.

[c] Ann. Reports Pestarena United Mines Company.

Val de Challant, Piedmont, Italy.

Val d'Anzasca, near Macugnaga, Piedmont, Italy.

In the Val Antigorio the chief gold mine worked was Crodo. It was very productive during the last years of the eighteenth century, and is locally believed to have furnished the funds for the construction of the magnificent Marini Palace at Milan. In the Val Antrona, at Trivera and Alle Mi, refractory auriferous sulphide (arsenopyrite and pyrrhotite) veins occur. None of these mines were worked much earlier than the commencement of the nineteenth century. Numerous small veins exist high up on the spurs of Monte Rosa, and in the Val Moriana facing Pestarena, but are unworkable owing to the high transport costs.

In the Val de Challant, a left-hand tributary valley of the Dorea Balta, is the Evançon mine, the only important gold mine working in Italy in 1908. It lies above Brusson, and comprises several widely separated veins, of which the Fînnâllaz is the chief. The veins cut transversely through gneiss and the overlying rocks, which are amphibolite and crystalline limestone, the whole series dipping sharply into the hill. It is, however, only for the few hundred feet that the veins pass through the amphibolite members of the series that they are auriferous. Unlike the great majority of the Italian occurrences above-mentioned, the gold is free, is often crystallized, and occurs disseminated through clear quartz, in shoots and pockets, some of the latter being exceedingly rich in quality if small in extent.[a]

At Monte Loreto, east of Genoa, auriferous chalcopyrite occurs in a gangue of calcite and quartz. The gold liberated from the chalcopyrite has been found in the form of octahedral crystals. Masses of crystallized gold weighing several pounds are reported to have been obtained from these veins.

It is estimated that since 1860 no less than £1,520,000 (38,000,000 lire) have been spent on the Italian Alpine gold veins for a total return in gold of only £680,000 (17,000,000 lire).

The gold production of Italy during recent years is shown in the following table :—[b]

	Metric Tons.	Lire.	Sterling.
1900	5,840	266,284	£10,651
1901	890	40,600	1,624
1902	1,215	51,348	2,053
1903	5,734	123,337	4,933
1904	6,746	—	8,263*
1905	1,200	36,000	1,440
1906	6,543	236,604	9,464

* Estimated.

[a] Schmidt, C., "Geologisches Gutachten über die goldführenden Gänge bei Brusson in Piemont," Bern, 1900.

[b] Revista del Servizio Minerario nel 1900-1906.

SERVIA.

The metalliferous region of Eastern Servia lies south of the Danube and between the Morava and the Timok, both northward-flowing tributaries of the great river. The region is therefore the southerly continuation across the Danube of the Transylvanian Alps that connect the Carpathians and the Balkans; it is in forcing a passage through these connecting ranges that the Danube has formed the famous gorge of the "Iron Gates." The highest mountains in Eastern Servia are the Stara Planina on the Bulgarian frontier, with a maximum height (in Midzor peak) of 7,106 feet. In the mineral region itself the mountains attain an altitude of some 4,000 feet, promising, therefore, from their streams and waterfalls an abundant supply of electrical power.

Mining has been carried on in Servia from the most ancient times, and numerous legends have consequently gathered around the industry. In this connection it is interesting to note the resemblance of one of these, accounting for the abandonment of the "Lakudin Beg" gold mine in the Pek Valley, to that advanced by the Tibetan miners for a similar sudden abandonment of goldfields.[a] In the Servian variant the diggers found a magnificent golden plough, and "craignant une malediction d'en haut"[b] incontinently ceased work. There appear to have been two distinct periods in ancient Servian mining, Latin and Slav; of the former but few traces now remain. The latter is best defined by the coins and jewels occasionally met with in the placers. The ancient workings were shallow, owing probably to the lack of pumping facilities. With the advent of Saxon miners, *circa* 1244 A.D., the Servian mineral industry assumed considerable importance, and from thence onwards numerous references are made in the literature of the Middle Ages to the gold mines of Servia. During the northward extension of the Turkish arms in the fifteenth century, the miners were swept across the Danube before the Moslem hordes, and the history of the Servian mines was closed for four centuries. Mining operations were finally resumed in 1849. Old workings are especially numerous in the valleys of the Pek, Mlava, and Timok.

The Stara Planina, the mountain range on the Servo-Bulgarian frontier, is composed mainly of metamorphic and crystalline schists, which stretch northward from Midzor peak to Golubac, Dobra, and Orsava on the Danube, with, however, a slight break in their continuity near Zajecar. The metamorphic rocks and schists comprise

[a] Maclaren, Min. Jour., June 22, 1907.

[b] Jovanovitch, "Or et Cuivre de la Serbie Orientale," Paris, 1907.

gneiss, amphibolite-schists, mica-schists, talc-schists, phyllites, and quartzites. Palæozoic rocks occur as two large areas to the west of the foregoing crystalline rocks, and are, in the main, slates, schists, and quartzites. Overlying these are Mesozoic beds—Permo-Trias, Jurassic, and Neocomian. A great part of the region is covered by fossiliferous Cretaceous limestone. Tertiary deposits also bulk large between the Morava and the Timok. They represent Miocene deposits of the Mediterranean, Sarmatian, and Levantine stages.

Among the eruptive rocks are Archæan and Palæozoic granites, granulites, porphyries, and porphyrites. Towards the close of the Mesozoic there appeared euphotides, peridotites, diorites, diabases, and lamprophyres. These basic intrusions ceased before the Tertiary period, which is characterised (as in the auriferous regions of Transylvania) by the appearance of andesites, dacites, and trachytes, closely connected, especially the first, with the mineral filling of the veins, which is probably of Miocene age. Andesitic rock is the country of the veins of Bor, Krivelj, Metovonica, Zlot, and Savinac. The gold-quartz veins of Deli-Jovan, although the country is serpentinous, owe their gold to andesite, and where this rock is absent there also is mineralisation absent. At Majdanpek and Kucajna andesite occupies an equally important place. The auriferous minerals of the former mines are quartz, galena, pyrite, blende, and chalcopyrite, while at the latter place, where andesite is intrusive through limestone, masses of auriferous galena have been deposited along the contacts. Similar relations exist at Ridang, on the Danube north of Kucajna, and also to the south-west in the districts of Bistrica and Breznica. In short, in all the places distinguished by the presence of chalcopyrite, galena, blende, or pyrite, with or without gold, andesites are the enclosing rocks, or are found in the immediate neighbourhood. It is from the degradation of these and similar pyritous veins that the alluvial deposits have derived their gold content.

Native amalgam, often accompanied by cinnabar, is found by the native washers. It occurs in light-grey, rounded grains, and is known as "zivak." Its composition appears to be: Hg, 30·96 per cent.; Au, 55·81 per cent.; Ag, 13·23 per cent.

According to Jovanovitch, the alluvial gold (*a*) from andesitic quartz veins contains very little silver; (*b*) from serpentine (euphotide) contains 8 to 10 per cent. silver; (*c*) from the crystalline schists contains as much as 30 per cent. silver—results which certainly do not accord with experience in other parts of the world. The alluvial gold, as a rule, is very fine in grain; but from Gindusa slugs as large as a hazel nut have been obtained; while at Crista-Pucina in 1886, a labourer working in his field found a nugget 7 ounces (218 grammes) in weight. Numerous pepites occur in the washings of Deli-Jovan and of the Pek river. In the veins, and especially in those in the mica-schist, gold is always absent when pyrite and chalcopyrite are lacking. These minerals occur either in pockets or disseminated throughout the quartz and country. In pyritous veins it seems fairly well established that the gold content diminishes with increasing depth. The Wilfley table concentrates (sulphides) of the St. Anne (Deli-Jovan) mine average from 2 to 3 ounces gold per ton. Chalcopyrite itself carries from 2 to 15 dwts. gold per ton. Arsenical pyrites and galena also carry gold. Galena is encountered more frequently in the metamorphic rocks than in the andesite. Its tenor ranges from 7½ to 20 dwts. in gold.

Kucajna Mines.—These lie on a mineral concession of 160 hectares (395·3 acres) to which are added subsidiary concessions. Explorations were commenced here in 1862. The mines at first promised to be successful, but collapse came when an unfortunate fire destroyed the surface works. The gold-quartz veins carry galena, blende, and pyrite. They have been followed to a depth of 320 feet below the surface. From 1873 to 1892 work has been carried on spasmodically. During eight years only of this period was smelting effected, and then not continuously. Nevertheless, the veins have produced 267·133 metric tons lead, 139·4 metric tons zinc, 41,566 ounces silver, and 2,005 ounces gold. The thickness of the veins is extremely variable, ranging from 6 inches to 5 feet.

St. Barbe Mines (Blagojev-Kamen).—These are on the upper valleys of the Pek, between Neresnica and Majdanpek. The region is well wooded, and contains old workings which at the St. Barbe mines cover 1,250 acres. The gold-quartz veins contain pyrite, chalcopyrite, and galena, giving occasionally very high assays. Work on this concession has as yet been purely exploratory; nevertheless, according to Jovanovitch,[a] they have shown that there are nearly 600,000 tons of ore available for exploitation.

St. Anne Mines (Deli-Jovan).—Numerous old workings occur here, and it was from here also that the nugget of 7 ounces weight already mentioned was obtained. The country is serpentine (euphotide), and comprises the *massif* of Deli-Jovan. The minerals in the veins are the same as those of the foregoing mines. The pyrites when concentrated may carry as much as 1⅓ to 6⅔ ounces of gold. From the shafts and levels on this property many thousands of tons of ore have been extracted. In 1900 a trial parcel of 97·876 metric tons of concentrates was sent to Kremnitz

[a] Loc. cit. sup.

(Hungary); from it were extracted 332 ounces of gold and 626 ounces silver.

Alluvial Deposits.—The Pek river carries alluvial gold from its source to its mouth, but from the time it leaves the Kucevska defile until it reaches the Danube the gold is too widely scattered over the broad valley to be of economic importance. Even on the shores of the Danube the sands are faintly auriferous. The chief dredging area on the Pek river lies in the broad valley-plain between Kucevo and Neresnica. At the latter place, "La Société d'Exploitations Minières," of Brussels (formerly the Servian Dredging and Mining Syndicate, of London), had in 1906 three dredgers working. Prospecting with Keystone drills in this area gave over a total length of 650 yards an average tenor of 13½ grains per cubic yard. Working results have, however, been as follows:—

DREDGE NO. 1.

Year.	Total Hours Worked.	Hours of Actual Dredging.	Quantity Cubic Yards.	Yield. Ounces.	Cost per Cubic Yard.	Hours of Actual Dredging per Month	Cubic Yards per Hour	Value of Gravel per Cubic Yard.
					d.			d.
1903–4...	3,768	2,891	135,356	1,076	2·5	361·3	46·9	7·6
1904–5...	5,349	4,637	203,507	1,226	2·8	488·1	43·8	5·8

DREDGE NO. 2.

Year.	Total Hours Worked.	Hours of Actual Dredging.	Quantity Cubic Yards.	Yield. Ounces.	Cost per Cubic Yard.	Hours of Actual Dredging per Month	Cubic Yards per Hour	Value of Gravel per Cubic Yard.
					d.			d.
1903–4...	1,569	1,112	55,264	361	2·4	370·6	49·6	5·4
1904–5...	5,582½	4,645	185,473	1,469	3·2	464·5	39·8	7·6

From March 21st to December 31st, 1906, the results were still lower, but the three dredgers were then engaged in cutting a channel through barren ground to reach better gravels. Nevertheless, the three dredges returned:—

Hours Actually Dredged.	Cubic Yards Raised.	Cubic Yards per Hour.	Yield. Ounces.	Value.	Value of Gravel per Cubic Yard.
					d.
9,794	621,060	63·3	3,082	£12,069	4·7

The Bela-Reka auriferous alluvials have a total thickness of some 10 to 13 feet, but of this only about 2½ feet are really productive. The overlying barren sands are from 3½ to 4 feet thick. The value appears to be about 8 grains per cubic yard (1·34 francs per cubic metre).

In the lower Timok valley the gravels have much the same thickness and disposition as in the Bela-Reka, but their value is slightly less—viz., about 6½ grains per cubic yard. The upper Timok has been examined by M. D. Levat, who found the valley very broad in places, reaching a maximum width of 660 yards. Of 53 bores put down none proved barren, and the average value was stated to be 12½ grains per cubic yard (1 92 francs per cubic metre). This result was considered to be sufficiently encouraging to proceed with the erection of dredges on the Timok river.

The gold production of Servia during the present century has been :—

	Kg. Fine Gold.	Value in Francs.	Value, Sterling.
			£
1901	30	98,881	3,955
1902	19	92,939	3,717
1903	11	34,802	1,392
1904	85	258,236	10,329
1905	87	251,494	10,059
1906	128	374,267	14,990

TURKEY.

Ancient writers make occasional references to the gold of the region now known as Turkey-in-Europe. Strabo mentions gold placers on the east of the Strymonic Gulf (mod. Orphani), near Mount Pangaeus. These were worked by Philip of Macedon in 358 B.C. Herodotus also describes these gold occurrences as lying on the Thracian coast opposite Thasos, while he refers to the island of Thasos as being itself auriferous. The auriferous country of the mainland lay between the Strymon (Struma) and Nestus (Mesta Kara Su) rivers, both flowing into the Ægean Sea, north and west respectively of the island of Thasos. Nothing, however, is known at the present day of the economic possibilities of these placers of the ancients.

The Turkish Empire during the years 1902-1904 is believed to have produced in gold the following :—

	Fine Ounces.	Value, Sterling.
		£
1902	1,480	6,286
1903	999	4,242
1904	1,400	5,945

All this must be regarded as having been derived from the Bulgar Ma'aden mines in Asia Minor, and not from Turkey-in-Europe.

GREECE.

Native gold is not recovered in Greece at the present day. It has been found, nevertheless, in alluvial deposits near the town of Skyros in the island of the same name ; in the vicinity of the village of Doliana (Arcadia) in small quantity in pyritiferous veins ; and also with silver in the argentiferous galena of the famous mines of Laurium. The ancient Greeks worked gold mines in the islands of Cyprus and of Siphanto (Siphnos) in the Cyclades group. Reference is made to these placer deposits both by Pausanias[a] and Herodotus.[b]

ROUMANIA.

Gold occurs in very small quantities in the river sands of the Juil, Oltul, Argesul, Bistritza, and their mountain affluents.[c] The Bistritza rises in the Rodna mountains in Eastern Hungary, flows through the south corner of Bukowina, and thence through Moldavia to join the Danube. Its gold has doubtless been derived from auriferous veins in andesite, similar to those of Nagybanya. Gold-quartz veins are, moreover, known in the portion of the Carpathians through which the Upper Bistritza flows.

AUSTRIA-HUNGARY.

Bohemia.—The gold mines of Eule-Jilova, 10 miles south of Prague, between the valleys of the Sazava and the Libre, were being worked in 734 A.D. They are said to have yielded in one year 1½ million ducats gold, and again in 1145 A.D. to have produced more than a ton of pure metal. The Borkowitz mines in the Kuttenberg district are also worked for gold.

The pyritous gold-veins of Mount Roudny, the only gold mine of present importance in Bohemia, lie 9½ miles east of Wotitz and 37 miles south-south-west of Prague. They have recently been re-opened by a British company after an abandonment of nearly a century, having previously been worked intermittently from the fourteenth century to 1804. The country of the veins is a grey biotite-granite, which becomes gneissose in places,

[a] Lib., X., cap. XI.

[b] I, 225, Thalia III, 57.

[c] Poni, Ann. Sci. de l'Univ. de Jassy, I, 1900, p. 145.

and which is associated with amphibolite. Both granite and amphibolite are traversed by aplitic dykes. The rocks are crossed by a system of east and west pyritous fissures, only a few inches in thickness. The adjacent country is also impregnated with pyrite. The gold usually occurs associated with the pyrite, but is also found native, either finely divided in the quartz, or as flakes and crystals in the veinlets. The thinnest veins are the richest, and finely crystallized pyrites contains more gold than the coarsely crystallized. The amphibolites contain little or no gold. Auriferous deposition and alteration of the granite walls preceded the formation of the aplitic dykes.[a] In 1906 the Mount Roudny mines crushed 32,985 tons ore for a yield of 3,977·5 ounces (123·9 kg.), worth £16,882.[b] Other minor gold occurrences of similar character in Bohemia are fully described by Posepny.[c]

In Southern Bohemia gold-quartz veins occur in gneiss, mica-schist, chlorite-schist, and greenstone. The quartz of the Kasejowitz (Kasejovic) veins is white and clean, with visible grains of a gold-telluride mineral resembling nagyagite, from which the free gold of the vein has originated. Assays have shown tenors of from ¾ to 2½ ounces gold per metric ton. The veins appear to be at the contact of the gneiss with granite apophyses. With the quartz is associated auriferous arsenical pyrites and gold-tellurides (nagyagite, petzite, and sylvanite).[d] North-north-west of the town of Wolin are the Na Zlatnici veins, worked in the eighteenth and nineteenth centuries. These also are at granite and gneiss contacts. Similar veins are known at other places in the neighbourhood. The Otava river gravels carry an average tenor of 2 grains per cubic yard (17 mg. per cubic metre), a tenor, of course, too small for profit.[e]

Austrian Silesia.—The earliest record of gold-mining in Austrian Silesia is dated 1556 A.D., and the positions of many of the mines then worked are still known. These lie in the Hohenberg and Oelberg mountains at and in the vicinity of Würbenthal, Engelsberg, and Freiwaldau, all in the north-west of the province. The lodes are in clay-slates that are associated with chlorite-schist, quartzose schist, and diorite, the whole series resting on Archæan gneiss. The veinstone is quartz, and carries pyrite and galena. The value of the richer ore varies from 17 to 36 dwts. per ton. All the streams

[a] Krusch, Zeit. der deutsch geol. Gesellsch., 1902, LIV, p. 58.
[b] Forbes, Cons. Rep., 1908.
[c] Archiv. für prakt. Geol., II, 1895, p. 79.
[d] Holy, Oesterr. Zeit. für Berg- und Hütt., April 4, 1908, p. 1.
[e] Zelizko, Zeit. für prakt. Geol., XVI, 1908, p. 63.

flowing from the Hohenberg and Oelberg mountains, and more especially the Oppa and Biela, contain small quantities of gold.[a]

Tyrol.—Gold-mining in the eastern Tyrol is believed to date from 1427 A.D. The well-known Heinzenberg mines near Zell in the Ziller Thal were opened up some 12 years later, but were not extensively worked until 1628. In 1630 rich alluvial deposits and quartz-veins were found. The apportionment of the prospective profits from these deposits nearly led to war between the owners, the Archduke Leopold of Austria and the Archbishop of Salzburg. The gold tenor of the veins was then from 1½ to 2 ounces per ton. The upper oxidised zones were rich and were easily mined and milled, but in depth the free gold was replaced by refractory auriferous arsenical pyrites, from which the gold was obtained with great difficulty. In 1681 some 400 workmen were employed, and quantities of quartz of a tenor of 107 ounces per ton were being obtained. In the eighteenth century the yield steadily declined, and from 1794 to the year 1869, when the Heinzenberg (Vincenzi) mines were finally closed down owing to an inrush of water, the annual yield had been only some 150 to 160 ounces. The veins lie in mica-schists, phyllites, and talc-schists. They are numerous but low-grade, and vary in thickness from a few inches to 36 feet.[b] Alluvial gold has been found along the gravels of the Wipp Thal from the Brenner Pass to Innsbruck.

Salzburg.—The gold mines of the Lungau Tauern chain lie on its northern flanks at Schellgaden, some four miles east of St. Michael, and on the northern side of the upper Mur Thal. Topographically and geologically, the country is a continuation of the Hohe Tauern. The veins were extensively worked in past centuries, but have been neglected in recent years. They are essentially small quartz-lenses in a hornblende-mica-schist that passes with increase of felspar to a gneissic rock. The lenses are disposed along a zone after the manner of quartz-lenses in schists, each lens tending to overlap its successor. The maximum thickness and length of the lenses appears to be 6 feet and 185 feet respectively. Working in the winter is rendered difficult, and at times impossible, by the avalanches to which the higher valleys and mountain slopes are subject.[c] The ores are highly pyritous, containing pyrite, chalcopyrite, and galena, with rare blende. The tenor of the ore during

[a] Lowag, Oesterr. Zeit. für Berg- und Hütt., 1901, XLIX, p. 415.

[b] Schmitt, Berg- und Hütt. Zeit., 1868, p. 11; Wolfskron, Oesterr. Zeit. für Berg- und Hütt., XLIII, 1895, p. 349.

[c] Beyschlag, Zeit. für prakt. Geol., 1897, p. 210.

the last 30 years (1789-1818) of active working was in gold 5¼ dwts. (9·2 grams.), and in silver 5 dwts. (8·9 grams.) per metric ton.[a] Elsewhere in Salzburg gold has been obtained from the marls of Gastein in the Gastein Thal, where it is associated with magnetite and garnet; from pyritous veins in gneiss at Bockstein in the same valley; from similar veins in the Rauris Thal and Fusch Thal; and from the neighbourhood of Zell.

Carinthia.—The formerly important gold-mines of Lengholz, near Steinfeld, and of Siflitz, near Lind, were discovered about 1660. They lie in the Drauthal, near Sachsenburg. Their veins are in mica-schist and gneiss. Recent explorations at Lengholz showed the old workings to have been driven on a brecciated vein cemented by calcite and carrying magnetite and chalcopyrite, together with a little mispickel. The magnetite on assay carried 6½ dwts. of gold and silver per ton. The Siflitz region lies north-east of Lind. Its gold-quartz veins occur in phyllite and biotite-mica-schist, and carry a large percentage of pyrites. The adjacent schists also are impregnated with pyrites. Free gold is found in the veins.[b] Auriferous gravels were formerly worked in Carinthia. Extensive remains of ancient washings are found at Weisenau, in the Lavant Thal in the east of the province. These appear to have been worked only spasmodically since 1757. Numerous heaps of pebbles and boulders testify to former activity. At Tragni, near Paternion, auriferous gravels were formerly worked by shafts and levels. The deposits of the Lieser Thal are less extensive than those of the two foregoing localities, though gold-washing in the Lieser Thal is possibly of greater antiquity, since it is believed to date from the fourteenth century, and was, indeed, the subject of numerous edicts during the sixteenth century.[c] Remains of ancient washings are disposed along the valley, principally between Gmünd and Spittal.

The veins of the Hohe Tauern mountains on the slopes of the upper valleys of the Möll, in the extreme north-west corner of Carinthia, were undoubtedly worked in Roman times. They appear to have reached a period of maximum production during the sixteenth century. The country in the neighbourhood of the veins is a complex of Archæan rocks made up of the gneisses and schists of the Central Alps. The schists are micaceous, chloritic, and calcareous. They are traversed by extremely thin quartz veins that carry gold, both free and associated with pyrite. The sulphides present are pyrite, chalcopyrite, arsenopyrite, blende, galena.

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[a] Posepny, Archiv. für prakt. Geol., I, 1879, p. 155.

[b] Canaval, Zeit. für prakt. Geol., IX, 1901, p. 425.

[c] Canaval, Archiv. für prakt. Geol., Freiberg in Sachs., II, 1895, p. 599.

silver sulphides, and occasional molybdenite. Associated with the veinlets of the Hohe Tauern are auriferous and pyritous impregnations of the adjacent rock walls, the whole forming well-defined lode-channels. One such—the Seiglitz-Pockhart—has been traced for nearly 4 miles along its strike. It carries gold only in the schists, becoming barren on passing into the gneiss. The principal occurrences are on the southern slopes of the Hohe Tauern, in the Möll, Fleiss, and Zirknitz valleys. The Kloben and Gutthal mines in the Möll valley lie at an altitude of 9,400 feet above sea-level. Very rich pockets were found in the Rathhausberg mines in this vicinity, in the first half of the eighteenth century. The pockets lay at a depth of 1,300 feet below the surface, and were therefore well within the sulphide zone. The tenor of the ore worked in the two principal mines of the Hohe Tauern, viz., the Rathhaus and the Rauris, has steadily fallen from $1\frac{1}{2}$ ounces in the first half of the seventeenth century to 8 dwts. in the beginning of the nineteenth century. The Rauris mines were especially productive from 1562 to 1579. The distribution of gold in the most recent workings is extremely capricious, and the yield of the whole group is, at the present time, unimportant.[a]

Bosnia.—As isolated historical records indicate, the gold industry of Bosnia was in former times of some considerable value to the Romans.[b] It was practically confined to working the extensive placer deposits, which are both Recent and Pleistocene. Some of the latter are quite 600 feet above the present valley-level, especially on the slopes of the Fojnica valley. In the alluvium of the valleys of the Urbas, Lasva, Fojnica, and Zeleznica, traces of the old workings can still be seen, in the form of huge boulder heaps or prospecting and mining pits. Similar traces of former mining activity are found in the mountains, in the portion of these old alluvials that lies above Fojnica in the Vranitza mountains. Lode-mining was carried on at one spot, namely, in the decomposed pyritous mass of Cervenika, north-west of the town of Fojnica. Further, there are, in the Vranitza mountains, numerous traces of ancient fruitless prospecting in slates and quartz-porphyry.

The origin of the old workings is to some extent known. They date from the fifth century B.C., and were made by the ancient Illyrians, who, from their knowledge gained in this work, became, after the Roman occupation (78 B.C.), the best miners the Romans possessed. Old Roman coins, inscriptions, tombs, and towers have been found in the immediate neighbourhood of the old workings. In the Biela valley the foundations of an old Roman

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[a] Krusch, Zeit. für prakt. Geol., 1897, p. 77.

[b] Rücker, "Einiges über das Gold Vorkommen in Bosnien," Vienna, 1896.

furnace have been exposed. There are also old aqueducts in the neighbourhood of Fojnica. The well-defined workings in the alluvial at Bistrica, Gornj-Vakuv, Kreševo, and Fojnica may date from the Middle Ages. To this period Rücker also ascribes the workings in the pyrites-mass of Cervenika. From the great extension of the ancient mining works Rücker concludes that Bosnia was a country once rich in gold.

Recent tests in the alluvium of the Urbas showed the average tenor in gold to be 10 grains per metric ton ; in the Bistrica it ranges from ·6 grain to 31 grains ; and in the neighbourhood of Lasva from ·6 grain to 23 grains, the whole averaging 4 grains per metric ton. The presence of gold in the sands of the Narenta, Rama, and Neretvica streams has also been determined. The source of the alluvial gold is doubtless in the Lower Triassic rocks (Bunt-sandstein), which, as near Djelilovac, carry tenors of 2½ grains gold per metric ton.

The sandstones are themselves secondary deposits, and the primary deposit appears to be that already mentioned, the Palæozoic pyritous slates of Cervenika. Two quartz-veins near Vilenisa and Heldovi, not far from Travnik, carrying hæmatite and pyrite, gave an average on assay of 14 dwts. and 10 dwts. gold per metric ton respectively. Gold occurrences are also known in the ferruginous beds of Varosluk, south of Lisac, and also in quartz veins west of Cehovac, in the Lasva region.[a]

The gold production of Austria alone (not including Hungary) during 1900 and the years of the present century, has been :—[b]

Year.	Metric Tons Ore.	Value.		Also produced at Metallurgical Works.	
		Kroner.	Sterling.	Kg. Fine Gold.	Value, Sterling.
1900	227	42,831	£1,784	71	£9,691·5
1901	143	31,814	1,325	47	6,415·5
1902	74	21,140	881	7	955·5
1903	2,148	105,779	4,407	8	1,092·0
1904	12,653	293,622	12,234	71	9,691·0
1905	35,937	757,523	31,563	204	27,846·0
1906	33,032	675,850	28,137	126	17,202·8
1907[c]	30,710	....	....	142	19,430·0

[a] Foullon, Jahrb. d.k.k. geol. Reichanst., XLII, 1892, pp. 1–52 ; Katzer, Oesterr. Zeit. für Berg- und Hütt., XLIX, 1901, pp. 277–280.

[b] Statistisches Jahrbuch des k.k. Ackerbau-Ministeriums, Vienna, 1901–1907.

[c] Oesterr. Statist. des Berg., 1907.

HUNGARY.

Three well-defined auriferous districts are known in Hungary. Two of these are of comparatively little importance. The third, in Transylvania, is the chief gold-producing district of Europe. Of the two former, one lies to the north of Buda-Pesth in the neighbourhood of Schemnitz (Selmeczbanya) and Kremnitz (Körmöczbanya), and the other in Eastern Hungary, near the Galician frontier. The Schemnitz and Kremnitz mines are among the oldest in Central Europe, and date probably from the commencement of the Christian Era. They passed into the possession of the Slavs in 745 A.D. The Schemnitz mines in 1690 produced 16,984 ounces of gold, while the production of precious metals from 1740 to 1773 is estimated at at least 70,000,000 gulden. In 1881 the annual production of gold was about 16,000 ounces ; ten years later it had fallen to 14,000 ounces. According to Böckh,[a] the oldest formation in the neighbourhood of Schemnitz is a Triassic slate through which diorites are intrusive as dykes and stocks that have altered the slates to mica-schists and hornstones along their contacts. Interbedded with the slates is a limestone. Nummulitic Eocene shales overlie the Triassic beds. During the Lower and Upper Mediterranean stages widespread volcanic eruptions here, as in Transylvania, furnished tuffs and lavas of an andesitic facies. The sequence of volcanic rocks has apparently been pyroxene-andesite, diorite and quartz-diorite, andesite, and finally rhyolite. Later, in the Pliocene period, basaltic eruptions occurred. The rhyolites are the most widely-developed rocks, and display glassy, perlitic, and pumiceous varieties. In the vicinity of the ore-bodies the volcanic rocks have undergone the usual propylitic (*grünsteinartig*) metamorphosis, are in places highly silicified, and always carry a high percentage of pyrites. The lodes of Schemnitz occur in andesite and rhyolite, and, to lesser extent, in diorite, while to the south-west they pass out of the volcanic rocks into Miocene strata. They are numerous and are characterised by great width. They have no well-defined walls, but often enclose large irregular fragments of country, in which case the ore occurs as the cementing material of the breccia. The usual gangue is quartz, but with it are associated calcite, brownspar, rhodochrosite, siderite, barytes, and gypsum. The sulphides present are galena, blende, chalcopyrite, and auriferous pyrite. These occur disseminated through a jasperoid quartz locally termed *zinopel*, which probably owes its red colour to the presence of iron-oxides. Silver sulphides are also common. Free gold is met with, more particularly in the *zinopel*. The principal

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[a] Földtani Közloni, XXXI, 1901.

lodes are the Grüner and the Spital. The former has been traced for a distance of nearly a mile. It varies in width from 6½ to 39 feet (2 to 12 m.). Its course is north-east and its dip south-east at 70° to 80°. The greater part of the ore-body is made up of rhyolitic breccia, highly impregnated with pyrites and traversed by quartz veinlets containing galena and silver sulphides. The richer ore occurs in shoots that pitch south-west in the vein, and are rarely more than 130 feet in width ; between the pay-shoots the ore is very low in grade. The Spital lode is even larger than the Grüner. It has been traced for 4·8 miles (8 km.), and may have a total length of 7 miles (12 km.). The lode is made up of a complex system of veins and stringers that on union may give a total working width of 16 feet (5 m.). The width of the lode-channel reaches a maximum of 120 feet. The vein-stone is mainly quartz associated with rhodochrosite, calcite, brownspar, and barytes. The ore is auriferous, being argentiferous galena, blende, chalcopyrite, and pyrite, with a little free gold and occasional grains of cinnabar.

At Kremnitz (Körmöczbanya), 18 miles north of Schemnitz, the lodes are similar to those of the latter place, and lie in andesitic (propylitic) and trachytic rocks. Two main lode-groups are known, in each of which the propylite rock is traversed by a complex network or stockwerk of veinlets and stringers. The stockwerks extend for a mile in length and for half a mile in width. The country is impregnated with finely disseminated pyrites, which increases in quantity on approach to the veins and fissures. In addition to the sulphides noted at Schemnitz, stibnite occurs in the ore at Kremnitz. In the Georg-Sigmund group, two defined lodes (Lettengang and Georg-Sigmund) may be made out. At Hodritsch auriferous lodes occur in a diorite highly impregnated with pyrites.

Nagybanya.—In Eastern Hungary, near the Galician frontier, is situated the Nagybanya group of mining districts, including Nagybanya, Felsobanya, Kapnikbanya, Laposbanya, Borpatak, and Olah Laposbanya.[a] Mining in this district dates back for very nearly 1,000 years, the oldest record extant of the Nagybanya mines appearing in 1086 A.D. The veins are in quartz-trachyte and andesite rocks that are intrusive through Tertiary strata. The chief lode in Nagybanya is the Kreuzberg, striking north and south, and dipping west 70° to 80°. It varies in thickness from 2 to 6 feet. It is without well-defined walls. The gangue is quartz, through which auriferous pyrite and chalcopyrite with pyrargyrite and argentiferous fahlore

[a] Skewes, Min. Sci. Press., Jan. 11, 1908, p. 66.

are disseminated. The walls of the veins are often well silicified. Felsobanya lies a few miles east of Nagybanya. Its lodes are in similar rocks. They are irregular in strike and dip, and vary in thickness from 1 to 72 feet, being, in the latter case, rather lode-channels than lodes. The cementing material is quartz containing pyrites, with which are often associated realgar, stibnite, blende, chalcopyrite, and argentite; carbonate and sulphate of lime, barium, and iron are abundant. At Kapnikbanya, still further east, the lodes occur in a conglomerate that lies at the junction of propylite and gray trachyte. The vein-stone and general characteristics of the lodes are similar to those of Felsobanya. Large vughs are found in the Kapnik lodes, and are often drusy with crystallized minerals.

Transylvania.—The auriferous deposits of Transylvania lie in the south-eastern portion of the Bihar mountains. Both geographically and geologically the boundaries of the region are sharply defined; in the north by the valley of the Aranyos, on the east and south by the Maros, and on the north-west by the White (Feher) Körös. On the south-west the geographical and geological boundaries are not distinct. An irregular quadrangle enclosed by lines drawn from Offenbanya to Körösbanya, from Körösbanya to Nagyag, from Nagyag to Zalatna, and from Zalatna to Offenbanya, will enclose nearly all the Transylvanian gold mines.

Of the early history of the gold workings of this region we have but little definite information, but it is certain that before the time of the Emperor Trajan the Romans had already carried on extensive work on the gold veins. Even at the present day the remains of their quarries and levels may be traced without difficulty, and are at times of a magnitude so great as to excite astonishment in the mind of the modern engineer. Numerous legends have grown up and are even now current in the country concerning the discovery or the production of the more famous deposits. It is related, for example, that the rich veins of Nagyag were discovered through the instrumentality of an Armenian who declared that he had seen an *ignis fatuus* hovering over the outcrop of the fissure. After several years of fruitless working on this spot the gold-telluride veins that have rendered the Nagyag field so famous were eventually disclosed.

The fundamental rocks of the region are Archæan. These are probably to be correlated with the mass of the Bihar mountains on the north, and with the rocks of the spurs of the Transylvanian Alps across the Maros on the south. The Archæan rocks are well exposed in the north-east, and in the region near Offenbanya where they occur as gneiss, mica-schist, and limestone. Near Toplicza and Vormaja in the south, minor exposures of Archæan phyllites are found. Overlying the Archæan rocks are widespread Jurassic strata (Klippenkalk or Stramberger Kalk), with which is associated an apparently contemporaneous melaphyre. These rocks are well developed throughout the Erzgebirge. By far the greater part of the surface of the region is formed by Carpathian (Creta-

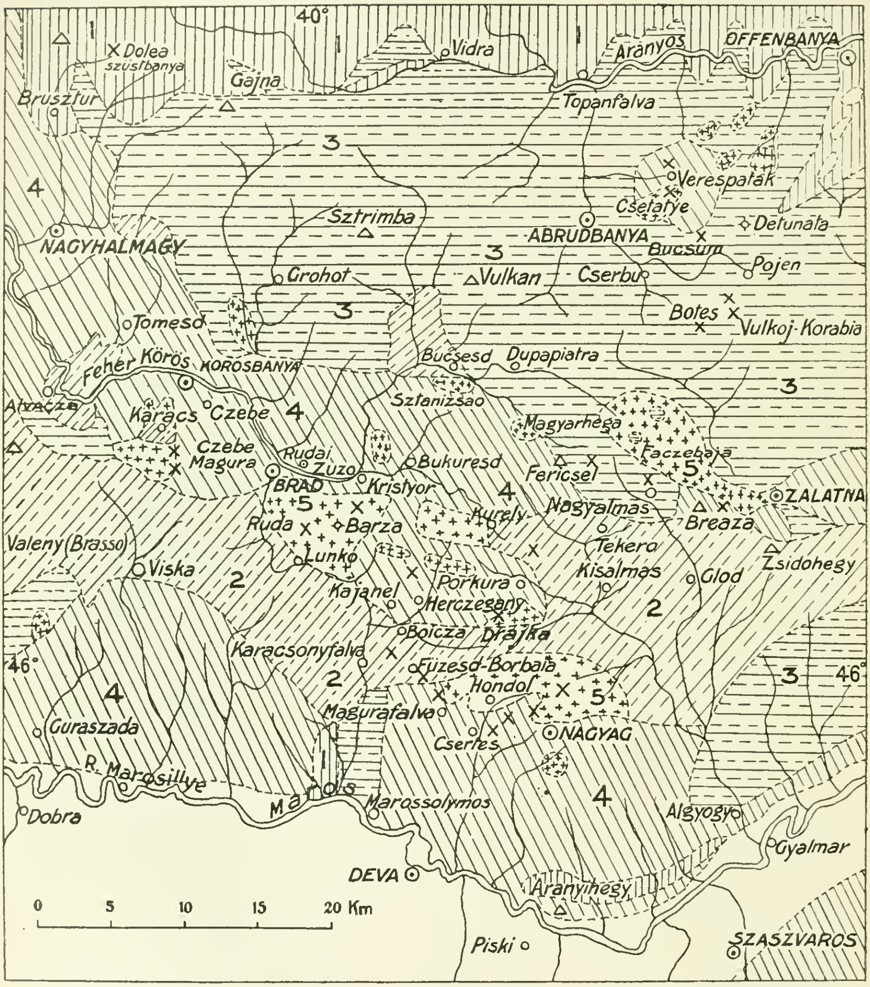

FIG. 76. GENERALIZED SKETCH MAP OF THE GEOLOGY OF THE TRANSYLVANIAN AURIFEROUS REGION.

1. Archæan schist and gneiss. 2. Melaphyre and Jurassic limestone. 3. Carpathian sandstone. 4. Tertiary sediments and tuffs. 5. Tertiary eruptive rocks.

ceous) sandstones. Through all these rocks there were erupted in Tertiary times the andesites, dacites, trachytes, and allied rocks (both as tuffs and as solid flows) that have been so closely connected with the genesis of the auriferous deposits. The general disposition of the foregoing beds is shown on the accompanying geological sketch map (Fig. 76). From it the predominance at the surface of the Cretaceous and Jurassic rocks will be apparent.

In describing the various more or less isolated Transylvanian goldfields those in the north-east will be first taken, followed by those occurring in successive order to the south-west.

Offenbanya.—At Offenbanya, situated on the Aranyos river in the extreme north-east of the auriferous region, the Tertiary eruptives rest on garnet- and staurolite-bearing mica-schists. In former days crystalline limestone adjacent to the igneous rocks carried rich pockets of gold, but these have long been exhausted. The particular country of the gold veins is a propylitised dacite. To the west and south of the propylitised area there occurs a normal unaltered dacite, while on the margin of the quartz-bearing andesites (dacites) are developed the hornblende-andesite of the Coltului Lazar, Piatra Capri, and Cartia Carolu mountains. The productive mines lie entirely beneath the Dialu Ambrului and Dialu Wunet mountains. The oldest and the most extensive workings lie in the Valea Boji, branching off from the interior of the Segengott Level, which commences in the mica-schist, passes through a breccia of mica-schist and dacite fragments, and finally enters the propylitised dacite. Owing to the closing of the older levels the relations of the auriferous deposits to the enclosing country are not now very clear. The mica-schist never carries auriferous veins, and these are found here either in dacite or as stockwerk replacements in crystalline limestone. The veins, however occurring, are always very thin. They have been divided by Semper, according to the vein-filling, as follows :—

(1) In the south (Franzisci) area : Native gold veins.

(2) In the central area : Native gold and gold-telluride veins.

(3) In the south : Telluride veins.

The gold-veins of the first group were not known in the upper levels, and were first met with in the contact-breccia between the mica-schist and the dacite. Their vein-filling is pyritous quartz carrying free gold in wires, plates, and strings. The pyrite of the adjacent country is also more or less auriferous.

The boundary between the gold veins and the gold-telluride veins is a brecciated fissure (the Widersinnige Kluft) that crosses the veins. The gold veins are developed on the foot-wall, the gold-telluride veins on the hanging-wall of the fissure. The matrix of the latter veins is quartz with occasional calcite, containing tetrahedrite, free gold, and telluride ores; as a rule, the gold-telluride ores are not of high tenor. The third, or telluride type of veins, comprises five main lodes, and a network of smaller veinlets. The latter are exceedingly thin, and carry gold tellurides (sylvanite and nagyagite), accompanied by blende, bournonite, tetrahedrite, and pyrargyrite. The matrix is quartz, calcite, and rhodochrosite.

At the contact of the limestone and the dacite, ore-bodies occur in cavities within the limestone. The gangue is here a brecciated rock carrying auriferous pyrite, argentiferous galena, arsenopyrite, &c. In these limestones numerous traces remain of former activity in mining. The general outstanding feature of the gold veins of Offenbanya is the diminution in the tenor of the ore-bodies with increase in depth.

Verespatak.—The village of Verespatak lies about 6 miles north-east of Abrudbanya in the upper Valea Rosia valley, which is bounded on the north-east and on the south-east by ranges of high andesitic mountains, on the south by the greater and lesser Kirnik and the Boj mountains, and finally on the west by mountain ridges of the Carpathian sandstones. The Verespatak complex is composed of several successive Tertiary eruptions that have broken through the Carpathian sandstones and have formed mountain peaks and ranges. The important mines of the region lie in the eruptive rocks of the greater and lesser Kirnik and of the Boj. These rocks are penetrated by the Orlau level, the mouth of which is in the Valea Rosia valley, about $1\frac{1}{4}$ miles west of the auriferous veins. Eastward from the mouth the tunnel passes through 2,328 feet (710 m.) of Carpathian sandstones, then through 5,445 feet (1,660 m.) of the Tertiary conglomerates, termed by Posepny the "Local Sediments," and finally through 1,738 feet (530 m.) of a second band of Carpathian sandstone. From this tunnel the principal mines have been worked. To the north of it the Orlau cross-cut was driven in the Local Sediments until beneath the andesite of the Gypele mountain. To the south, the dacite of Boj was met with; this rock in its eastern portion carried one of the most famous of the stockwerks of Verespatak (the Katroneza). The eruptive rocks, though differing considerably in local characters, are apparently nevertheless all products of differentiation from a single dacite magma. Rhyolites with a pumiceous ground-mass form the cementing material of the breccias of the summit of Boj and also of those found in the east of the Katroneza level. In the Csetatye cross-cut the rhyolite appears as the grey cementing material of a breccia that is largely made up of fragments of Carpathian sandstone, Archæan rock, dacite, and white rhyolite. The Local Sediments filling the real valley basin of Verespatak, and occurring also in the Korna stream to the south of the Kirnik mountains, show distinct stratification. They are composed partly of conglomerate and partly of soft clayey cementing matter enclosing scattered blocks of the older rocks. The sediments are in many places overlain by dacite.

Closely akin to the Lower Tertiary conglomeratic Local Sediments is a peculiar rock locally designated *glamm*. It is a completely unstratified breccia of a grey or grey-black colour, in which a clayey matrix carries angular fragments of Carpathian sandstone, mica-schist, phyllite, and Tertiary eruptive rocks. The cement of the glamm is impregnated with exceedingly finely-divided pyrite. The glamm is especially well pyritised at its contact with dacite. Its passage into the Local Sediments is gradual, whereas its boundary with the dacite is always sharply defined. Its thickness is on an average between 45 and 50 feet, where met with on the boundary between the northern Local Sediments and the dacite. It surrounds the dacite and the rhyolite of the Boj and of the Kirnik mountains as a narrow border in the north and a broad one in the south. Semper,[a] who has devoted a considerable amount of attention to the subject, and from whose description most of the following details are derived, assumes that the glamm has been formed by a sudden upward outwelling of mud that broke off numerous fragments of Archæan, Cretaceous, and Tertiary rocks in its passage through the underlying rocks, and carried them to the surface.

The general relations of the Verespatak strata are expressed by the following upward succession : Carpathian sandstone, true rhyolite, glamm, Local Sediment, younger rhyolite with pumiceous ground-mass, and finally hornblende-andesite.

The gold veins lie indifferently in the dacite of the Boj and Kirnik mountains, in the Local Sediment, and in the Carpathian sandstone. Payable mines occur neither in the hornblende-andesite nor in the glamm. On the whole the most favourable rocks appear to be the highly-weathered and pyritised dacite and older rhyolite. The vein-filling shows occasionally a laminated and banded structure. It is generally quartz with calcite and rhodochrosite, impregnated with auriferous pyrite or with free gold. Quartz with pyrite and black alabandite (Mn S) is not uncommon. Chalcopyrite, fahlore, galena, and tetrahedrite are met with more generally in the silver lodes of the district than in the gold veins. Stockwerks are a characteristic feature of the Verespatak gold deposits. They are formed by the close interlacing of a great number of veins and veinlets. In their neighbourhood the highly propylitised country-rock is silicified and pyritised. As a rule, stockwerks are developed in those eruptive breccias, of which the cement is the above-mentioned porous pumiceous rhyolite impregnated with secondary silica and with auriferous pyrite. The

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[a] "Beiträge zur Kenntniss der Goldlagerstätten des Siebenbürgischen Erzgebirges," Abhand. der Kön. Preuss. geol. Landesanst., XXXIII, 1900, p. 146.

famous "Katroneza Stock" is a brecciated stockwerk forming a chimney in the dacite. Its cementing material was largely quartz and pyrite that carried finely-divided native gold. As in the majority of the Transylvanian ore-deposits, the tenor of the ore steadily decreases in depth. The richer parts appear to be the central portions of the stockwerks. Another well-known ore-body is the "Csetatye-Stock," which is formed of a close network of fissures and veinlets reticulating the dacites, Local Sediments, and Carpathian sandstone of the Boj Hill.

In the Local Sediments the gold veins are, as a rule, small, but regular. The ores are auriferous pyrite and free gold lying in quartz matrix that is occasionally associated with calcite. The number of veins in these beds is relatively much smaller than in the dacite and rhyolite. The workable veins in the Carpathian sandstone are of very little importance. They follow the regular strike and dip of the strata; their filling is quartz, calcite, auriferous pyrite, free gold, and more rarely, galena, blende, marcasite, and chalcopyrite.

As a rule, the walls of the veins, for a distance within the country of at least a foot, are generally worth milling. Stockwerk deposits have occasionally been found in the Carpathian sandstone near its contact with the Local Sediment. Of these the "Letyeer-Stock" has been the richest.

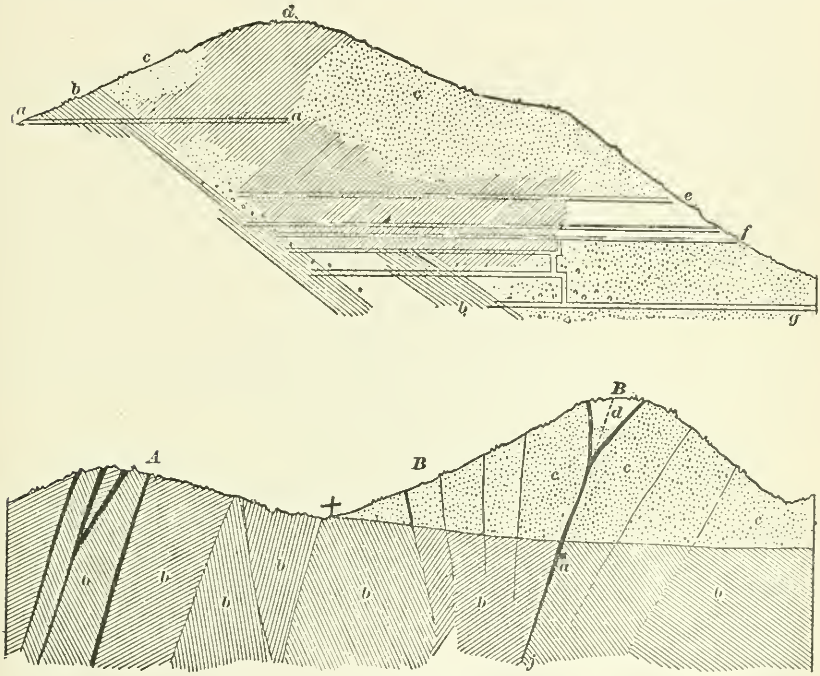
The gold of Verespatak occurs crystallized in vughs, free in the quartz, or associated with pyrite. Its fineness is only about 500. The dacites and rhyolites carry more auriferous sulphide ore and less free gold than the Local Sediment. The richness of the deposits is directly proportional to the degree of silicification of the rock. The general rules applying to the Transylvanian mines, viz., that the richness of a deposit is largely dependent on degree of alteration, on thickness of vein, on intersection of veins, &c., are also applicable to the Verespatak deposits. It is worthy of note that galena is locally considered to indicate poverty of ore. The upper workings yield much more vugh-gold than is found at depth, but the deeper levels nevertheless still furnish rich pockets of crystallized gold.

In the Korna and Bucsum valleys, a few miles south-east of Verespatak, Jurassic limestones and Carpathian sandstones are intruded and covered by Tertiary andesites, dacites, and volcanic breccias. In bygone centuries a flourishing mining industry was conducted in these valleys; in the Bucsum valley at the Concordia mine, rich deposits were found at the intersection of vertical and flat fissures. The gangue of the veins is calcite and the country is a siliceous contact-breccia.[a] In all respects the

[a] Gesell, Jahrsber. der kön. Ungarischen- Geol. Anstalt., 1899, pp. 97–103.

general characters of the mines of these valleys are similar to those of Verespatak and require, therefore, no further mention in this place.

A few miles south of Bucsum there lies a small group of mines in the neighbourhood of Botes, Vulkoj, and Korabia. The peak of Botes (Dialu-Botesiu, 1,362 m.) is connected with the Korabia range by a low saddle composed, as indeed is the mountain itself, of younger Carpathian sandstone. The veins of the area traverse a micaceous sandstone. They are from 4 inches to 3½ feet in thick-



FIGS. 77 AND 78.

Fig. 77. N.-S. section through Vulkoj Mines (*Posepny*). Fig. 78. E.-W. section through Botesiu and Vulkoj.

A. Botesiu ; *B.* Vulkoj ; *b.* Sandstone ; *c.* Andesite ; *a.* Nepomuk adit ; *d.* Korabia open workings ; *j.* Jeruga vein.

ness, and strike approximately at right-angles to the country. Their underlie is very steep (70° to 75° to the west). The vein-stone is quartz associated with pyrite, chalcopyrite, galena and blende, the sulphides occurring either as deposits contemporaneous with the quartz, or as a later deposition. Free gold is not uncommon; enrichments containing it occur at intersections and are generally denoted by a cherty gangue containing hessite.

On the north-east slope of the Korabia mountains, numerous veins are worked. These occur exclusively in the andesite or at its contact with the micaceous clay-slates and Carpathian sandstone. The vein-stone in this case is composed of quartz or calcite, with pyrite and some blende, galena, and free gold. The tenor of the sulphide ore varies from ¼ to ½ ounce (7 to 15 grams.) per ton. Posepny[a] shows that the veins of Vulkoj and Botes have a common origin, and are merely developed in different rocks. The mines of this region were formerly very profitable, but the industry is now on the point of extinction. As a general rule, the veins are impoverished on passing from the igneous rocks to the underlying sedimentaries.

Between Zalathna and Sztanizsa there runs the lofty north-west and south-east range of the Grohasel mountains, trending from about 2 miles south of the village of Sztanizsa to the south of Zalathna, a distance of some 12 miles, with a width over this length of 2 to 6 miles. The basement rock beneath the andesite is the Carpathian sandstone. In the south and south-east it is bounded by the melaphyre range in the neighbourhood of Porkura, and by the older Miocene sediments of the Almas valley. Payable gold and gold-tellurium veins have been worked on the north-west slopes of Fericsel and of Vurfu Ungeri (Sztanizsa); in the valley between Fericsel and Vurfu Negri (Tekerö); on the eastern slopes of the Grohasel mountains (Faczebaj); and also in the neighbourhood of Nagyalmas.

Faczebaj.—At Faezebaj the Grohasel mountains, the main ranges of the central auriferous area, are composed of hornblende-andesite. From their eastern slopes minor spurs composed of Carpathian sandstone are thrown off and are traversed by gold-quartz lodes. The sedimentary strata here strike north and south and dip west. The veins also strike north and south, but their dip is to the east at varying angles. Their thickness varies from less than an inch to less than a foot, and they are much faulted both in hard and soft rocks. The gangue mineral is quartz, which is often chalcedonic. Native gold occurs crystallized in octahedra, and also as moss gold; combined it is found with and in pyrite, native tellurium, tetrahedrite, chalcopyrite, bornite, dyscrasite, bismuthinite, galena, malachite, marcasite, pyrrhotite, realgar, stephanite, and tellurite. The fineness of the free gold is often more than 930. Enrichments are found where silicified country is adjaeent to a quartz vein, and seldom occur in the softer rocks. The average value of the ore extracted averages some 5 dwts. gold per ton.

Veins are also worked in the hornblende-andesite of the Breaza mountains lying to the south-west of Zalathna. These

[a] "Genesis of Ore Deposits," Trans. Amer. Inst. M.E., XXIII, 1894, p. 276.

carry the same minerals as are found in the veins of the Carpathian sandstone of Faczebaj, indicating thus a close genetic relationship with them, and with the veins of the Grohasel mountains.

The veins of Nagyalmas, a short distance to the south of Faczebaj, are of no great present importance. They lie in a breccia at the contact of hornblende-andesite and Carpathian sandstone. Leaves and plates of free gold occur in a quartzose and calcitic matrix. Gold is also found in a state of fine division associated with other ores, and more especially with stibnite, in which case the ore may reach a tenor of 20 ounces gold per ton. The gold is of an average fineness of 650.

The hornblende-andesite of Fericsel and Sztanizsa (Vurfu Ungeri) is decomposed in the immediate neighbourhood of the veins to propylite (*grünsteintrachyte*). Its numerous veins are poor and unprofitable. At Tekerö the slopes of the valley are melaphyre, in which are numerous exploratory workings. The veins along which search for gold has been made lie in highly altered melaphyre rock. They are only 2 inches to 3 inches wide, and carry a pre-

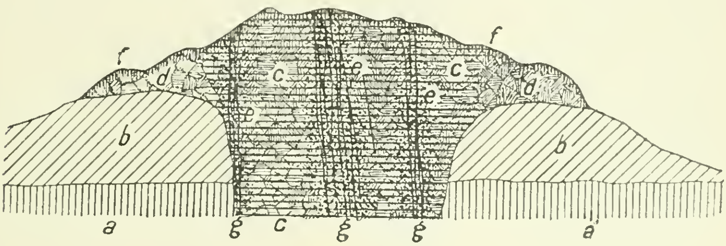


FIG. 79. IDEAL CROSS-SECTION THROUGH THE NAGYAG MOUNTAINS (*V. Inkey*).
a. Phyllite. *b.* Lower Miocene sediments. *c.* Propylitised rock. *d.* Normal dacite. *e.* Kaolinised zones. *f.* Surface weathering. *g.* Vein zones.

dominantly calcitic gangue with occasionally a little quartz and free gold, auriferous pyrite, chalcopyrite, and blende. Crystallized gold of later deposition occurs in vughs in the veins, but the greater part of the gold is associated with pyrite, forming an ore so refractory that the ordinary amalgamation process cannot be employed for the recovery of the gold. Beyond Tekerö numerous veins lie in andesite and furnish small mines.

Nagyag.—The auriferous veins of Nagyag are probably among the best known of those of Transylvania. They lie in the extreme southern corner of the quadrangular auriferous area outlined at the beginning of this section. Nagyag itself lies on the northern slopes of the watershed of the Maros. The bed-rock of these mountains is Archæan clay-slate, on which have been deposited Mesozoic strata, now only locally preserved, and of little importance. In the immediate vicinity of the Nagyag veins Lower Miocene shales, sandstones, and conglomerates form the basement rocks on which are deposited great flows of dacite and hornblende-andesite. The latter rock, which is rich in augite, carries no gold-quartz veins, and the universal country of the ore-bodies is a quartz-bearing dacite, particularly when it has undergone extensive propylitisation, a pathological feature which, indeed, is generally characteristic of the country of the ore-bodies of the Transylvanian auriferous region. The process of propylitisation extends outward from the veins, and appears to arise from the passage of the solfataric waters that have presumably also furnished the vein-filling.

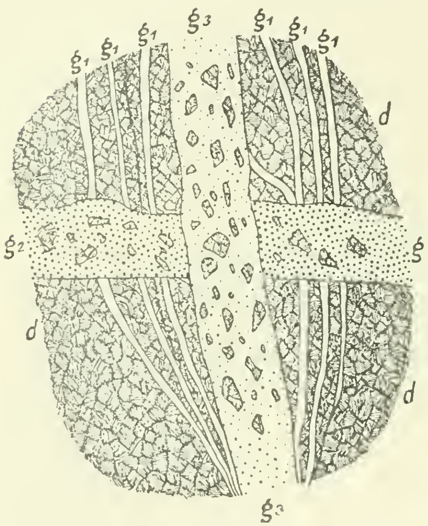


Fig. 80. Glauch Veins, Nagyag (*V. Inkey*). *d*. Dacite. g^1g^1. Oldest Glauch veins. g^2. Second Glauch vein. g^3. Youngest Glauch vein, 6in. thick.

Independently of the fissures induced in various ways at the former surface, there may be distinguished in the dacite of Nagyag three kinds of fissures, viz., *glauch* veins, ore-bearing veins, and barren "pug" (clay) veins. The *glauch* veins are characteristic of Nagyag. Their filling is a soft clayey mass of dark grey colour, in which are usually contained brecciated fragments of dacite, sandstone, and shale, or more rarely, of phyllite and mica-schist. The fragments occur in extremely variable size and quantity. They may be considered to be fault-breccias in which the larger material, as well as the finer, is derived from the crushed country walls of the fissures. Their thickness varies considerably. They may be thin as leaves or may be yards in width. Throughout their mass there is generally disseminated an abundance of finely-divided pyrite, to which, indeed, the dark colour of the glauch is probably due. They traverse not only the dacite, but also the Tertiary sandstones and conglomerates. On the whole, they are developed apparently in close proximity to the ore-bodies, on which they appear to exercise a favourable influence.

The association of tellurium and gold is also characteristic of the Nagyag veins. Nagyagite is the principal telluride, while sylvanite is much less common. Petzite and krennerite are rare. The chief sulphides are pyrite, chalcopyrite, galena, and blende. Native gold is rarely seen, and when visible is of secondary origin and arises from the decomposition of the tellurides.

According to Von Inkey, the following succession of minerals within the vein-fissures may be made out :—

(1) Quartz (earliest, but also occurs in later formations).
(2) Sulphides (alabandite, galena, blende, fahlore, pyrite, chalcopyrite, bournonite).
(3) Tellurides and gold.
(4) Calcite.
(5) Stibnite, arsenic, barytes, gypsum, and realgar.

The veins in the dacite are richest when they are of medium thickness ; they are clearly defined in the propylitised country. Great thicknesses of silica are met with in brecciated zones, and are always associated with the above-mentioned alteration of the dacite. The veins are continued into the sedimentary rocks, but the latter are ordinarily considered in Nagyag to be unfavourable for ore-deposition. On the other hand, rich ore-bodies are found in veins lying along the contact of the dacite and the sedimentary rocks. Experience has shown that at the intersection of veins, deposits of increased richness may be expected to be found. Similar enrichments are met with near the point of departure of stringers, hangers, or droppers from a main vein. It is noted that enrichments are more frequent when the angle of intersection is acute (20° to 40°). The actual vein crossings at Nagyag are themselves generally rather poor, and the rich ore is found at a little distance (a few feet) from the actual intersection. Often the connection between the two frayed or broken ends of a transverse vein is made by numerous small stringers that cross the main vein. The intersection or junction of two veins of unequal thickness, or the contact of a vein with the glauch, are regions of local enrichment. Great help in the search for rich veins is afforded by the stockwerks of minute pyrite-stringers (*kiesschnüre*). Between these pyritous stringers the dacite itself is always strongly impregnated with pyrite. The thickness of the pyrite veinlets is often microscopical,

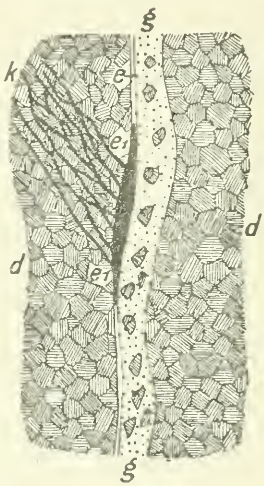


Fig. 81. Enrichment at Junction of Pyritous Veins and "Glauch" Vein, Nagyag (*Semper*).
d. Dacite. *e*. Barren vein (*Longinkluft*). *k*. Pyritous stringers. *g*. Glauch vein. e^1e^1. Enrichment.

but local experience has shown that at the contact with the ore veins, or at their intersection by such pyritous bands, the richest deposits are found. Blende and alabandite (Mn S) are considered unfavourable "indicators," while a large body of quartz often indicates a high value. For Nagyag an absolute diminution in the gold tenor in depth cannot certainly be made out. Special enrichment at any given zone has, on the other hand, not been observed.

The gold-quartz veins of Hondol, lying north-west of Nagyag, traverse propylitised quartz-free hornblende-andesite. The adjacent dacite of the Beszerikucza mountain ridges is, however, quite unaltered, and carries no ore-deposits of value. Many of the mines of Hondol are very ancient; of these the Maria-Regina has been the most productive, whilst the Karoli has for many centuries been famed for its free gold.

To the west and north-west of the above-mentioned dacite the mountain range is composed of hornblende-andesite. Towards its south-western end and more especially at Toplicza and Magura, under the heights of the Fourazberges at Csertes, are numerous remains of ancient gold mines. The western ridge of this andesite *massif* is in contact, to the east of Fuzesd-Barbara, with the melaphyre of the Boicza mountains. On the slopes of Mala, Piczegus, Runk, &c., are a number of unimportant mines, whose veins lie indifferently in the melaphyre and in the hornblende-andesite. They are worked by Wallachian lessees or by small companies. The combined gold-districts of Tresztya, Troicza, and Barbara, lying a little further to the north-west, are of much more importance. The principal workings in the Fuzesd valley radiate from the Grimm tunnel which traverses Miocene strata for 984 feet, and then passes through melaphyre tuff, then through a melaphyre flow, meeting at 1,968 feet (600 metres) from its mouth the first gold vein (Antonien). Further to the east, within the tunnel, the gold-quartz veinlets are close together, and the alteration of the melaphyre is more advanced. The melaphyre is decomposed to form a kaolin-calcite product. Veins are also found in the hornblende-andesite. Along the Grimm tunnel the veins strike north and south, parallel indeed to the contact of the melaphyre and the hornblende-andesite. The width of the veins is rarely more than 4 inches. The gangue is quartz and calcite. Free gold is associated with pyrargyrite, stephanite, fahlore, bournonite, chalcopyrite, pyrite, marcasite, galena, blende, and stibnite. The greater part of the auriferous content is, however, enclosed in pyrite. The tenor of the ore is from 3 to 33 dwts. (5 to 50 grams) gold and silver bullion per metric ton. Silver ores are restricted more particularly to the

Troicza district. The relation between the tenor of the quartz and its country walls resembles much that obtaining at Nagyag. Grey compact quartz is locally considered to be the best host for gold. Galena and blende with white sugary quartz, are, on the other hand, unfavourable "indicators." Junctions of lines of pyritous impregnation are regarded as particularly favourable spots of enrichment here, as at Nagyag. The complete absence of marked relations between the gold tenor of the quartz veins and the enclosing country indicates with sufficient clearness that the vein-filling has been dependent on the younger Tertiary volcanic activity. The high values obtained in the upper zones of the Troicza, Tresztya, and Barbara mines have not persisted into the lower levels.

The Kisalmas-Porkura mines lie on the northern boundary of the Csetras mountains and some 7 miles north of Nagyag. The fundamental rock of the district is melaphyre. The veins lie in melaphyre and also in quartz-porphyry (porphyrite). The stockwerk of the Ludwig mine is situated within a zone of contact-breccia, formed at the junction of a dacite that is intrusive through the melaphyre. The breccia is 50 to 100 feet wide, and has been followed for a length of 200 feet, and for a depth of nearly 500 feet. The highly decomposed breccia fragments are thoroughly impregnated with pyrite and are cemented by calcite, quartz, and auriferous pyrite. The dacite fragments in the breccia carry, however, but little pyrite. It is notable that, in these ore-deposits, free gold is found resting on the predominant octahedral planes of the pyrite. The gold thus obtained has a fineness of 853. The tenor of the ore varies from a few pennyweights to 3 ounces per ton, with an average of perhaps an ounce. The occurrence of amethystine quartz is locally considered to indicate the presence of gold. Semper conjectures that the vein-filling came along the fissures and into the breccia from a hornblende-andesite magma lying at depth.

Boicza.—The Boicza mines, lying midway between Nagyag and Brad, date back to Roman times. They lie on the northern slopes of the Szvregyel mountain, 2,237 feet (682 m.) high, which forms here the highest point of the mountain complex of Jura-Cretaceous melaphyre and of quartz-porphyry rocks. The oldest levels (Katherina and Barbara) lie on the southern slopes of this hill, whilst further north are the Rudolf and Josef levels. The Klein level first traverses highly-weathered melaphyre and then passes into a soft grey kaolinised rock termed "dacit-tuff," which, however, is really a weathered quartz-porphyry that has been intruded through the melaphyre. The latter is much altered, and in the neighbourhood of the ore-fissures often decomposes spheroidally, with a deposit of greyish hornstone or brick-red chalcedony between the spheroids. In contact with the vein the melaphyre is decomposed to a soft calcareous kaolinic mass. Two systems of fissuring are evident. Glauch veins of 33 to 66 feet in thickness occur at Boicza, but differ from those of Nagyag in the greater size of the brecciated fragments and in their greater regularity in strike and dip, and further by the absence of the dark colour due to impregnated pyrite. The ore-bodies follow the course of the glauch veins, especially in the hanging-wall country. Many also lie in the breccia itself. The width of the veins is small, and seldom reaches a foot. The vein matter is similar to that of Troicza and Tresztya. The free gold has a fineness of 600 to 700. Nothing positive may be said concerning the distribution of the richer ore-bodies. Great thickness of vein and extensive alteration of the country are here, as elsewhere in Transylvania, indications of enrichment. Those veins that accompany glauch lodes may generally be distinguished by greater productiveness. Local enrichments occur at the junctions and intersections of veins where these make an acute angle. Higher values are found also on the hanging-wall when the breccia there contains no melaphyre fragments. Further, a quartzose gangue, especially when in the form of amethystine or brick-red chalcedonic concretions in a weathered melaphyre, generally indicates high values. With increase in depth, the gold tenor is gradually diminished, a feature due, probably, to the removal of base matter and gangue in the upper levels. In 1895, 9,452 ounces (294 kg.) gold and 5,359 ounces (166·7 kg.) silver were produced from these mines. The fineness of the gold was 668.

The most important mines of Transylvania at the present day lie in the Western Csetras mountains, which are formed of dacite hills, the product, not of a single-fissure eruption as in the Eastern Csetras, but of a succession of eruptions. The region is characterised by great abundance of hypersthene-amphibole-andesite together with apparently younger eruptive rocks. Jurassic melaphyre is associated with the Klippenkalk (cliff-limestone), and further with a quartz-porphyry a little to the south of Brad. It, however, carries no workable deposits. The Tertiary eruptive rocks overlie the Carpathian sandstone (Cretaceous) in the north, while in the south and west they cover Lower Miocene shales, sandstone and conglomerate.

In the eastern spurs of these mountains lie the few rich occurrences of Felso-Kajanel. Here the dacites have broken through the Miocene sediments which form the basement rock of the Kajanel mountains. The dacites and dacite-tuffs are developed in the mountains of Gorona and Manesiu. They are in their turn intruded by hornblende-andesite. The auriferous veins lie in the dacite and dacite-tuffs. They also pass into the hornblende-andesite, but there soon thin out into barren stringers. The two most important veins are the "Gold" and "Silver" veins. Three generations of quartz have been made out. The oldest formed quartz of the Kajanel mines carries free gold, pyrite, marcasite, chalcopyrite, and silver sulphides. A younger quartz carries galena, blende, pyrite, chalcopyrite, brownspar, and calcite; a still younger, brownspar, barytes, and gypsum, with gold, silver, fahlore, chalcopyrite, &c. Propylitisation of the dacite is a characteristic feature, and is attended by considerable richness in adjacent veins. The *kies-schnüre* (pyritous impregnations) above-mentioned, also indicate an enrichment that may take place in well-defined shoots. Despite several such rich shoots the mines have, on the whole, not been profitable.

Ruda.—In the western end of the Csetras mountains, between the hills of Gyalu Fetye, 2,300 feet (701 m.), and of Hrenyak, 2,460 feet (750 m.), are the Muszari mines. The basement rock is melaphyre. Hypersthene-bearing dacite and hornblende-andesite are traversed by various levels of the mines, thus affording considerable scope for observation of propylitic changes. In the east of the field the veins strike from north to north-west, but in the southern portion they intersect so irregularly that they appear almost to radiate from a centre. The thickness of the veins is generally less than 4 inches. The gangue minerals resemble those found elsewhere in Transylvania, free gold being found with pyrite and showing often fine distorted crystallized plates and leaves, with masses of crystal aggregates. The more characteristic associates of the gold are crystallized black blende, galena, marcasite, and grey or green chalcedonic quartz. In age the grey chalcedonic quartz appears to be the oldest. After it were deposited pyrite, free gold, galena, and blende, then chalcopyrite, and marcasite, and finally a second deposition of free gold. Calcite and dolomite are sometimes younger and sometimes older than free gold. The veins in the andesite are, as a rule, calcitic, and those in the dacite, quartzose. Local enrichments are always expected at junctions or intersections; indeed, the mines of Muszari largely owe their productiveness to the great number of such gold-bearing junctions. In the year 1891 a central point was reached to which all the veins in the vicinity appeared to be converging. Ore from this rich central deposit yielded gold to the amount of 30 to even 100 ounces per metric ton. There is thus in this feature considerable analogy with the far richer deposits in similar rocks of the Thames goldfield in the North Island of New Zealand, where similar intersections ("Shotover" and "Caledonian") yielded bonanzas of many hundred thousands of ounces gold. At Muszari the galena itself is auriferous in bulk. Other indications of the proximity of bonanzas are: extensive alteration of the country; a medium thickness of vein; and contact with the so-called *kiesschnüre.* The workings have reached a depth of more than 750 feet without perceptible impoverishment in the tenor of the ore.

The mining districts of the Barza region, to the east of Hrenyak, lie in the valleys of Ruda, Barza, Valea Mori, and Valea Arszului, and together with Muszari, are combined to form the property of the Harkort Gold Mining Company, better known as the Twelve Apostles Mine, in 1908 the richest and most productive gold mine in Europe.

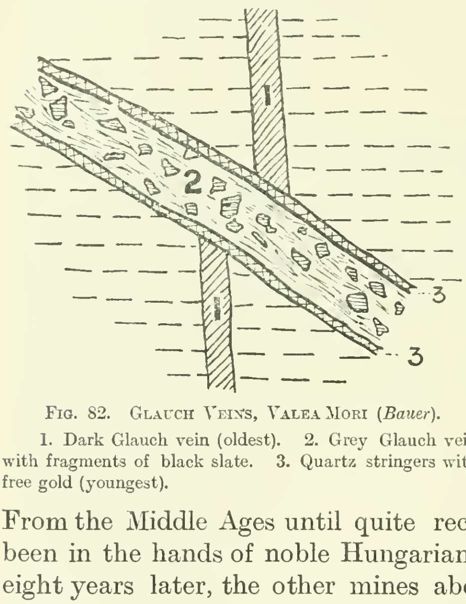


Fig. 82. Glauch Veins, Valea Mori (*Bauer*).
1. Dark Glauch vein (oldest). 2. Grey Glauch vein with fragments of black slate. 3. Quartz stringers with free gold (youngest).

These mines were undoubtedly worked by the Romans, and numerous traces of their extensive operations are still extant in the form of levels and shafts, implements, and machinery. Indeed, Roman activity was widespread over the whole of the Transylvanian Erzgebirge, and few valleys are without traces of their mining works. From the Middle Ages until quite recently the Ruda mines have been in the hands of noble Hungarian families. In 1884, they, and eight years later, the other mines above-mentioned, came into the possession of the present company (Harkortsche Bergwerk, &c.).

The general geological formations represented in the neighbourhood of the Twelve Apostles Mines may, for comparison with other Transylvanian occurrences, be briefly summarised in the table below:—

Age.	Eruptive Rocks.	Sedimentary Rocks.
Trias-Jura	Melaphyre	Klippenkalk.
Cretaceous	Porphyrite	Carpathian Sandstone.
Miocene	Andesite...	Mediterranean Beds.
Recent	... ...	Diluvium.
... ...	... ...	Alluvium.

The oldest rocks are the melaphyre-tuffs and lavas of the Lower Trias. These are largely developed in the lower Ruda Valley. They were depressed below the level of the sea at the close of the Trias, permitting the deposition of the coral reefs of the Klippenkalk of the Jurassic period. This formation is not widespread in the immediate neighbourhood of the mines, but it has a considerable development along the main water parting between the Maros and the White Körös. Then followed an eruption of

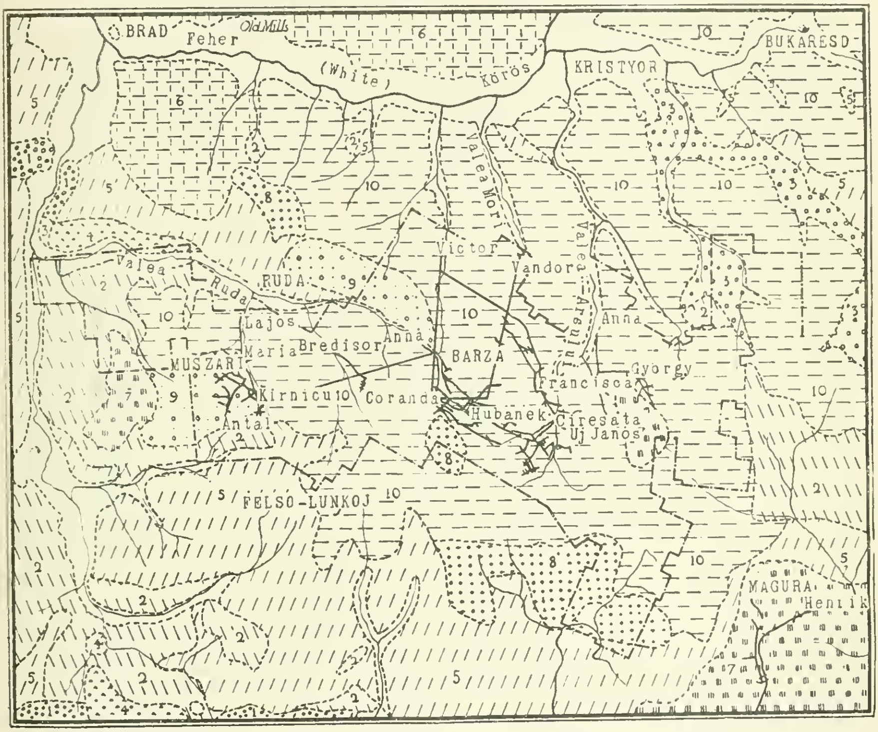


FIG. 83. GEOLOGICAL SKETCH MAP OF THE "TWELVE APOSTLES" MINE, RUDA, TRANSYLVANIA (*Primics*).

1. Jurassic limestone. 2. Melaphyre. 3. Carpathian Sandstone. 4. Quartz-porphyry. 5. Mediterranean (Miocene) Beds. 6. Andesitic tuffs. 7. Dacite. 8. Amphibole-andesite. 9. Garnet-andesite. 10. Hypersthene-hornblende-andesite.

porphyrite (quartz-porphyry) succeeded by the deposition in Cretaceous times of the Carpathian sandstone. Thereafter a great gap in time intervenes until the deposition of the Mediterranean Beds (Miocene). The lower beds of this stage are made up of red greyish clays, with and without pebble beds; the middle beds are conglomerate, grit, and sandstone, and contain at times workable coal seams. Somewhat remarkable black shales occur in these beds in the Valea Mori, and are believed by Semper to represent mud eruptions ;

Von Palfy, on the other hand, considers them to be of entirely normal sedimentary origin.

The beds of the Mediterranean stage were intruded and covered by great andesitic eruptions that produced tuffs, breccias, and lavas. The last, when broadly considered, show four fairly distinct types :—

(1) Pyroxene-amphibole-andesite.
(2) Amphibole-andesite.
(3) Dacite (quartz-bearing biotite-amphibole-andesite).
(4) Garnetiferous dacite.

According to Von Palfy, the above is also the order of the eruption. The rocks are largely altered or propylitised (*in grünsteinartige modifikation umgewandelte*). A number of old levels on the slopes of Barza and Koranda mountains are in propylitised hornblende-andesite, with which also are associated the productive veins in the deeper workings.

The mines of Ruda and Barza are working a double system of veins, the members of which have an average thickness of 15 inches to 3 feet. The more important are the Magdana, Kornya, Michaeli, and Josephi veins. A third system lies further west than the foregoing. The minerals occurring in the Valea Mori, Ruda, and Barza Mines are essentially the same as those of Muszari already described. In the Valea Mori the country of the Francisca vein is the above-mentioned black shale of the Mediterranean stage. It has been concluded by B. Von Inkey that the vein fissures of this region are a direct result of contraction due to the cooling of the eruptive rocks. With this view, most authorities who have visited the field express themselves in complete accord.

About one half the gold yield of the Twelve Apostles Mines comes from free gold of an average fineness of 700. In the vein-filling the oldest deposited member appears to be solid calcite or quartz, the latter being often chalcedonic. Of contemporaneous age are probably the associated gold, pyrite, chalcopyrite, galena, and blende. The rhodochrosite of the Valea Mori veins comes next in age. The walls of the drusy cavities between the older minerals are covered with crystals of quartz and calcite on which the later generation of gold, pyrite, chalcopyrite, galena, and blende is deposited. The youngest vein-deposits are siderite, barytes, and gypsum. The chalcopyrite that accompanies the gold pockets is itself often very highly auriferous. As a rule, the thin veins in the rocks of the crater walls of the ancient Valea Mori volcano are richer than the larger and better-defined veins that traverse the andesite of Barza and Ruda. The ores of Valea Mori carry from 2 to 3½ ounces (60 to 105 grams) gold, of which 16 dwts. to 2 ounces (25 to 63 grams) are free gold ; those from Ruda only carry from 13 to 21 dwts. (20 to 33 grams), of which all except 5 to 7½ dwts. (8 to 12 grams) is free milling. Considering the veins broadly no depreciation in value can be made out with increase in depth; on the contrary, the gold production tends to rise from year to year. The level of the richest zone is about 1,150 to 1,230 feet (350 to 375 metres) above sea-level. The following table shows the product of these mines from 1885 to 1904, a period of 20 years.[a]

Year.	Metric Tons Crushed.	Kg. Crude Gold.	Gram Gold per Ton.	Costs per Ton in Kroner.*
1885	5,855	60·164	10·27	34·45
1886	6,362	58·929	9·27	49·56
1887	13,360	114·384	8·56	23·30
1888	17,898	209·019	11·67	17·64
1889	28,659	467·035	16·06	19·94
1890	44,403	687·630	15·49	17·90
1891	57,751	770·490	13·34	18·21
1892	54,373	654·326	12·04	18·71
1893	53,686	619·725	11·53	18·14
1894	56,719	530·758	9·35	17·12
1895	53,236	549·571	10·32	17·64
1896	57,824	660·567	11·41	16·44
1897	71,807	833·343	11·59	14·77
1898	68,193	786·582	11·51	15·17
1899	94,900	877·143	9·24	12·89
1900	118,424	1138·255	9·61	11·03
1901	134,114	1198·019	8·41	10·82
1902	151,484	1167·033	7·70	10·38
1903	157,803	1219·034	7·72	9·85
1904	163,358	1412·464	8·64	10·05

* An Austrian crown is worth 10d.

The total amount of crude gold produced to the end of 1904 was therefore 450,243 ounces (14,004·471 kg.) derived from 1,410,209 tons ore, or an average return of 6·3 dwts. (9·9 grams) per metric ton. The fineness of the bullion varies from 600 to 700. The total value of the output of these mines in the stated time is somewhat less than one and a quarter millions sterling.

Karacs-Czebe.—The Karacs-Czebe district, a few miles south of Körösbanya on the white Körös River, contains the most westerly mines of the Transylvanian auriferous region. The oldest rock of the area is melaphyre or augite-porphyry, which occurs both as flows and as tuffs distinguishable from each other only with the greatest difficulty. These are overlain, as in the Barza region, first by the Jura-Triassic Klippenkalk, then by the Cretaceous Carpathian sandstone, and again by Miocene reddish clays and conglomerates on

[a] Bauer, Berg- und Hütt. Jahrs. der k.k. montan. Hochsch. zu Leoben und Pribram, LIII, 1905, p. 85.

which workable seams of brown coal lie. On these sedimentary rocks andesite lava streams were poured forth during the Mediterranean and Sarmatian (Miocene) stages, and were propylitised by subsequent solfataric action, during which operation ore-deposition took place. The minerals of the Karacs-Czebe mines are native gold (750 to 795 fine), sylvanite, nagyagite, pyrite, galena, blende, rhodochrosite, alabandite, and pyrolusite, all in a gangue of quartz and calcite. The tellurides are especially characteristic of the Czebe stock. The Peter-Paul lodes of Karacs have a tenor of about 9 dwts. gold per ton, and the Peter-Paul stock of Czebe from 6 dwts. to 18 dwts. per ton. The general result of the actual working of these deposits for a year and a half showed an average recovery of 5 dwts. (8 grams) per ton, which is very probably a closer approximation to their true value than numerous high assays that have been published from time to time. Von Papp[a] estimates that in the 2,000 years of working at Karacs-Czebe at least 7,500 kg. (241,125 ounces) gold has been extracted from the veins and a further 5,000 kg. (167,500 ounces) from the placer deposits of the streams that run from the veins towards the White Körös at Körösbanya. These last are worked even at the present day, and rough trials made by Von Papp showed tenors over limited areas of from $1\frac{1}{4}$ to $1\frac{1}{2}$ dwts. (2 to 2·5 grams) per metric ton.[b]

Placer Deposits.—The auriferous placer deposits of Austria-Hungary have been described in detail by Grimm.[c] They have been found more particularly on the Aranyos (golden river) in Transylvania, from its source in the Bihar mountains to its junction with the Maros. The Aranyos lies on the northern boundary of Transylvanian auriferous region, whence its gold has certainly been derived. The Warme Czamos flowing to the north-east from the Bihar mountains also carries appreciable quantities of gold, as, indeed, do most of the streams cutting through the auriferous area (e.g., the Feher (white) Körös at Czebe, and the Maros at Magyar-Csesztye). Further south, across the Maros, the streams flowing from the Pojana Ruska and from the Golubinje mountains,

[a] Von Papp, Zeit. für prakt. Geol., XIV, 1906, p. 305.

[b] The literature of the Transylvanian ore-deposits is extensive. The following list perhaps comprises the more important papers: Richthofen, Jahrb. der k.k. geol. Reich. zu Wien, 1860, pp. 153–277; Von Cotta and Von Fellenberg, "Ueber Erzlagerstätten Ungarns und Siebenbürgens," Gangstudien, IV, pp. 65, 156; Von Hauer und Stache, "Geologie Siebenbürgens," Vienna, 1863; Posepny, Jahrb. der k.k. geol. Reich., 1868, I, p. 53; Id., loc. cit., 1868, II, p. 7; Doelter, loc. cit., 1874, I, p. 7; Id., Tschermak's Mittheil, 1874, p. 13; Id., loc. cit., 1880, p. 1; Thilo, Berg- und Hütten Zeitung, 1889, pp. 125, 133; Weisz, Jahrb. der kgl. ungar. geol. Landesanst., IX, Pt. 6, p. 105; Semper, "Beiträge zur kenntniss der Goldlagerstätten des Siebenbürgischen Erzgebirges." Abhand. kon. Preuss. geol. Land., XXXIII, 1900, Berlin, p. 219; Bauer, Berg- und Hütt. Jahrb der k.k. montan. Hochsch. zu Leoben und Przibram, LIII, 1905, p. 85.

[c] Oesterr. Zeit. für Bergwesen, II, 1854, pp. 91, *et. seq.*; see also Horvath, Montan Zeitung, 1907, translated Min. Jour., Sep. 7, 1907.

and indeed those of the Banat mountains generally, all carry a little gold. Small dredges have been operated during 1907 on the Aranyos, but, being of faulty construction and design, have not proved satisfactory.[a]

Old gold washings are known in the valley of the Bistritza in Bukowina in Eastern Hungary. These lie between Jakobeni and Watro-Derna. The Moldava in Bukowina also carries traces of gold, derived, as in the case of the former river, from andesitic auriferous occurrences similar to those of Nagybanya. According to Von Gernet[b] two hundred men earn from 2s. to 3s. per day per man by working the surface gravels of the beaches of the Drave (Drau), especially between Lakany and Visvar.[c]

The gold production of Hungary has increased largely during the last three decades as is shown by the yield of the four selected years below :—[d]

	Kroner.	Sterling.
1867	4,935,760	£205,656
1882	4,796,746	199,864
1892	6,268,874	261,203
1902	11,150,296	464,595

Of the foregoing yield of 1902 about 30 per cent. was produced by the Twelve Apostles mines.

The recent available gold returns of Hungary are as follows :—

Year.	Washed Gravel and Veinstone.			Also produced at Metallurgical Works. Vein Gold.	
	Metric Tons.	Value.		Fine Gold. Kg.	Value. Sterling.
		Kroner.	Sterling.		
1900	6,246	713,800	£29,742	3,267	£445,945
1901	6,859	973,600	40,566	3,293	449,494
1902	5,655	892,600	36,358	3,400	464,100
1903	5,483	955,600	39,816	3,376	460,824
1904	5,622	912,800	38,033	3,669	500,818
1905	6,457	1,002,000	41,715	3,665	500,272
1906	6,597	1,006,006	41,882	3,738	510,349

[a] Horvath, loc. cit. sup.

[b] Adv. Sheets Inst. Min. Met., 1908.

[c] See also St. Rainer, "Die Gold-baggerei in Europa," Oesterr. Zeit. für Berg- und Hütt., Ap. 27, 1907.

[d] Bauer, loc. cit. sup.

GERMANY.

The Rhine.—Gold washing, especially along the banks of the Rhine, has been practised in Germany from the earliest times. Gold-quartz veins have also been worked during many centuries. The gold washings along the Rhine between Basle and Mayence were, as early as 667 A.D., the subject of a grant by the ruler of Alsace to a monastery. The industry is now, however, conducted on a very small scale, and the former working of gold is, indeed, in many places quite forgotten. At Waldshut, above Basle, gold is known to occur in minute quantities, but the principal deposits of the Rhine lie along the stretch of 160 miles between Basle and Mayence. Descending the stream, deposits are even now from time to time washed at Istein, Kleinkems, Rheinweiler, and Niffer. Richer gravels, but of extremely irregular tenor, occur at Nambsheim, Geiswasser, and Altbreisach; the majority of the workings are, however, still further down the river, below Rheinau, on the Alsace side, and Wittenweyer, about 65 miles below Basle. The best reach is from above Kehl (opposite Strasburg) to Dachslander, near Karlsruhe, and more particularly that portion of it at Helmlingen, some 14 miles below Kehl. From Speyer to Mayence—the remainder of the auriferous reach—the deposits are unimportant. On the whole, the deposits of the right bank (Baden) are richer than those of the left (Alsace).

The gold occurs as tiny flakes in the coarser gravel, being distributed through it in association with the larger pebbles, that make up 40 to 50 per cent. of the auriferous sands. The auriferous stratum lies mostly on the surface of the beaches, and is seldom more than 6 to 10 inches deep, sometimes, however, being covered by a layer of fine sand. The tenor of the gravel is 1·7 to 12 grains per cubic yard (·0146 to 1·011 gram. per cubic metre). The lowest tenor nowadays considered profitable is at least 2·75 grains per cubic yard. This tenor is not now found in the present bed of the Rhine, but in the gravels of the valley, some 6 to 8 miles distant from the stream; also a like tenor may be obtained in the gravels of the Ill, near Geispolsheim, that are covered by fine sand of no value. According to Daubrée, the quartz-pebbles of the Rhine occasionally carry gold, one such found in the Ill near Strasburg, being thickly impregnated.

The gold of the Rhine is 934 fine, with 66 silver. Platinum to the extent of ·069 per cent. has also been found. The heavy sands contain 10 to 14 per cent. titanite, with rose quartz and a little zircon. Of the Alsace yield there is no definite information, but records were kept of the production of the Grand-Duchy of Baden until 1874, when the yield became too trifling to record. From

1748 to 1799 about 1,850 ounces (57·6 kilos) and from 1800 to 1874, 9,810 ounces (305·61 kilos) were recovered. Von Cotta states that 400 washers were at work in Baden in 1859. In the Pfalz Palatinate from 1825 to 1862 some 1,573 ounces (49 kilos) were obtained.[a] The Rhine washings are now completely abandoned, except for a little occasional amateur washing. It is said that, towards the close of the eighteenth century, the lower Rhine in the neighbourhood of Wesel (Dusseldorf) produced gold.[b]

Small grains of gold are met with from the Lower Devonian of Goldbach, west of Bernkastel in the bed of the Andel, which falls from the south into the Moselle (Trier or Treves district). These are especially numerous after floods, and possibly point to the occurrence in the immediate neighbourhood of gold-quartz veins, similar to those found across the French frontier in the Ardennes. In the Aachen district also, east and south of Malmedy, near Buttgenbach, at Montenau, Born, and Recht, and from Ligneuville as far as Stavelot (Belgium), are old gold-washers' pits. They follow a bed of quartzite and conglomerate, which lies for about 35 miles along the contact of the Lower Devonian and Cambrian, and which appears to be the matrix of the gold. Prospecting along this line has, however, met with no success.[c]

Other Rivers.—Gold in valley alluvials occurs along the Westphalian mountains in the Brilon circle, Arnsberg district; in the Diemel from Westheim above Stradtberge to its junction with the Rehne; and in the Hoppeke from its junction with the Diemel to the boundary of the principality of Waldeck; in the Orke at Ronningshausen; and in the Aar below Titmaringhausen. Old mine workings in this region carry pyrites, and in the adjacent principality of Waldeck, at Goldhausen in the Eisenberg, a gold-bearing copper pyrite deposit occurs in sandy slates and limestones. These deposits in the fifteenth, and more particularly about the middle of the sixteenth century, yielded gold. In the eighteenth century explorations were made, and were from time to time continued, always unsuccessfully, as between 1850-1860, into the nineteenth century. The sands of the Eder are auriferous from Frankenberg (Cassel) through Waldeck and the Fritzlar district, to its junction with the Fulda at Guntershausen, and although extended trials have failed, yet gold in small quantities has been washed in recent times in the neighbourhood of Fritzlar, Altenberg, and Felsberg.

[a] Neumann, "Die Goldwascherei am Rhein," Zeit. Berg. Hütt. und Sal. Wesen, LI, 1903, pp. 377–420.

[b] Bruhns, "Nutzbaren Mineralien im deutschen Reiche," Berlin, 1906, p. 559.

[c] Berg- und Hütten Zeitung, 1899, p. 265.

Thuringer Wald.—Important gold mines were worked in ancient times at Goldisthal, Reichmannsdorf, and Steinheide, north of Coburg in the south-eastern portion of the Thuringer Wald. They were flourishing in 1209, were abandoned by 1430, and re-opened in 1533. The Güte-Gottes mine at Petersburg from 1576 to 1580 yielded about 75lbs. fine gold. Abandoned in 1635 on account of the Thirty Years' War, it was re-opened by Duke Albrecht in 1692. In 1700 there were gold washings on the Werra and the Ilz near Schwarzen-brunn and Schalkau (Meiningen), but these have long been abandoned. The gold-quartz veins formerly worked lay in the Cambrian quartzites and carried pyrite, mispickel, and hæmatite. The gold occurs as grains and flakes. The neighbouring Schwarza from its source to its mouth yielded alluvial gold. In 1530 there were no less than 20 gold washings in the principality of Schwarzburg-Rudolstadt, and trials made in 1859 proved the continued existence of gold. In Schwarzburg gold has been washed in modern times. At Reichmannsdorf gold-quartz veins occur in the Cambrian. Below Glasbach veins in granite yield gold associated with hæmatite and titanite. There is alluvial gold in the Lauscha, Göritz, Goldbach, and Rogitz, and at Steinheide and Selsendorf, and in the neighbourhood; also in the Grand Duchy of Sachsen-Weimar at Weida and Kreuzberg, and at Jena on the Saal. There is still preserved in the church of Jena a nugget of gold, which was found in the neighbouring washings in 1587.

Harz.—In the Harz mountains gold occurs in the pyritous ores of the Rammelsberg to the extent of 7½ to 15 grains per metric ton. In 1894 the Rammelsberg smelting works thus produced 2,450 ounces (76·3 kg.) gold worth £10,682. Native gold has also been observed at Tilkerode in plates, leaves, and small crystals associated with clausthalite, Pb Se, and lehrbachite, $(Pb\,Hg_2)\,Se$, in a gangue of calcite.[a]

Bavaria.—In the Fichtelgebirge gold occurs in several localities, either in veins or in gravels. The Goldkronach mine, according to Agricola, yielded weekly a profit of 1,500 Rhenish gulden. Mining at Goldkronach dates back at least to the fourteenth century. After a long abandonment, operations were actively resumed in 1800 under the direction of the famous traveller, Von Humboldt, but ceased again in 1861. The veins occur mainly in light green Cambrian slates. The gangue is quartz, spathic iron, and calcite, with occasional barytes. The minerals in the matrix are antimonite, auriferous and argentiferous pyrite, and mispickel with occasional galena, blende, and free gold.[b]

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[a] Pogg. Ann., III, 1825, p. 297.

[b] Schmidt, Zeit. für Berg.-Hütt-u. Sal. Wesen, LV, 1907, Abh. p. 449.

These veins yield the alluvial deposits that lie in the Zoppatenbach. Auriferous pyrite has been worked at Goldberg, near Reichmannsdorf.

In the eastern Bavarian mountains (Bohmer Wald) at Neualbenreuth, and at Bodenmais, are gold occurrences. In Upper Bavaria, the Iser, Inn, Ammer, Salzach, Alz, and Donau rivers, all carry gold.

Saxony.—Many localities are known on the northern flanks of the Erzgebirge in which gold was formerly washed. The principal auriferous stream is the Göltzsch, particularly at Falkenstein, Ellefeld, Mühlgrun, Auerbach, Rodewisch, &c. The oldest washing appears to have been that of Mylau (1564 A.D.). The rocks of Johanngeorgenstadt and Eibenstock on the Bohemian frontier contain auriferous galena veins. Numerous Saxon streams (Striegis, Schwarzwasser, &c.) carry gold, but all in exceedingly small quantities.

Silesia.—Of much greater importance are those Silesian alluvial occurrences that were most profitably worked during the twelfth and thirteenth centuries ; they lie especially on the northern side of the Reisengebirge in the districts of Liegnitz, Goldberg-Haynau, and Löwenberg. These ancient workings were extensive, and spread not only over the valley gravels, but also into the older post-Pliocene terraces. The principal workings appear to have been at Plagwitz, Petersdorf, Löwenberg, Goldberg, Wahlstatt, Strachwitz, and Liegnitz.

Gold occurs at the Reicher Trost mines, Reichenstein, in arsenical sulphides (löllingite, $Fe\ As_2$, and leucopyrite, $Fe_2\ As_3$) together with auriferous galena, blende, chalcopyrite, and pyrite. These ancient mines were re-opened for arsenic at the beginning of the nineteenth century, but their gold content was neglected until 1895, when the employment of the chlorination process permitted of its extraction. The ore-deposits lie in dolomitic rocks closely associated with mica-schists. The deposit is 30 to 130 feet thick, and is 1,300 yards along the strike. In 1903, 3,530 metric tons of ore were raised from the Reicher Trost mine, worth about £14,120 (282,400 m.). From 1895 to 1906 about 1,446 ounces (45 kg.) 995 fine have been obtained. A small part of the gold appears to be amalgamable, but the greater part is not free. The general tenor of the arsenical ore varies from 2½ dwts. to 21 dwts. per ton.[a]

Gold also occurs in the mispickel ores of Rotenzechau, near Schmiedeberg (Hirschberg). These lie in a talc-schist band in

[a] Weinecke, Zeit. für prakt. Geol., Sep., 1907, XV, p. 274 ; Sachs, "Die Bodenschätze Schlesiens," Leipzig, 1906.

mica-schists near a granite contact. The gold tenor is 3 dwts. per metric ton (·00048 per cent.).[a] Near Kauffung (Altenberg) in the Katzbach mountains, auriferous pyrites occurs impregnating an olivine-kersantite intrusion.[b] Neither of the two last occurrences are now being worked. Ancient alluvial gravels have also been washed near Löwenberg. Their gold content is believed to be derived from quartz lenses in a pyritous graphitic schist.[c]

The following table shows the available returns of the production of gold and silver within the German Empire. Separate returns for gold are not available. The probable percentage of gold value in the following returns is from 10 to 15, the annual gold yield of the Empire being apparently about 100 kg. (3,215 ounces).[d]

	Metric Tons.	Value. Marks.	Value. Sterling.
1900	12,593	2,059,000	£102,950
1901	11,577	1,551,000	77,550
1902	11,724	1,389,000	69,450
1903	11,467	1,245,000	62,250
1904	10,405	1,206,000	60,300
1905	10,286	1,194,000	59,700
1906	8,066	1,206,000	60,300

From the Kingdom of Prussia during the same period gold and silver to the following values were obtained :—[e]

	Tons.	Value. Marks.	Value. Sterling.
1900	1	30,664	£1,503
1901	6	39,579	1,940
1902	18	183,441	8,992
1903	13	80,624	3,952
1904	8	71,425	3,501
1905	4	10,828	530
1906	239	49,480	2,474

[a] Kosmann, Berg- und Hütten Zeitung, 1891, p. 329.

[b] Bruhns, loc. cit. sup., p. 581.

[c] Rosenberg-Lipinsky, Zeit. für prakt. Geol., 1897, p. 156.

[d] Vierteljahrshefte zur Statistik des deutschen Reichs, Heft IV, 1901–1907, Berlin.

[e] Zeit. Berg. Hütt. Sal. Wesen, XLIX-LIV, 1901-1907.

NORWAY.

The first recorded discovery of gold in Norway took place during the reign of Christian IV. (1588-1642) in the rich silver veins of Kongsberg, where State silver mines are being worked to the present day.[a] In 1705 gold was found in copper-ore at the Aardal mines on the Sogne Fjord. In 1788 several thousand grammes gold were extracted from the veins of the Eidsvold mines, 45 miles north of Christiania. Numerous pyritous veins in Norway contain small quantities of gold, as also do the galena and blende mines in Hatlefjelddalen. The silver from the Svenningdalen mines often contains one per cent. gold.

The only important auriferous occurrences in Norway are those of Bömmel Island, midway between Bergen and Stavanger.[b] The gold veins are restricted to an area of a half-mile square on the north-eastern portion of the southern half of the island. The outcrops were discovered in 1883, and from their great richness attracted a considerable amount of attention. Their tenor, however, decreased with depth, and only one company (the Oscar, afterwards the Bremnaes) continued work. The rock of the southern portion of Bömmel Island is a fine crystalline greenish schist in which are contained large masses of dioritic rock (saussurite-gabbro of Dahll), and of a quartz-porphyry that may pass into an epidote-granite. This complex is traversed by altered diabasic dykes with which the auriferous quartz veins are closely connected. The gold-quartz veins occur principally in the quartz-porphyry. The veins are numerous. Their quartz is white and sugary, and contains pyrite, chalcopyrite, galena, and tetradymite, with occasional blende. The free gold is generally associated with pockets of calcite. When this is so, the ore may reach a tenor of 7 to 20 ounces gold per ton. Occasionally the walls of the lodes, for a distance of 6 to 12 inches from the vein, are highly mineralised, and may contain several pennyweights gold per ton. The width and value of the veins are extremely variable factors, and the former may range from a few inches to 6 feet. A considerable amount of work has been done on some of the veins, a shaft on the Oscar Lode reaching a depth of 550 feet. The average tenor in 1896 was about 7½ dwts. per ton, and from 1884 to that year about 30,000 tons ore had been crushed, and about £30,000 gold obtained.

Other auriferous areas occur on the mainland, ten miles from the Bömmel veins. The country in these areas is granite intruded

[a] Daw, Trans. Inst. Min. Met., V, 1896–1897, p. 212.

[b] Reusch, Neues Jahrb. für Min., 1887, Beil. Bd., V, p. 61.

by diabasic dykes entirely similar to those of Bömmel Island. The gold-quartz veins are small and low-grade. Thirty-five miles further north, in the parish of Olve, Hardanger Fjord, there occurs a network of small gold-quartz veins in green crystalline, chloritic, hornblendic, and talcose schists. The gold occurs not only in the veins, but disseminated throughout the schists. Early trials showed that the gold at the outcrop was very largely due to surface enrichment, and that at shallow depths the general tenor was only 1 dwt. per ton.

Gold-quartz veins are known on Talg Island, near Stavanger, and also in Thelemark, but neither have been extensively worked. The Svartdal tourmaline-bearing lodes in the Thelemark region, in which copper ores carry appreciable quantities of gold, have been generally described as occurring in granite. Vogt[a] has, however, shown that the country is really a quartz-mica-diorite, thus adding another example to the type of veins in quartz-mica-diorite to be considered later from Eastern North America and Eastern Australia.

Many Norwegian rivers contain gold in small quantities. The richest are those which have their sources in the far-north district of Karasjok, Finmark, where there are numerous quartz veins, probably the source of the gold. The rivers usually worked are the Altan, Tana, Jesjok, and Anarjok. The deposits are not rich, and extensive work is hindered by the climate, which permits of only four to five months work in the year, since the rivers are 180 miles within the Arctic Circle, and are, with a possible exception from the Upper Koyukkuk in Northern Alaska, the most northerly gold occurrences recorded. It is reported that by panning a man may collect 1 to 1½ dwts. daily. The gold is rough, and is about 930 fine. A little alluvial gold has also been reported from the Topdal and Torrisdal rivers, near Christiansand, South Norway.[b]

The gold production of Norway from the most recent returns available are :—

	Kg. Fine Gold.	Value. Kron.	Value. Sterling.
1900	4·4	9,000	£500
1901	5·0	10,000	655
1902	52·0	137,000	7,611
1903	11·0	31,000	1,722
1904	......	......	......
1905	......	......	......

[a] Zeit. für prakt. Geol., 1895, p. 149.

[b] Min. Journ., May 16, 1908.

SWEDEN.

Nearly all the gold produced in Sweden comes from the treatment by the Munketell process of the residual products of the silver-copper ores of the famous Falun mine, situated in the province of Kopparberg, north-west of Stockholm. This mine has been worked continuously for many hundred years. According to Törnebohm [a] the country is mainly a fine grained biotite-gneiss with very little mica. Associated with the biotite-gneiss are mica- and hornblende-schists, quartzites, limestones, and garnetiferous rocks. The foot-wall of the deposit is a grey micaceous quartzite intercalated in gneiss, while the great mass of the deposit is itself a quartzite thoroughly impregnated with sulphides. The ordinary copper-ore contains perhaps 1 to 3½ dwts. gold per ton. In 1881 a boy discovered free gold in white quartz veinlets that traverse the harder sulphide ore. Free gold in these is always associated with seleniferous galena and bismuthinite. Tenors of 3 to 10 ounces gold per ton were not uncommon, but the average free gold-ore contains only from 6 dwts. to an ounce per ton. The richest gold-quartz is found near intrusive diorites.[b]

A little gold has also been obtained from the silver-lead mines of Kafveltberg ; from quartz-veins in the gneissose granite of Adelfors in Småland, where the gold is associated with pyrite, galena, &c. ; and as rare occurrences in the Svappavara mine, Tornea district, and in the Bastnäs mine in Westmanland.[c] Towards the end of 1907 the discovery of a rich gold-copper vein was reported from the Nantanen mines, Bjorquirgts goldfield, Norboten province, in the extreme north of Sweden.[d]

The total gold yield of Sweden has been estimated as follows:—[e]

Period.	Ounces.
1400—1493	1,980,130
1506—1600	3,055,246
1601—1700	1,952,405
1701—1800	1,173,732
1801—1900	3,966,827

[a] Geol. Fören. i. Stockholm Förhandl., XV, 1893, p. 409.

[b] Sundbaerg, "Sweden," Stockholm, 1904, p. 758.

[c] Erdmann, Mineral., 1853, p. 174.

[d] Min. Jour., Nov. 30, 1907.

[e] Sundbaerg, loc. cit. sup., p. 753.

The available returns since 1900 are :—

Year.	Kg. Fine Gold.	Ounces.	Value. Sterling.
1901	62·7	2013	£8,558
1902	94·3	3027	12,872
1903	50·6	1624	6,907
1904	60·9	1954	8,313
1905	55·0	1765	7,594
1906	20·5	658	2,800

RUSSIA.

Finland.—The first gold found in 1836 in Finland lay in fragments of dolomite. The discovery engendered a considerable amount of prospecting in succeeding years in the neighbourhood of the Kemi and Tornea rivers towards the Swedish frontier. A fresh impetus was given to prospecting by the discoveries of Thellef Dahll in the Tana and other rivers of the Norwegian province of Finmark. In 1868, a Finnish prospecting party discovered gold in Finnish Lapland, along the upper course of the Ivalojoki river, which flows through Lake Enara into Varanger Fjord. This river has since furnished nearly all the gold produced from Finland. It has never been very rich, the best return being obtained by a party of three in 1869, who recovered 60 ounces in a few weeks. The year of greatest production was 1871, when 1,823 ounces (56,700 grammes) were obtained. During a period of 30 years the average annual production has been 463 ounces (14,396·7 grammes).[a] From 1870 to 1904 it is estimated that 298,350 cubic yards (229,500 cubic m.) had been washed for a yield of 14,284 ounces (444,250 grammes) or a little more than 1 dwt. per cubic yard. In 1904 the output was only 63 ounces (1,950 grammes), and in 1906, 92·8 ounces (2,887 grammes) worth 9,095 Finnish marks. The alluvial gravels are very thin and narrow. Their depth is from 1½ to 6 feet, and their width only from 6 to 45 feet.[b] The heavy sands contain magnetite and garnet with monazite and zircon.

The country of the gold-quartz veins, the degradation of which has furnished the placer gold of Finnish Lapland, is a granulite that is traversed both by acidic (quartz-porphyry) and basic (diabase)

[a] Fircks, Bull. Com. Geol. de Finlande, Helsingfors, XVII, 1906, pp. 1-33. (In English).

[b] Sarlin, Meddelanden frän Industristyrelsen i Finland, Helsingfors, No, 32, 1902, p. 1.

dykes. The gangue of the veins is quartz, with a considerable admixture of siderite and calcite. Hæmatite, magnetite, pyrite, and chalcopyrite are associated with the gold. These veins have been closely examined, but none of any size or value have as yet been found. The climate of Finnish Lapland is exceedingly severe, the Ivalojoki river lying five degrees within the Arctic Circle. The conditions under which the placers occur are therefore entirely comparable with those of Northern Alaska.

Olenetz and Archangel.—The earliest recorded gold discovery in Russia appears to have been made in 1737 at Voitsk in the Wyg river, in the Archangel district, where auriferous quartz-veins occur in isolated areas of talcose schists in the great granite *massif* of North-Western Russia. The schists in all cases are intruded by diabasic rocks. These deposits were never very profitable, and were abandoned in 1794, after having produced a little more than 2,000 ounces gold. Two gold-quartz veins are also known in the province of Olenetz, about 30 miles east-north-east and east-south-east respectively of Povenetz on the northern shore of Lake Onega. These were discovered in 1744.[a]

Ural Mountains.—Long before the conquest of Siberia by the Russians, vague stories of its wealth were in circulation in Western Europe, but despite vigorous search, it was not until 1743 that gold was found. The discovery was made by a peasant in a quartz-vein at a spot close to the junction of the Pyshma and Berezovsk rivers, some seven miles from Ekaterinburg. Of former workings in the Urals there is no definite information. Gmelin,[b] who journeyed through the Urals in 1733-1743, describes, however, ancient narrow and cramped workings, presumably for gold. They were so low that they could be entered only by crawling on the stomach. Remains were found of miners who had perished in a collapse of the workings. It is possible that some of the gold of ancient Bactria was derived from the Urals. The first discovery, strangely enough, appears to have been of vein-gold, the placer deposits of the region remaining undisturbed until 1774.

Gold occurs throughout the whole length of the Ural chain, and more particularly on its eastern flanks. In the north the upper waters of the Petchora, Vishera, Shigor, and Vychegda flowing west from the Urals, all carry a little gold. In the Petchora, near the northern Troitzk, platinum is associated with the gold. The upper waters of the Sossva, which flows into the Obi at Berezov, are also

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[a] Kokscharov, Mat. Min. Russlands, VI, 1870, p. 350.

[b] "Reise durch Siberien," Göttingen, 1751–2, III, p. 299.

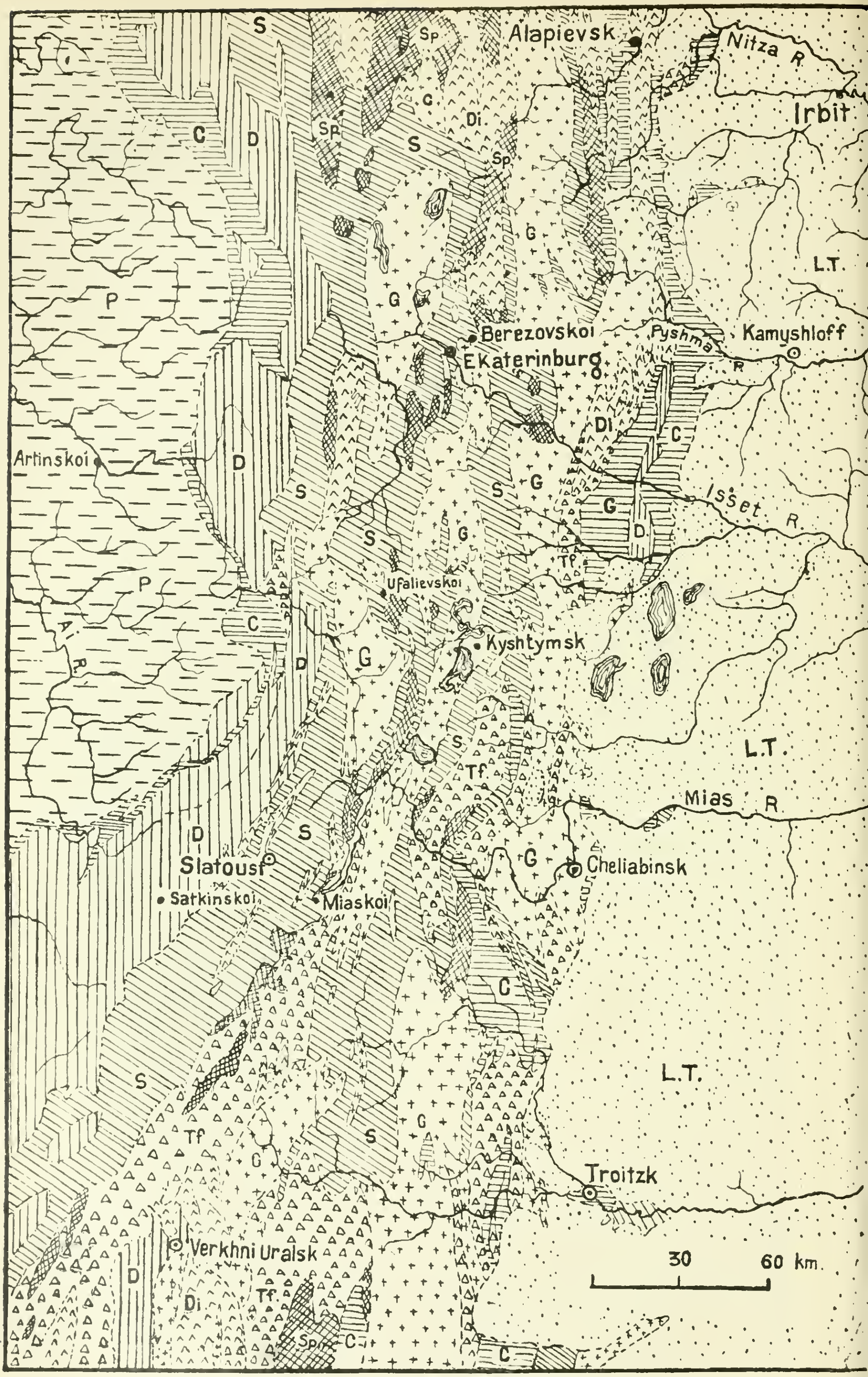

Fig. 84. Geological Sketch Map of the Southern Urals.
S. Crystalline schists. *G*. Gneiss, granite, syenite, and porphyry. *Di*. Diorite, diabase, and porphyrite. *Tf*. Greenstone tuffs. *Sp*. Serpentine. *D*. Devonian. *C*. Carboniferous. *P*. Permo-Carboniferous. *LT*. Lower Tertiary.

believed to carry gold-gravels. All these occurrences are alluvial. South of the foregoing, and between 60° and 62° N. lat., especially in the neighbourhood of Nikito-Ivdel, are numerous occurrences associated with diabase, diabase-porphyrite, and augite porphyrite. Placer gravels are widely developed, especially on the Ivdel and Wijai rivers, tributaries of the Lossva,[a] but other streams to the north of Petropavlovsk are also auriferous.

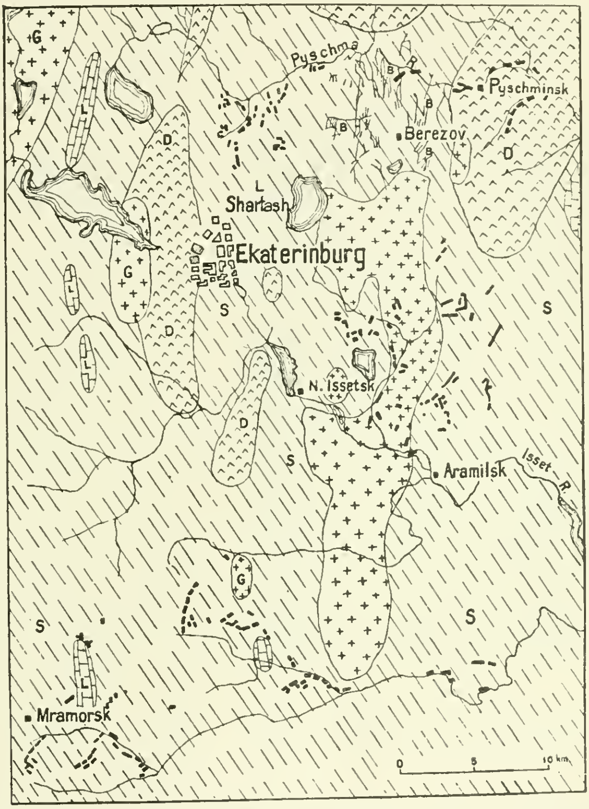

Fig. 85. Geological Sketch Map of Neighbourhood of Ekaterinburg.
G. Granite and syenite. *D*. Diorite, diabase, and basic rocks. *S*. Crystalline schists.
L. Lower Devonian Limestone. *B*. "Beresite" dykes.

The most northerly goldfields now worked on an extensive scale are near Bogoslovsk, where the placers lie along the tributaries of the Lossva and (southern) Sossva streams that flow to join the Tavda. The gold of the Bogoslovsk placers is associated with pebbles of augite-porphyry, jasper, clay-slate, quartz, and grains of hæmatite and magnetite. Gold is found *in situ*, near Koptekorskoi, six miles from Turinsk, in quartz veins in serpentine.

[a] Federov, Tscherm. Mittheil, N.F., XIV, 1894, p. 86.

The gravels of the Lata and other tributaries of the Lobva are auriferous. Next to the south is the district of Likolai-Pavdinsk, where are small placer deposits and an auriferous vein carrying pyrite in a quartz matrix. It is situated south of the Suchogorsky iron smelters.[a] Near Bissersk, on the western flank of the Urals, gold-gravels have been worked since 1824. Diamonds have at times been found in the wash. All the streams in the neighbourhood of Kushirnsk carry gold. The richest appears to be the Uralicha.

At Nijni-Tagilsk gold is found on both sides of the Tagil, and also between the Tagil and the Nieva river next to the south. The bed-rock of these placers is talcose and chloritic schist. The gold-quartz veins of Neviansk lie partly in a rock resembling "beresite" (microgranite), and partly in chlorite-schist. The gold occurs in thin plates in vughs in quartz.[b]

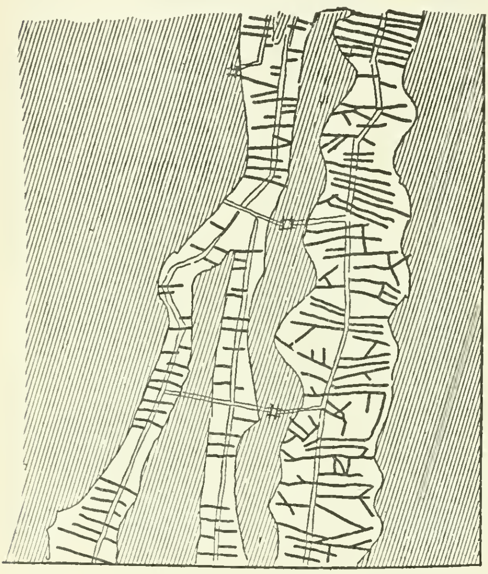

Fig. 86. Plan of Gold-bearing Quartz Veinlets, striking E. to W., in N. to S. Beresite (microgranite) Dykes, Berezovsk, Urals (*Posepny*).

The gold deposits of Berezovsk, among the most important in the Urals, are distributed over an area of 246 square miles (56 square versts), near the Berezovsk mill, about 7½ miles north-east of Ekaterinburg. They were discovered in 1745, and have been worked ever since. The surface of the country is undulating and is sparsely timbered with pine and willow. The rocks are mica-schists and muscovite-granite-schists, now largely decomposed to a soft red rock. With the schists are found exposures of serpentine, and to the west a peculiar metamorphosed dolomitic limestone (listvenite) consisting of magnesite, siderite, and calcite. The schists are traversed by a network of almost vertical microgranitic (beresite) dykes, which appear to be connected with the neighbouring granite *massif* of Lake Shartash. The beresites are, as a rule, much altered, and vary considerably in character.

[a] Stahl, Chem. Centralblatt, II, 1897, p. 58.

[b] Von Arzruni, Zeit. deutsch. geol. Gesell., XXXVII, 1885, p. 873.

They range in width from 6 to 130 feet.[a] Many of the larger beresite dykes show a more or less parallel arrangement, and some are persistent for a length of more than 5 miles (8 km.). They are traversed from wall to wall by numerous nearly vertical veinlets of gold-quartz of a thickness of a few inches to 3½ feet. Ordinarily, veins do not go beyond the beresite, but they are occasionally found in the schists beyond the dyke wall. The origin of the vein-fissures has been ascribed by Posepny to contraction of the intrusive rock on cooling, an explanation that has generally been accepted. Purington,[b] however, shows that two systems of fissuring traverse the whole series, but that these fissures, owing to physical conditions, are developed much more strongly in the microgranitic dykes than in the adjacent metamorphic rocks. The fissures strike either N. 80° E. or N. 30° W. In the neighbourhood are basic dykes that carry no ore, and show no evidence of having been crossed by the above-mentioned fissures. Purington, therefore, concludes that ore-impregnation was contemporaneous with or was directly consequent on the intrusion of the basic dykes. He further shows that the gold-deposits of the Urals are remarkably coincident with the distribution of the basic rocks of the region.

The gold-quartz of Berezovsk is sometimes compact, sometimes porous, and generally contains pyrite. Gold is found either free in the quartz, or contained in the pyrite. Associated minerals are numerous: chalcopyrite, covellite, galena, magnetite, aikinite (copper-bismuth sulphide), tennantite, and tetrahedrite, with derivative minerals. The quartz often contains acicular crystals of a pale green tourmaline, disposed at right angles to the walls. The pyrite may contain from 1½ dwts. to 1 ounce gold per ton, and assays of even 8 ounces per ton have been obtained. The general tenor of the Berezovsk veins is some 8½ dwts. (13 grammes) per metric ton. The placers of Berezovsk lie on the same rocks that contain the gold-quartz veins.

Since 1885, the auriferous veins of Pychminsk, 4½ miles (7 km.) north-east of Berezovsk, have also been worked. The country of the veins is listvenite (magnesite, calcite, and breunerite) and serpentine arranged in more or less parallel bands, all being traversed by dykes of microgranite, quartz-porphyry, and felsite. Numerous gold-quartz veins occur almost entirely in the intrusive porphyry (diorite of Posepny) and, like the veins in the beresite of Berezovsk, do not extend appreciably into the enclosing country, but lie trans-

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[a] Karpinsky, Guide du VII Congrès Geolog. Internat., V, 1897, p. 42; Posepny, Archiv. für prakt. Geol., II, 1895, p. 499.

[b] Eng. Min. Jour., June 13, 1903, p. 894.

versely across the dykes. The thickness of the veins is from 2 to 3 feet. The gold is accompanied by pyrite, chalcopyrite, galena, and their oxidation products. The tenor of the ore varies from ½ dwt. to 7 ounces per ton, while the average during the five years prior to 1898 was 17½ dwts. (27 grammes) per metric or short ton.[a]

The placers of Sysertsk and Kyshtimsk further south have yielded notable quantities of crystallized gold.[b] (Figs. 13-34.) Succeeding these, but after a considerable interval, come the important deposits of the Miäsk district, where the auriferous placers are exceedingly numerous and were formerly of considerable richness.[c] They have furnished many large nuggets, the heaviest found in 1842 weighing 1,158 ounces (36 kg.).

In the neighbourhood of Tcheliabinsk and some 10 to 13 miles south-west of that town, gold-quartz veins are worked in a highly dynamo-metamorphosed hornblendic granite. In the region there are also found beresite, porphyries, diabase, and tuff. The country is highly faulted and the lodes are filled with brecciated matter traversed by white opaque quartz stringers and veins ranging from 8 inches to 2½ feet in thickness. The oxidised zone extends to a depth of 100 to 130 feet. At lower depths sulphides and arsenides make their appearance. The tenor of the ore varies from 1½ to 6½ dwts. per ton, with occasional enrichment to an ounce per ton. In the Verkhny-Uralsk district the principal mines are those of Semionowski-Prisk, north of the town of Verkhny-Uralsk. The region was originally worked for placer gold, but now produces nearly all its gold from a talcose and dolomitic schistose zone of alteration products that lies between serpentine and fine-grained peridotite.[d] Lenses of clean white quartz occur within the schistose zone, but are always barren, and the gold of the lode is distributed mainly through the talcose-schist band in the crushed zone. The outcrop ore was very rich, yielding as much as 3 ounces per pound (6 pfund per pood). The first year of mining produced 5,266 ounces (163·808 kg.) gold. A similar occurrence is met with at Kamyschak, where the talcose zone lies between serpentine and hornblende-schist. The talcose rock is apparently derived from the weathering of the serpentine. The tenor of the ore here, as in the foregoing occurrence, diminishes materially in depth. Tschernychew[e] describes a gold-bearing lode in the Poliakowski mountains, near Balbuk, in which the gold is finely disseminated through the mass of the serpentine and quartz

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[a] Karpinsky, loc. cit. sup.

[b] Rose, G., "Reise, &c.," 1842, II, p. 156.

[c] Posepny, loc. cit. sup.

[d] Futterer, Zeit. für prakt. Geol., 1897, p. 388.

[e] Mem. du. Com. Geol., Petersburg, III, No. 4, 1889, p. 389.

veins are entirely absent. Quartz veins in the neighbourhood, however, carry fine gold. The degradation of these rocks and veins has furnished much alluvial gold. At Absakowa, west of

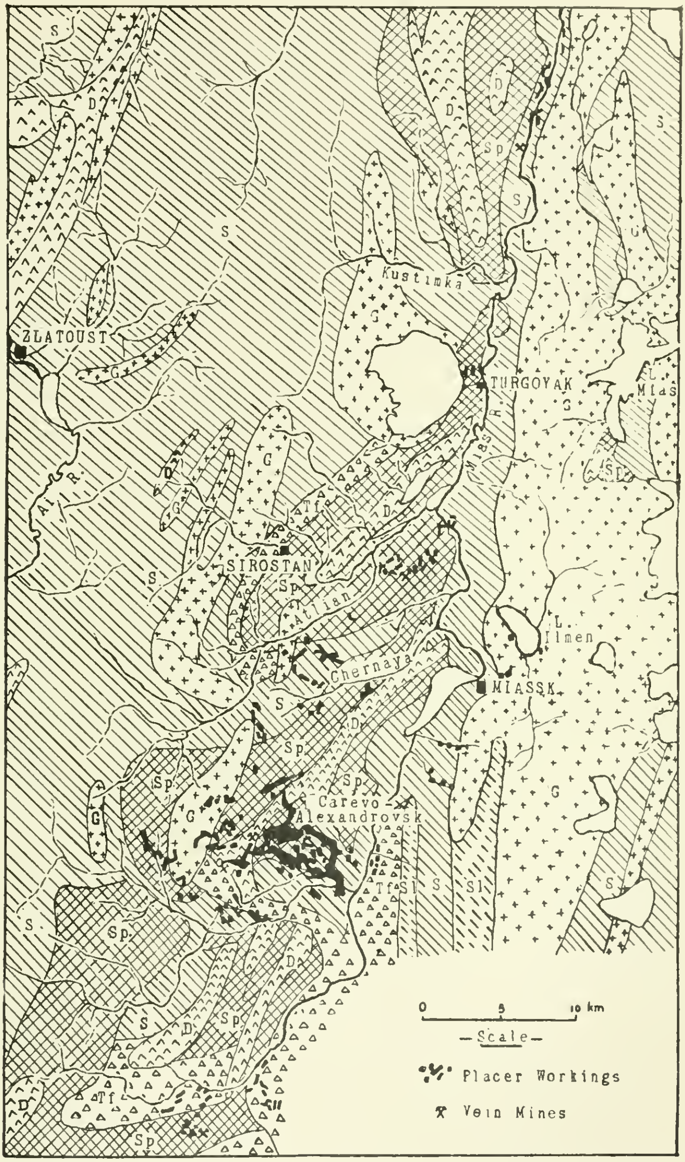

Fig. 87. Geological Sketch Map of the Neighbourhood of Miassk (*Tschernychew*).
S. Crystalline schist. *Sl* Slate. *G.* Granite and syenite. *D.* Diorite and diabase.
Tf. Greenstone tuff. *Sp.* Serpentine.

Verkhni-Uralsk, auriferous calcite veins containing serpentine inclusions lie in serpentine near its contact with a grey metamorphic schist.[a] The gold often occurs as thin films in the cleavage planes of the calcite, and also in the schistose fissuring of the adjacent serpentine. Numerous similar poor and narrow veins occur on the eastern slopes of the southern Urals.

The Kotchkar mines lie 50 miles south-west of Miass. Its 360 to 400 auriferous veins lie on the upper waters of the Kotchkara, Tchornaia, Osseika, Kamenka, and Sanarka.[b] The exploitation of gold in this region dates from 1844, when placers were discovered in the southern portion of the region. The veins of the region were first opened up between 1863 and 1867. In 1897 these veins were yielding from 42,000 to 45,800 ounces (1,300 to 1,425 kg.) gold annually, while the annual placer yield was only from 9,600 to 11,250 ounces (300 to 350 kg.). The total production of the field from 1844 to 1897 was about 1,512,979 ounces (47,060 kg.), of which 808,894 ounces (25,160 kg.) was placer gold. The greater number of veins are enclosed within an area of 20 square miles. The country of the veins is a fine-grained grey granitic rock, the beresite of many writers. Owing to intense dynamic metamorphism, schists have been produced in the granite along zones of shearing. The intermediate bands of granite are quite solid, and show no signs of schistosity. The gold-quartz veins lie along these schistose zones, and in strike are generally parallel with them. According to Purington,[c] auriferous impregnation is here directly connected with the occurrence of two peridotite stocks. Around the more southerly of the two the richer veins are grouped. The width of the lode channels may range from 3 to 20 feet, but that of the quartz stringers themselves is only from 1 to 4 inches. The schistose zones may be only a few feet apart, or may be separated by hundreds of feet. The gangue of the veins is a grey opaque quartz that is often chalcedonic or chloritic. Associates of the gold are mispickel, pyrite, galena, and stibnite. The average tenor of the quartz is 3 to 8½ dwts. per metric ton. Occasionally, the walls are sufficiently impregnated with auriferous pyrites to be worth working. Experience has shown that a considerable amount of secondary enrichment has taken place near the surface, with a consequent formation of rich pockets. The average tenor of the Ouspensky outcrop ore, for example, has been nearly 2 ounces per ton. This mine was in 1898 the best developed in the district, with a shaft 400 feet deep. It had to that year produced £570,000 gold out of a total Kotchkar product of £5,833,000. The Troitzk mine, operated by an English

[a] Futterer, loc. cit., p. 339.

[b] Wyssotsky, Guide du VII Congrès Geol. Internat., VI, p. 2; Nitze and Purington, Trans. Am. Inst. M.E., XXVIII, 1898, p. 24.

[c] Eng. Min. Jour., June 13, 1903, p. 894.

company, lies in this district. This mine, from October 28th, 1906, to January 13th, 1908, milled 37,629 tons ore for 8,830 ounces fine gold worth £37,268, the ore milled being of a tenor of almost exactly £1 per ton.

The Orsk goldfields mark the southern limit of the gold occurrences of the Urals. Several placer deposits are worked. The gold-quartz veins appear to occur in intrusive basic rocks, as diorite or diabase-porphyrite, or in tuffs of similar rocks.[a] An English company operating in this district was in 1907 producing 500 to 750 ounces per month, but ceased operations in 1908.

Reviewing the auriferous deposits of the Urals, it may be said that they are disposed mainly along the eastern flanks of those mountains. The metamorphic rocks underlying the placers are gneisses, schists, phyllites, and quartzites, with occasional calcareous and dolomitic members in the crystalline schists. The massive rocks are granite, syenite, quartz-porphyry, felsite, diorite, gabbro, norite, diabase, porphyrite, and pyroxenite. Nearly all have been subjected to intense dynamic metamorphism. The gold in the northern portion is associated with acidic intrusive rocks (micro-granite or beresite), while in the south the association is rather with basic rocks: diorites, serpentines, peridotites, &c. The evidence available shows that the gold disseminated through the serpentines is to be regarded as an entirely secondary impregnation, and not as a primary constituent of the serpentine.

The placers of the Urals are fairly uniform in character. Their average thickness is only from 1½ to 3 feet, with a maximum of 12 to 14 feet. Their average length is from 20 to 50 yards, and may reach one-third of a mile. The Petchanka placer in the Bogoslovsk district had, however, a total length of 8 miles. The average width may be estimated at from 20 to 45 yards. They are occasionally covered by a thin soil, but more ordinarily lie buried beneath a barren bed of peat and soil (*tourbe*), which may vary in thickness from a few feet to 65 feet or more. The pay-streak usually rests on hard, little-decomposed rock (*plotik*), and rarely on a "false bottom." Every thalweg and stream bed lying on crystalline rocks with auriferous veins, may contain auriferous alluvial gravels. The richness of the placers does not, however, always depend on the nature of the adjacent rocks; the richest are apparently those derived from dioritic or talcose crystalline schist areas, while those arising from the denudation of gneiss, granite, or mica-schist are much poorer. The distribution of the gold within the pay-streak is very irregular, rich layers, and poor bands alternating in most cases. The general tenor of the workable Ural placers lies between 10 and 50 grains

[a] Tschernychew, Russ. min. Gesell., XXIX, 1892, p. 225.

per cubic yard. Higher values are rarely met with, and then only in very restricted areas. Nevertheless, tenors of 500 ounces per ton have been reached. The heaviest nugget obtained in the Urals was that already mentioned as weighing 1,158 ounces (36 kg.). It came from the Tzarevo-Alexandrovski placer in the Miass district. The gold in the pay-streak is almost always accompanied by magnetite, more rarely by ilmenite and chromite. Platinum is often recovered with the gold. Zircon, disthene, and diamonds have also been found in the wash. The total length of the Ural placer region, from 50 miles north of Bogoslovsk in the north to near Orsk in the south, is more than 660 miles.

It is somewhat difficult to obtain separate returns for European and for Asiatic Russia. Those available are fragmentary, and often conflicting. The following table gives the available yields for recent years of the Russian Empire :—[a]

Year.	Kg. (Crude).	Crude Ounces.	Value. Sterling.
			£
1898	......	1,235,764	......
1899	38,868	1,208,795	......
1900	38,796	1,206,556	......
1901	39,140	1,217,254	4,651,682
1902	34,857	1,120,678	4,163,278
1903	35,271	1,134,000	4,145,967
1904	42,295	1,382,481	5,084,656
1905	33,542	1,078,400	4,569,778
1906	......	......	3,996,413*

* Rep. Dir. U.S. Mint, Washington, 1907.

For the Urals alone the annual gold yield appears to vary between 250,000 and 300,000 ounces, being in 1900, 291,235 ounces ; in 1902, 281,742 ounces ; and in 1903, 264,898 ounces.

Caucasus.—The streams of the Caucasus, the land of the Golden Fleece of Jason and of the Argonauts, have been found singularly deficient in auriferous deposits in recent centuries. The existence of gold has been proved in isolated districts, but nothing beyond the merest traces have been obtained. The Rion river, supposed to be the Phasis of the ancients, was, together with its tributaries, carefully, but fruitlessly, prospected for gold in 1854.[b] Nevertheless, the upper waters of the Rion, 60 miles east of Sukhum-Kale on the Black Sea, are marked as auriferous on the map of the mineral districts of Russia compiled by de Moeller.[c] Other gold-gravels are situated respectively north and east of the lake of Gotcha, along the mountain ranges between the Kur and Arax rivers, or, measuring

[a] Dipl. and Consl. Reports, 1900–1907.
[b] Ann. des. Mines, Ser. 5, III, 1853, p. 830.
[c] St. Petersburg, 1878.

from another centre, at spots some 50 miles south and west respectively of Elizabethpol. Bogdanovitch[a] records the occurrence of gold and silver midway between Nukha and Kuba on the slopes of the great Shalbuz-Dagh mountain.

[a] Mem. Geol. Com. Russ., XIX, 1902.

ASIA.

SIBERIA.

As early as 1820 alluvial gold-gravels were being worked in the Altai region. Eighteen years later all Siberia, with the exception of the Altai and the Nerchinsk circles, still retained as the personal property of the Tsar, was thrown open to public enterprise. Since 1837 the gold production of Siberia for the periods given below has been as follows :—

	Ounces (Crude).		Ounces (Crude).
1837—1847	1,065,451	1898	839,805
1848—1857	1,421,030	1899	828,917
1858—1867	1,265,424	1900	......
1868—1877	2,105,825	1901	......
1878—1887	5,023,855	1902	838,385
[a] 1888—1897	9,346,197	1903	850,517

The present annual yield of Siberia may be estimated at 800,000 to 900,000 ounces of gold.

For convenience of description, the auriferous areas of Siberia are enumerated as follows from west to east : Tobolsk-Akmolinsk; Bokhara (Russian Turkestan); Semipalatinsk-Semiretchensk ; Tomsk ; Atchinsk-Minusinsk ; South Yenisei ; North Yenisei ; Transbaikalia ; Yakutsk (Lena) ; Amur ; and Primorskoi (Maritime Province).

The first three areas are widely separated geographically, each group being itself composed of small isolated placers. The Tomsk, Atchinsk, and Minusinsk districts, on the other hand, together form a compact auriferous district divided only politically, and lying, for the most part, south of Krasnoiarsk, a town on the Yenisei river and also on the Trans-Siberian Railway. North of this area, on the right bank of the Yenisei, and between the Podkamennaïa-Tunguska and the Angara tributaries, lies the Yenisei group. With the exception of the western portion of Transbaikalia, lying south of the south-western end of Lake Baikal, all the remaining districts (Eastern Transbaikalia, Lena, Amur, and Primorskoi) form one continuous auriferous area stretching east as a fairly narrow band from Lake Baikal to the south-western shores of the Sea of Okhotsk.

[a] Glasser, Annales des Mines, XVIII, Ser. IX, 1900, p. 9.

This belt may be termed the Eastern Siberian field, all the other districts to the west forming the less important Western Siberian field. The following comparative table shows the yields in average years of these two areas :—

	1897. Ounces.	1898. Ounces.	1899. Ounces.
Eastern Siberia	645,449	680,094	652,779
Western Siberia...	167,715	159,711	176,138

The Siberian placers are Recent or Pleistocene. They are all above sea level, ranging as high as 1,850 feet in the Alatau mountains, and to 2,300 feet in the valleys of the Olekma, and in the Yenisei district. Many, especially in the Lena district, and in the Zeïa branch of the Amur, are contained in or are covered by perpetually frozen gravel. Of late years, considerable progress has been made in dredging in the Urals and in Siberia. During 1906-7 there were in all some 40 dredges at work in the Russian Empire. Returns were obtained for the working season of 1906 from 32 of these. The aggregate amount of gold and platinum recovered by dredging was 43,081 ounces, of which 36,609 ounces were gold, and 6,472 ounces were platinum. The largest individual return came from a dredge in the Ural district, that saved during the season of 175 days, 3,328 ounces from 207,970 cubic yards. Dredging operations have, on the whole, been unprofitable, owing apparently to defective machinery and to lack of experience. The average yield per dredge calculated from 32 dredges giving returns for 1906 is as follows :—[a]

Working days of season		173
Working hours of season		2,837
Gravel washed	cubic yards	159,537
Gold and platinum extracted ...	... ounces	1,346
Average yield per cubic yard ...	... grains	4·2[b]

Tobolsk-Akmolinsk.—The placers of the Tobolsk-Akmolinsk district are grouped in a small area to the east-south-east of the village of Kokchietav, which lies about 170 versts (113 miles) south of Petropaulovsk. They are neither extensive nor rich.

Bokhara.—The Bokhara khanate lies immediately to the north and north-east of Afghanistan. Its gold deposits have been washed for centuries by the Sarts, the semi-nomadic inhabitants of the region. The known auriferous placers lie in Eastern Bokhara, along the courses of the Wahsch, Kizil-Su, Mazar-Su,

[a] Bogovin, Eng. Min. Jour., Aug. 17, 1907.

[b] This figure is given as ·10125 ounces in the original paper.

Yak-Su, and the Ravno streams, all eventually falling into the Panj River on its right or northern bank. The Panj separates Bokhara from Afghanistan. Below its junction with the Wahsch, this river is known as the Amu-darya or Oxus. It also is auriferous, at least, as far down its course as the "Golden Isle," near Awadje, north-east of Balkh. The "Golden Isle" is some 165 miles (250 versts) from the high-level gravels that furnish the fine gold of the Kizil-Su.

The general geology of the country is simple. The great mountain ranges in the east and south-east are areas of metamorphic

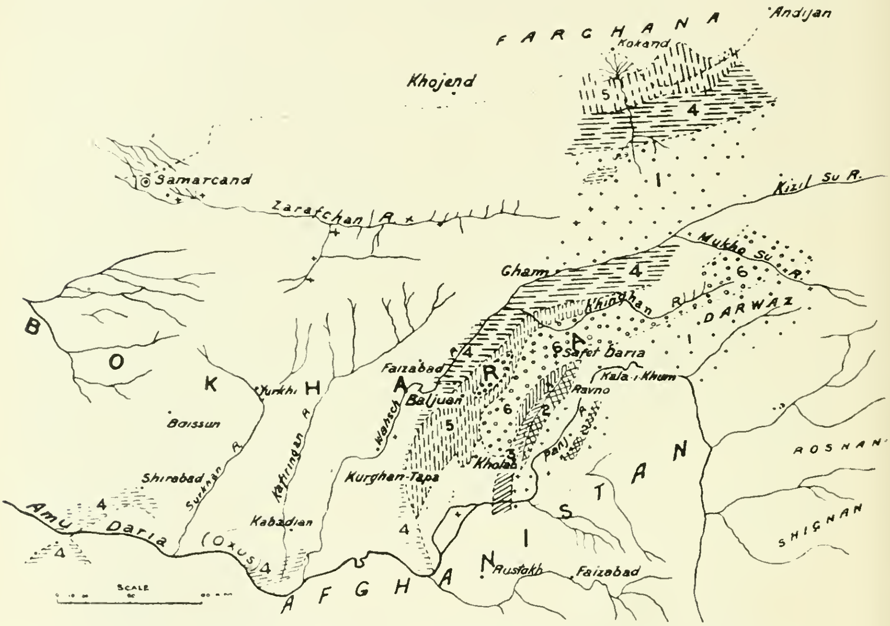

FIG. 88. GEOLOGICAL SKETCH MAP OF AURIFEROUS AREA, BOKHARA (*Levat*).

1. Granite, gneiss, and mica-schist. 2. Fusulina limestone (Carboniferous). 3. Trias. 4. Cretaceous shales. 5. Tertiary clays. 6. Auriferous conglomerates. + Placer-deposits.

and plutonic rocks, while the lower ranges, together with the plains to the north, are made up of little-disturbed and generally horizontal Cretaceous and Tertiary strata. The original source of the gold appears to have been small veins in the metamorphic schists of the Altai mountains. A gold-quartz vein is known and has been worked near Dorsch.[a] During the erosion and degradation of these mountains in Eocene times great beds of conglomerates with associated placer gold were formed in the lower courses

[a] Von Krafft, Zeit. für prakt. Geol., 1899, p. 37.

of the mountain streams far from the parent veins. From the varied character of the boulders found in the conglomerate the then existing streams appear to have drained a large stretch of country. The predominant rocks are green diabase-tuff, red felso-porphyrite, diorite, porphyritic diabase, porphyrite, gneiss, amphibolite, quartz-schist, quartzite, and various sedimentary rocks. The cement is calcareous or arenaceous, or at times, calcareo-arenaceous. Opinions are divided as to the method of formation of the conglomerates, Levat, from whom most of our information on this region is derived,[a] being firmly convinced that they are glacial in origin. The gold is contained in the cement, nearly always as flattened plates, and rarely as nuggets. The tenor of the older conglomerates is low, but long-continued erosion and concentration by subsequent streams has furnished workable river gravels, both high-level and also in the beds of the existing streams. The auriferous conglomerates have a considerable development on the western flanks of the Darwaz chain, where they cover hundreds of square miles. Their maximum thickness is perhaps 2,000 feet. The main conglomerate band runs in a north-east direction, from a point some 15 miles east of Kolab to the north of Kali-i-khumb, where it strikes due east. Two minor bands occur on the east and west of the main band, at Ravno and at Obi-Sanghi-Khergov respectively. The principal placer workings lie near or on the conglomerate beds in the old river terraces, and in the present stream beds. The former, being easily drained, have, as a rule, been worked and re-worked many times by the Sarts, and now offer but little scope for industrial development. All deposits below water-level are virgin, and are apparently fairly rich. At a placer deposit leased by M. Pakorski, the overlying gravels already worked by the Sarts to a depth of 14 feet (2 sajenes) contained only 1 71 grains per cubic yard (2½ dolis per 100 poods). At the water-level the gold content rises to 20·6 to 27·4 grains per cubic yard (30 to 40 dolis per 100 poods), while at a depth of 42 feet (6 sajenes) a tenor of 65·78 grains per cubic yard (1 zolotnik per 100 poods) was reached, and even then bed-rock had not been reached. The gold of the gravels occurs in small flattened grains. Nuggets of more than 13 to 16 dwts. (5 to 6 zolotniks) are rare. The gold is from 920 to 927 fine.

The washings conducted by Levat showed, on the whole, low values. At the Nicholas placer on the Mozar-Su he obtained 14 4 grains per cubic yard (1·218 grammes per cubic metre); at Obi-Sanghi-Khergov, the conglomerate carried usually not

[a] Bull. Soc. Geol. de France, II, Series 4, 1902, p. 447 *et seq.*; Annales des Mines, III. Series 10, 1903, p. 201.

more than 3¼ grains per cubic yard (·275 grammes per cubic metre). In the Safet-darya the alluvials had been worked for some six years prior to 1902 by Russian concessionaires. There the lower beds averaged 41 grains per cubic yard (6·4 francs per cubic metre). The Russian workings in 1902 were, however, exceedingly primitive. The Tibi-darya and the Sagri-datch placers on tributaries of the Klungau, or Wahsch, gave prospects of only 1·3 grains per cubic yard (20 centimes per cubic metre).

The native (Sart) methods of working and washing are crude. The placers are drained, where possible, by long adit levels, that are ventilated by a series of inclined shafts carried down to the drainage level from the surface, a new ventilation shaft being sunk on the course of the adit whenever the face becomes too far advanced to be served by the existing shaft. The gravel is carried by boys from the bottom of the inclined shafts to washing trays at the surface, where the sand is washed over felts. Sometimes fleeces or camel skins are used, in which case the hair of the former is cut to a uniform length of ·4 inches and the fleece is further often transversely ribbed every 2 inches by shaving to the skin for a width of $\frac{1}{5}$ inch. Miniature riffles are thus formed, assisting in the retention of the gold. Such a fleece resembles the long-pile velvet strakes commonly used on modern dredges. The minimum earnings of the Sarts appear to be sixpence per diem. The gold yield of Eastern Bokhara was estimated in 1899 at £20,000 to £30,000 per annum.[a]

Semipalatinsk-Semiretchensk.—These districts lie to the north-east and south-east respectively of Lake Balkash. The placer deposits of the former are disposed along the Irtish River, between Lake Zaisan and the town of Ust-Kamenogorsk, south-east of Semipalatinsk. The deposits are thin and poor, and would be unworkable were it not for the abundance and cheapness of the Kirghiz labour. Gravels containing as little as 4 grains per cubic yard can thus be worked. In 1897 about 1,200,000 cubic yards of sand were treated for 16,846 ounces of gold, or nearly 7 grains gold per cubic yard. More than 5,000 Kirghiz were employed on the various claims.[b]

The Semiretchensk placers are scattered along the head-waters of streams flowing north-west into Lake Balkash. They have no present importance.

Tomsk.—The Tomsk mining field includes the Altai and Mariinsk districts in Tomsk proper, together with the Atchinsk, Minusinsk,

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[a] Rickmers, Geog. Jour., XIV, 1899, p. 606.

[b] Glasser, loc. cit. sup., p. 45.

and Yenisei districts in Yeniseisk. The production of this mining district from 1900-1904 was :—[a]

Year.		Tons.	Ounces.	Total Ounces.
1900...	Quartz	25,081	9,976	181,792
	Gravel	7,201,455	171,816	
1901...	Quartz	26,944	25,120	197,049
	Gravel	7,101,045	171,929	
1902...	Quartz	25,483	26,811	145,006
	Gravel	5,493,823	118,195	
1903...	Quartz	41,766	38,735	130,305
	Gravel	5,585,976	91,569	
1904...	Quartz	61,420	29,654	130,750
	Gravel	6,842,227	81,096	

It therefore appears that the yield from alluvial mining is steadily diminishing, while that from quartz mining is increasing.

Altai.—The Altai district lies on the northern slopes of the Altai mountains, and near the boundary of Eastern or Chinese Turkestan. A great part of the mineral area is the private property of the Tsar, and is administered by the Cabinet. Placers open to the public are either on the tributaries of the Abakan, flowing into the Yenisei near Minusinsk, or on the tributaries of the Tom (Taidon, Ters, Oos, Mras, and Kondom). From these, in 1897, some 1,280,000 cubic yards of gravel, yielding 48,225 ounces gold, were washed. The average tenor was therefore about 18 grains per cubic yard.

The placers administered by the Cabinet are on the affluents of the Biya, a tributary of the Ob. These yield about 5,000 ounces per annum. With the Altai district may be taken the Mariinsk district, where gravel deposits are worked on the Kiya and Teïa streams, tributaries of the Chulim. In this district a quartz vein furnished in 1897 about 650 ounces of gold, while in 1904 the Sixth Berikal gold-quartz mine crushed 9,477 tons for a yield of 9,460 ounces, and the G. M. Miller mine, also in the Mariinsk district, crushed 4,358 tons for 1,934 ounces.

The following table (Loranski) shows the relative importance of the principal streams of the Altai and Mariinsk districts during 1896 :—

River System.	Cubic Yards Treated.	Number of Mines.	Total Yield. Sterling.	Value per Cubic Yard.
				s. d.
Kiya	311,000	75	£47,700	2 11
Chorni Oos ...	167,000	24	15,833	1 8
Byeli Oos ...	87,000	13	9,792	2 3

[a] Tovey, Eng. Min. Jour., Sept. 29, 1906, p. 577.

The stripping necessary averaged about 10 feet, while the pay-dirt varied in depth from 5 to 8 feet. Much deeper gravels occur in the Byeli (White) Oos. The working season in this region is from the end of April to the end of October, or six months, and is therefore longer than in most other parts of Siberia. The bed-rock of the placers, as, for example, on the Blagodatny stream, is mica-schist intruded by numerous diorite dykes. The gold probably comes from minute veinlets in the neighbourhood. At the head of a tributary of the Byeli Oos, viz., The Sorela Oos, from which more than £1,000,000 of gold was taken in the early days of Siberian gold-washing, the mountains are of diorite, but graphitic slates and fine-grained porphyries also occur. Gold-quartz veins are numerous in the diorite.

Little, however, can be said about the primary gold deposits of the Altai and Mariinsk districts, since up to the present time they have been but cursorily examined. Prof. Zaitzeff, in 1900, found native gold in diorite at the head of the Fyedorovski stream, a tributary of the Chulim river. No quartz vein occurred within 500 feet of the gold deposit, but there was, quite near, a basic dyke, that was perhaps a peridotite. A thousand feet away, productive gold-quartz veins have been worked.[a] Korotkoff,[b] in describing the gold-quartz veins of the Birikoulski mine, Mariinsk district, points out the presence of löllingite ($Fe\,As_2$), together with blende and galena. This mine was not discovered until 1901, though its placers had yielded abundantly for 15 years previously.

Atchinsk-Minusinsk Districts.—These are in Southern Yeniseisk, south of Krasnoiarsk. They contain several gold-quartz mines. In the Atchinsk district the Joannovski (Podvintzeff) veins lie in a fine-grained greenish diabase. The mine is on the left bank of the Bezimian stream, a tributary of the Saral-Oos. It was discovered in Sept., 1899, and work was commenced on it in 1900. The first crushings yielded from 350 tons about 22 dwts. per ton, a tenor not sustained, since later crushings fell to 16 dwts. per ton. The bullion obtained was 788 fine. The lode out-cropped on the steep mountain-side, and was from 16 to 23 feet in width, but bands of country within the vein reduced the width of crushing quartz to 5 to 8½ feet. The quartz is richest nearest the walls. Another vein in similar rock occurs in the neighbouring Toumani mine.[c]

In the basin of the Byeli-Oos, south-east of Tchebaki, is the Ivanitzki or Bogom-Darovanni ("Gift of God") mine. It was discovered in 1896, and from 1898 to May, 1902, had produced £60,000

[a] Brown, Trans. Amer. Inst. M.E., XXXIV, 1904, p. 786.
[b] Bull. Soc. Oural, XXV, 1905, p. 69.
[c] Bordeaux, Ann. des Mines, II, Ser. X, 1902, p. 505.

gold. The vein is in syenite, and carries epidote, calcite, pyrite, and carbonates of copper. The auriferous band is from 20 to 23 feet thick, but the quartz veins within it themselves make up a total thickness of only 3 to 10 feet. During the foregoing period 10,000 metric tons were raised and crushed for a yield of 16,720 ounces, or a little more than $1\frac{1}{2}$ ounces per ton. In the Minusinsk district the principal mines are those of Kuznetzoff, lying about midway between the towns of Tchebaki and Minusinsk. The Kuznetzoff mines are on a small tributary of the Tibika, which itself joins the Uibaka, a tributary of the Yenisei. Numerous veins occur, of which the majority are in muscovite-granite. One, however, is in a hornblende-mica-gneiss. The majority are small. Zaitzeff[a] groups the veins of the Atchinsk-Minusinsk region into two series coursing at right angles, one series running meridionally and the other east and west. The Bogom-Darovanni mine of Minusinsk (named after that already mentioned of Ivanitzki in the Atchinsk district) is one of the best in the region. Its output for 1904 was 8,874 tons for 10,649 ounces or 1·2 ounces per ton. Wages are low, and labour good.

Yenisei.—The Yenisei auriferous area, as already has been stated, lies between the Podkamennaïa-Tunguska and the Angara rivers, both tributaries on the right bank of the great Yenisei river. Explorations were first actively undertaken here in 1840. From that year to 1900, a period of 60 years, the Yenisei placers had produced about 14,146,000 ounces gold. In 1857, their yield was 643,000 ounces. Thereafter their decline was rapid, falling in the last years of the nineteenth century to 80,000 to 100,000 ounces per annum. The decline was due entirely to the exhaustion of the more readily accessible placers. At the present time washings are being conducted in gravel of a tenor of less than 9 grains per cubic yard. In the early days of Yenisei mining the yield per cubic yard often rose to 16 dwts. The richest gravels worked in 1897 were those of the Udoronga Valley, of a tenor of some 2 dwts. per cubic yard.[b] The south Yenisei portion of the above district lies between the Great Pit and the Angara rivers. Its placers are developed along the upper waters of the various northward-flowing tributaries of the Great Pit (Gorbilok, Penchanga, &c.), and also along the upper courses of the Udereïa, Udoronga, Ribnaïa, Mourzhnaïa, and Tatarskaïa, all the members of the latter group eventually flowing southward to join the Angara. The bed-rock is largely composed of argillaceous and quartz-schists, fairly pyritous in bulk. Massive granites and diorites also occur. Meister[c] reports that the

[a] Centralblatt für Mineral., XXXIV, 1901, p. 137.
[b] Glasser, Ann. des Mines, XVIII, Ser. IX, 1900, p. 36.
[c] Com. Geol. Russ., I, 1900, p. 86, Yenisei.

granites and metamorphic schists of the Udereïa and Udoronga are traversed by diabase dykes. Quartz veins are numerous through the country. Some are auriferous, notably in the valley of the Ribnaïa north of Ribinskoi, and also on the right bank of the Angara, east of Blokhino. They are, however, of fairly low grade, averaging in small veins about 8 dwts. per ton. Meister[a] concluded that the placers of the Great and Little Mourozhnaïa, Tchernaïa, Tatarka, and Ribnaïa, had derived their gold from similar veins in the adjacent argillaceous schists. The argillaceous schists without pyrite, in the region south-west of Yeniseisk, contain no gold, while those impregnated with pyrite contain as much as 6 grains per ton (20 dolis per 100 poods).

All the placers so far exploited appear to be of recent origin, and occupy the bottoms of existing valleys. Generally they are shallow, and require but little stripping. The yield per cubic yard would appear to vary between 5 and 18 grains. Much of the poorer gravel is available for dredging. The native placer industry is now of little importance in the Penchanga, Gorbilok, and Ichimba rivers.

The North Yenisei district is situated on the east of the Yenisei river in the upper basins of the Teïa and Kalami rivers, tributaries from the south of the lower Podkamennaïa-Tunguska. Its rocks, like those of the southern Yenisei field, are gneisses, mica-schists, and amphibolites with ancient sedimentary rocks. These are traversed by small dykes of granitite and diabase. Gold-quartz veins occur in the schists, but gold is also found in the schist rock itself.[b] In 1902, Jacewski[c] found that a highly pyritous (·1 to 1·33 per cent.) biotite-quartz-schist of the Teisskaïa Series was auriferous to the extent of 14 grains per ton (·00008 per cent.). A tourmaline-bearing gneiss yielded 7 grains, while a conglomerate with schist pebbles gave from 7 grains to 3 dwts. gold per ton. The problem whether the gold lay in the cement or the pebbles remained unsolved. The most important placers now being worked in the North Yenisei field are in the Teïa, Enachimo, and Kalami rivers. Their production is not great.

Transbaikalia.—The Transbaikalia (Zabaikalskaïa) province is situated between Lake Baikal and the Manchurian frontier. The minerals of the greater portion of the province are the private property of the Tsar. The silver mines of Nerchinsk have been worked since 1703. From that year to 1870 they had yielded more than 400 tons (422,314 kg.) of silver. With the silver was associated

[a] Ib., III, 1902, p. 37, Yenisei.

[b] Jacewski, Com. Geol. Russ., I, 1900, p. 33, Yenisei.

[c] Loc. cit. III, 1903, p. 78, Yenisei.

a very small proportion of gold, which, nevertheless, for the same period amounted to no less than 43,274 ounces (1,346 kg.).

Within the province there are three principal gold-quartz mining centres, viz., Onon, Nerchinsk, and Chilka. The Onon deposits have been described in detail by Levat.[a] They lie in a region of slates and shales traversed by numerous igneous rocks, of which the chief types are granite, aplite, syenite, diorite, and kersantite. The gold-quartz veins occasionally pass from the granites into the slates. At Khangarok the veins were in 1902 being worked by two companies, viz., the Bielogolovi, and the Sabachnikoff at Baian-Zurga. The principal veins of the former company are in the slates (schists), near their contact with granite, the latter rock also containing numerous small veins. The thickness of the main vein varies from a few inches to 3 feet. Its tenor may be as high as an ounce per ton, but from the following figures its average tenor appears to be in the neighbourhood of 7 dwts. From 1879 to 1887, 66,450 metric tons were treated for 23,627 ounces (727 kg.) gold. For the next ten years the mines were closed, but in the five-year period of 1897-1901, a further 3,734 ounces gold were obtained, the tenor of the quartz varying from 3½ to 7½ dwts. per ton. The vein has been worked for a length of 450 feet. The Sabachnikoff Company worked a vein at Baian-Zurga, in slate, but also near a granite contact. The vein was from 4 inches to 2½ feet in thickness and appeared to average about 12½ dwts. per ton, 2,446 metric tons in 1886-7 having produced 1,513 ounces (46,550 kg.).

A gold-quartz vein has been worked at Oloviannaia, nearer Nerchinsk. At Dalmatchik in the Chilka district, north of Nerchinsk an auriferous syenitic vein occurs in the granite.[b] Along the contact of the two rocks there runs a thin vein of galena. The auriferous band varies in thickness from 2 to 8 feet, and appears to be worth about 17 dwts. per ton.

The Kluchi mine is worked by a subsidiary company of the Nerchinsk G.M. Co., the latter holding a general concession from the Private Cabinet of the Tsar. The lode formation consists of a highly altered and silicified quartz-porphyry, mineralised with pyrite and gold. From July, 1905, to the end of Aug., 1906, 5,214 tons treated gave 2,420 ounces with tailings reported to average 8 dwts. 9 grains, indicating a total tenor of 17 dwts. 16 grains per ton.

Auriferous placers are scattered throughout the Transbaikalia province. The majority have been known for many years. In 1897, more than two-thirds of the total gold produced (77,803 ounces) came from the Emperor's private mines, of which 10 were being

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[a] "L'or en Siberie orientale," Paris, I, 1897.

[b] Bordeaux, Ann. des Mines, II, Ser. X, 1902, p. 537.

worked. They yielded 56,875 ounces from 600,000 cubic yards, or an average yield of 1·9 dwts. per cubic yard. The Cabinet placers are situated on the tributaries of the lower portion of the Chilka (Geltuga, Kara, &c.); between the Chilka and Unda (Kazakova, Novo-Troïtzk, Uralguinski, &c.); and in the neighbourhood of Nerchinsky-Zavod (Burza, &c.). Poorer placers belonging to the Crown are worked by private individuals on the lower Geltuga. The tenor of these is not more than 18 grains to the cubic yard. Those worked by and in the possession of private individuals carry even lower values (12 to 15 grains per cubic yard). The more important of the private mines are the Malomalski placer on the Bystra, where the pay-streak lies under 25 feet of cover; the Chakhtaminsk placer, a little further west; and the placers of the Onon river, immediately north of the Mongolian frontier. All the placers are geologically of recent origin, and have but little cover. The source of the gold is known for the Onon and Ilia deposits, where the gold descends from a granite *massif* in old schists and slates. Working costs are low in Transbaikalia, since labour is cheap and abundant. Chinese workmen will attack favourably situated gravels containing no more than 5 to 6 grains per cubic yard.[a]

Yakutsk (Lena).—The auriferous portion of the great Yakutsk province of Siberia, lies in its south-western corner, in the Lena district, and north-east of Lake Baikal. The principal deposits are grouped along both slopes of the Krapotkin mountains, which rise to a height of 3,000 to 4,000 feet. The auriferous gravels occur in the valleys of the head-waters of the Patom and Yonya rivers flowing north, and in the Bodaibo and other streams flowing south to the Vitim river. They are evidently a northward continuation of the Transbaikalian auriferous belt. Work was commenced on the Olekma and Vitim placers about fifty years ago, gold being first discovered by Tungouse hunters. The placers were rapidly developed, but, as the following table, giving the yield at five-year intervals, will show, appear to be declining in importance under existing Siberian methods:—

Year.	Ounces.	Year.	Ounces.
1850	96	1877	488,680
1852	16,075	1882	394,802
1857	80,375	1887	241,125
1862	105,740	1892	345,281
1867	141,460	1897	310,247
1872	331,788		

The annual yield during the last years of the century would therefore appear to have been worth about one and a quarter millions sterling. This is largely the produce of a few great companies.

[a] Glasser, loc. cit., p. 35.

Worked Gravels, Lower Ourum Valley.

Modern Workings, Upper Ourum Valley.

Placer Mines of the Imperial Cabinet, Ourum Valley, Chilka River, Siberia.

The Ivanovski (Vitim) and the Lena companies furnished each about £250,000; the Prokopeiovski (Bodaibo) about £150,000, &c. The last-mentioned mine from 1890 to 1900 inclusive produced £1,875,000 gold. For the whole region, from 1897 to 1900 inclusive, there were treated 4,360,000 cubic yards sand, yielding approximately £4,480,000, or a little more than 5 dwts. per cubic yard.[a] The bulk of this came from the Bodaibo stream. The alluvium is perpetually frozen, and no more than a hundred working days in the season may be anticipated.[b]

The rocks of the region are schists and gneiss, with quartzites and minor exposures of syenite, aplite, kersantite, and diorite. They are traversed by white lenticular veins of barren quartz, which nevertheless sometimes contain crystals of galena or pyrite, in which case the latter may contain a little gold. Further up the Vitim than the rich placers, and near the Orlofka river, gold-quartz veins are known at the Tagarak (Kamen) mine, where the gold occurs as scales in the quartz. Still higher up in the Vitimkhane, north-east of Barguzinsk, thin quartz veins carrying gold occur in schists.

To return, however, to the Olekma-Vitim placers, these are of two ages, Pleistocene and Recent. The latter lie in the beds of the existing rivers, and are of little importance. The former lie buried beneath frozen alluvium of an extraordinary depth. It is never less than 65 feet, and may reach 300 feet. It is made up of successive beds of clay, mud, and sand. The pay-streak is on bed-rock, and is from 2½ to 5 feet thick. It is generally a clayey sand, with flat angular pebbles, of many rocks, but principally of schist. The gold tenor may vary suddenly, in any given placer, from 4 dwts. to 1¾ ounces per cubic yard. The gold of these ancient deposits is rough, coarse, and crystallized (octahedra and cubes), while that of the recent gravels is fine and flaky. Nuggets weighing 26 dwts. have been found in the Tikhona-Zadonsky placer. Both pyrite and pseudomorphs of limonite after pyrite are common in the drift.

A remarkable light on the origin of the alluvial gold has been furnished by the researches of Sementchenko and others. In the Nijni placer the Lena Company separated the pay-streak as far as possible into its component parts, obtaining:—

60·9 per cent. sand, pebbles, &c.,
32·6 per cent. clay and mud, yielding 19·3 dwts. of gold per cubic yard,
5·4 per cent. heavy sand,
1·09 per cent. pyrites, yielding nearly 14 ounces gold per cubic yard.

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[a] Purington, Min. Jour., April 20, 1907.

[b] Glasser, Ann. des Mines, Ser. IX, 1900, XVIII, p. 18.

while the total loss in separation and remaining in pyrites was 9¾ dwts. per cubic yard.[a] Sementchenko has separated and assayed the pyrites with equally remarkable results. From the Konstantinovsky placer the pyrites residues yielded 50·9 ounces (1,582 grammes) gold per metric ton[b]; from the Krutoï placer 10·7 ounces (332·87 grammes) per metric ton.[c] A further trial on the pyrites of the Tikhono-Zadonsky placer gave the same investigator:—[d]

By cyanide	9 ounces per metric ton.
By fire after cyaniding ..	23·7 ,, ,,
By fire of the whole ..	31·6 ,, ,,

Further analysis of the bullion thus obtained showed that it was only 758 fine in gold, the remainder being silver, while alluvial gold from the same placers from which the pyrites was gathered is on an average 918 fine. Obrutchev and Guerrassimov have therefore concluded that much of the Vitim and Olekma gold has been derived not from gold-quartz veins, but from the pyrites in the schists.

Amur (Amurskaïa).—The deposits of this province are to be found almost entirely in the valleys of three tributaries of the Amur: the Zeïa, which flows into the Amur at Blagovieschensk; the Bureïa, meeting the Amur a little further down stream, and flowing from the same direction as the Zeïa; and the Urmi, which meets the main river at Khabarovsk. The last are often known as the Malïy-Khigan, from the mountains in which they lie. The following returns for 1897 illustrate the then relative richness of the Amur gold-fields:—

	Ounces.	Kg.
Zeïa Basin	148,693	4,625
Bureïa Basin	26,845	835
Malïy-Khigan Basin	16,139	502
Head-waters of the Amur	8,616	268

The basin of the Zeïa is therefore by far the most important. Its principal auriferous affluents are the Gilyui and the Brianta, the latter having as tributaries the Djolon, Ilikhan, and Unakha. The first deposits known (in 1867) in this region were those of the Djalinda, at the head of the Ur, a tributary of the Zeïa, and also those of the Oldoi, in the immediate neighbourhood of the preceding. Both these lie to the north of Reinova on the Amur. Their annual

[a] Guerrassimov, Com. Geol. Russ., 1904, p. 81, Lena.
[b] Loc. cit., 1901, p. 29, Lena.
[c] Ib., 1904, p. 81.
[d] Loc. cit. sup., p. 238.

yield was at first about 97,500 ounces gold. The now more important placers on Gilyui and Brianta rivers were discovered about 1870, and their exploration dates from 1875. The working season is here slightly longer than on the Lena tributaries, averaging from 100 to 120 days.[a]

The rocks of the Zeïa district are gneiss, amphibolitic schists, (accompanied often by eclogite) and granite, together with Jurassic and Pleistocene deposits. Gold has been found in lenticular veinlets, both in the gneiss and in the schists, and it has further been observed that those in the amphibolite schists are richer than those in other members of the complex.[b] According. to Ivanov,[c] however, the veins in the gneiss are pegmatitic, containing also mica and felspar. They may therefore be compared with the alaskite veins or dykes of Spurr from the not greatly dissimilar auriferous region of Alaska. The gold of the Jazonof Klad and Dojdlivoï placers on the Unakha, and of the Troitzki, on the Murzinski, is derived exclusively, according to Yavorovsky,[d] from these pegmatitic veins.

The placers of the Amur region are not deeply buried, as on the Lena. They are often less than a yard thick, and are covered by 14 to 21 feet of clayey sand. The cover rarely reaches 35 feet in thickness. Some of the pay-streaks have been very rich. The Leonovski placer on the Djolon produced in two years (1889-90) 73,945 ounces gold from 140,800 cubic yards, a yield of 10½ dwts. per cubic yard. During fourteen years of work, the tenor of the wash treated at this placer has been 3½ dwts. per metric ton, and no less than 401,875 ounces have been recovered. Terrace deposits and lacustrine deposits (as high as 400 feet above the present valley level) occur in addition to the recent valley placers. The Bureïa placers lie in the upper valleys of the Niman, on the opposite side of the mountains from those of Amgun (Primorskoi Province). Their characters agree with those already described for the Zeïa. The deposits of the Malïy-Khigan are at the head of the Urmi, north-north-west of Khabarovsk. They are numerous, but are neither extensive nor rich.[e]

Primorskoi (Maritime Province).—This province, as its name, both in Russian and in English, indicates, lies along the Pacific sea-board. In the south of the province near Vladivostock

[a] Glasser, Ann. des Mines, XVIII, Sér. IX, 1900, p. 21.

[b] Yavorovsky, Com. Geol. Russ., 1900, p. 48, Amur.

[c] Ib., p. 90.

[d] Ib., 1901, p. 26.

[e] For a full description of the Amur placers consult Yavorovsky, St. Petersb. Min. Soc., XXXIII, Sér. II, 1896, p. 305; and Levat, "L'or en Sibérie Orientale," Paris, 1897, vol. II.

are several auriferous occurrences. On the island of Askold, 37 miles east of Vladivostock, a gold-quartz lode lies between quartzites and crystalline rocks. The lode is composed of several very thin, generally parallel, veinlets. Normally, there are two main veinlets, 1 to 4 inches wide and 12 inches apart. The average tenor is 33 dwts. per ton in a shoot from 130 to 160 feet long. Beyond the shoot the tenor falls to a little under an ounce for nearly 500 feet. In depth the veinlets appear to weaken. To 1902 £32,000 gold had been extracted from the mine.[a] Another auriferous vein has been worked at Nakhoda, 25 miles east of Askold Island, and on the mainland. Auriferous placers occur a little distance both to the east and west of Vladivostock ; west of Lake Khapka, and along the Imani river, but all are of little present importance.

The placer deposits of the northern portion of the Primorskoï province are, on the other hand, of considerable value. The richest are on the head-waters of tributaries of the Amgun, which joins the Amur very near Nikolaevsk and the sea. These were first worked in 1872, but then yielded little. Towards 1891, richer beds were found, especially on the Semi, Kerbi, and Nimelien tributaries, and for a few years the annual output was some 64,000 ounces. From 1891 to 1904 the Amgun region produced 739,450 ounces (23,000 kg.) gold. Other alluvial placers occur near Lakes Orel and Tchlia, to the north-west of Nikolaevsk.

The Kerbi, Nilaw, and Semi, with their various tributaries having their sources in the Lesser Chingan mountains, form the Upper Amgun auriferous region. Their areas of erosion, unlike those of the other rivers of the Amgun system, which flow through granite hills, are exclusively in crystalline schists and phyllites. In the Semi valley itself the length of the workable deposit is 6½ miles, while in its tributary streams 5·9 miles are available. In the richest part (Rozhdestvensky) of the valley, the auriferous gravels have a total width of nearly half a mile, with a workable width of a quarter of a mile. The overburden (*torf*) is about 13 feet, and the pay-gravel (*plast*) from 5 to 7 feet in thickness. In many places, however, and especially in the smaller valleys, gold is found in fairly large grains directly under the surface soil. The tenor of the pay-gravel is extremely variable. It may vary in small patches up to one and even to 3 ounces per cubic yard, but the average yield of the gravels hitherto washed has been from 1½ to 8 dwts. (2·6 to 12·7 grams.) gold per metric ton. The gravel washed during 1906 had a tenor of 1 to 1½ dwts. (1·9 to 1·6 grams.) gold per metric ton. Nuggets weighing from ½ dwt. to 3 dwts. are numerous, and they are occasionally found up to 3 ounces in weight.

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[a] Bordeaux, Ann. des Mines, II, Sér. X, 1902, p. 544.

The largest found weighed nearly 26 ounces. The gold found is often crystallized, with sharp, well-defined edges. Its fineness varies from 910 to 952.[a] All the Primorskoi placers hitherto discovered have been Pleistocene in age. They appear to have derived their gold from gneisses and crystalline schists.

Scattered auriferous deposits occur further north, along the shores of the Sea of Okhotsk south-west of Port Ayan ; at Okhotyek ; and at the base of the Taigonoskaïa Peninsula. Gold also occurs in limited quantities in Kamchatka itself (Lat. 55° N. and Long. 127° E.). Bogdanovitch and Lemiakin found auriferous gravels near Ayan on the banks of the Aikaschra river. These were made up of the débris of volcanic rocks and carried nuggets of fine gold.[b]

Recent explorations, instigated by the discovery of the extremely rich placer deposits of the neighbouring Seward Peninsula in Alaska, have led to the discovery of auriferous alluvial gravels near Cape Deshneff (East Cape) on the Chukchi Peninsula, the most easterly land projection of Asia. They occur on the Thunilthan river, not far from its mouth, and a few miles south-west of Cape Deshneff. The bed-rock is metamorphic, mainly mica-schist and clay-schist. The gravels are not very rich, averaging perhaps only 6 grains per metric ton. Their value is therefore, to judge from present information, inconsiderable.[c]

ASIA MINOR.

Numerous small veins of auriferous mispickel are found in western Asia Minor, especially in the neighbourhood of Mount Tmolos, on the northern slopes of which, near Sardis, were the streams of the golden Pactolus of the Greek historians. Their sands are reputed to have furnished the wealth of Croesus, but their gold content, probably never great, despite the stories of the ancient writers, was exhausted long before the Christian era. The strongest mispickel vein observed in this neighbourhood was of low-grade quartz 15 feet wide, but the majority are smaller and richer. The gold content varied from a trace to a little over three ounces, but none of the richer veins were sufficiently large or permanent to warrant working.[d]

North of the Bay of Smyrna, and in the neighbourhood of the Dardanelles, extensive ancient workings have been discovered. Those at Serdjiller, 12 miles from the Dardanelles, correspond

[a] Maier, Zeit. für prakt. Geol., XIV, 1906, p. 101.

[b] Zeit. für prakt. Geol., IV, 1896, p. 456.

[c] Korsuchin, Zeit. für prakt. Geol., XIV, 1906, p. 380.

[d] Thomæ, Trans. Amer. Inst. M.E., XXVIII, 1898, p. 216.

fairly closely with the site of the ancient Astyra. The country of the old workings is mica-schist overlain and intruded by Lower Tertiary igneous rocks. These latter were termed "trachyte" by Tchihatchef (1867), but have been referred by Diller,[a] English, and Flett,[b] to liparites, mica- and hornblende-andesites, augite-andesite, and basalt. The andesites were usually much decomposed. There would thus appear to be some analogy, and indeed a possible genetic connection between this auriferous area and those of Transylvania and of Eastern Servia. The quartz veinlets in the volcanic rocks carry argentiferous galena, blende, pyrite, chalcopyrite, stibnite, and a little free gold. The gold content is, however, very low. The mines north of Smyrna were opened up by an English company in 1900, but though a considerable sum was spent no gold was obtained.

The only important gold mines in Asia Minor are those of Bulgar Ma'aden in the Boulgar Dagh mountains. (Long. 32° 20′ E.; Lat. 37° 25′ N.) Their rocks appear from Tchihatchef's map (1867) to be Lower Tertiary sedimentaries, with dolerite in the vicinity. The veins are galeniferous, yielding 21 per cent. of lead. The smelted lead may carry as much as 296 ounces silver and 2¾ ounces gold per ton. The yield of the mines for 1901 was 401 tons litharge, 263,983 ounces silver, and 343 ounces gold.[c] These mines are worked under a Turkish *irade* of 1821 by the peasants, but are nevertheless the property of the Crown. The buying of the produce is a Government monopoly, the Government giving 12¾ piastres (2s. 7d.) for each dirhem (2 dwts.) of gold (?).[d]

South of Trebizond, at Gumesh-Khana (Long. 39° 25′ E.; Lat. 40° 30′ N.) are auriferous silver mines, apparently associated with igneous rocks. Alluvial gold occurs in the Dumludagh range, north of Erzeroum (a diorite area on Tchihatchef's map).

ARABIA.

No gold mines are known to exist in Arabia. The only available information is a statement of Capt. Burton that gold is to be found near Muwaylah in the Hejaz district.[e]

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[a] Q.J.G.S., XXXIX, 1883, p. 627.

[b] Ib., LX, 1904, pp. 254–276.

[c] Simmersbach, Zeit. Berg-Hütten und Sal. Wesen, LII, 1904, p. 540.

[d] Wylie, Cons. Rep., 1907.

[e] Burton, "The Gold Mines of Midian," London, 1878.

PERSIA.

Persia also appears to be devoid of important auriferous deposits. In 1899 a British company was formed to work the metalliferous deposits of the country. Its operations resulted in failure. Old gold placers, now exhausted, occur between Nishapur and Meshed in the Binalud mountains. The copper veins of Far Dáod, near Bosmishk, are said to have yielded 7 dwts. gold per ton.[a] Gold is said to occur in the granite and crystalline schist of the Elwund mountain, near Hamadan (the ancient Ecbatana); in the vicinity of Teheran and Shah Abdul Azim; and near Galügo.[b] Veins in mica-schist were formerly worked near Meshed in the Binalud mountains. Ancient gold washings are reported from Kawend, west of Zengan and south-west of Reshd.[c]

BALUCHISTAN.

Gold is absent from Baluchistan, so far as is known at present. In Seistan, to the north of Baluchistan proper, and towards the south-west corner of Afghanistan, gold may possibly occur, for old Mahommedan records, in other respects fairly accurate, relate that a vein of gold was found there in 998 A.D., and was worked until the reign of Musaud (1031-1042 A.D.), when it was destroyed by an earthquake.[d]

AFGHANISTAN.

Gold, both vein and alluvial, has long been worked in Afghanistan. Gold-quartz veins, apparently forming a stockwork, occur three miles north of Kandahar city. They traverse a zone of contact between hippuritic limestone and trap (andesite ?). The country is greatly decomposed, so much so that it is impossible from the examination of the specimens collected in 1880 and now deposited in the Calcutta Museum, to determine definitely the original nature of the rock. It is probably, however, to be grouped with the intrusive Eocene andesitic or dioritic rocks that occur elsewhere in Afghanistan. The gold is coarse, and generally lies in vughs.[e] An immense number of veinlets run through the rock,

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[a] Hennecke, Zeit. für Berg-Hütt. und Sal. Wesen. XLVII, 1899, p. 272.

[b] Tietze, Jahrb. Geol. Reichanst., XXIX, 1879, p. 648.

[c] Schindler, Ib., XXXI, 1881, pp. 171, 179, 188.

[d] Briggs, "Mahommedan Power in India," I, p. 33.

[e] Bellew, "From the Indus to the Tigris," London, 1874, pp. 137–140; Griesbach, Memoirs Geol. Surv. India, XVIII, 1880, p. 86.

and pieces of gold as large as an almond have been picked out. The mine was discovered in 1860, and yielded well for the first two or three years. Later, it was farmed out for Rs. 5,000 (£500) per annum. The annual return was said to be £1,000, but the mine was, nevertheless, worked only at intervals. Work ceased when the open-cast pit had reached a depth of 80 feet. At that depth the sides fell in and killed the workmen, who were notoriously unskilled miners.

Alluvial gold is reported from the Hazara country; from the neighbourhood of Istalif, about 20 miles north of Kabul; and from the Kohistan country generally, but the quantity obtained is probably insignificant. Deposits analogous to those already described north of the Panj river, in Bokhara, may also be reasonably expected to occur to the south of that territorial boundary.

TIBET.[a]

Tibet is the only one of the world's goldfields now remaining closed to modern enterprise, and even to scientific examination. The vast gold-bearing area of south-western Tibet stretches east-south-east from Rudok, near the Ladakh frontier, towards the Zilling Cho, with an indefinite extension towards the north, but certainly as far as the northern slopes of the Kuen-Lun Mountains. No mining engineer has seen its workings, no geologist has examined its rocks. The following is believed to comprise the sum of our available information on the gold deposits of the region.

The earliest positive reference to Tibetan gold is contained in the "Kitabu-l-Akhbar" of 'Ubaidu-l-lah (*circa* 900 A.D.). He quotes the old tradition of the invasion of Tibbat (Tibet) by the Hamiri rulers of Yemen in Arabia. One Sabit, their viceroy, was incited thereto by the following passage from a letter describing the country of Tibbat: "One of the Tubba'yawa (the rulers of Yemen) set out towards the east, and used great efforts until he reached a country, the verdure of which was gold, and its earth musk, and its herbage incense, its game the musk deer, its mountains snow, and its plains most pleasant." Needless to say, Sabit went, and, according to the chronicle, found that it was so.

The first European traveller to Central Asia of whose journey a record has been preserved, was William de Rubruquis, a Fleming born near Brussels, who was sent in 1253 A.D. on a Papal mission to the Tartars. He was himself never nearer Tibet than Karakoram, but mentions having at that place met one William Bourchier, a

[a] Maclaren, Min. Jour., LXXI, 1907, p. 826.

Parisian goldsmith, who had resided for some time in Tibet at the gold mines of "Bocol." It is probable, as Sandberg suggests, that "Bocol" is identical with Bokalik (Long. 91° E., Lat. 36° 28′ N.), where both Carey and Bonvalot report gold diggings. Seventy-three years later Lhasa itself was visited by Friar Odoric of Pordenone. In his narrative, which was dictated in Padua in 1330 A.D., and which, together with that of Rubruquis, supplied the compiler of "The Travels of Sir John Mandeville" with much of his material, there is no mention of gold in Tibet, but as the friar's route from China did not pass by any goldfields now known, the omission has no great significance. The famous Marco Polo was never in Tibet itself, but travelled both to the north in Chinese Turkestan, and to the east and south-east in China, and merely reports the existence of gold in Tibetan territory.

We turn again to a Mussulman chronicle, the "Tarikh-i-Rashidi" of the Mirza (Prince) Muhammed Haidar, a viceroy of Tashkend, who, proclaiming a *jehad*, led, about 1530, an expedition into Tibet. Haidar's avowed object was to burn and utterly destroy Usang or Ursang (Lhasa), a seat of infidel error, and so an accursed object in the sight of all true believers. He failed signally, defeated by the Arctic rigour of the country, and, with a few followers, finally escaped with difficulty. His chronicle is somewhat discursive, but the words of the translator[a] are here quoted: "Among the astonishing things of Tibbat, one is the gold mines. In most places frequented by the Canbahs (the nomads of Tibet) there are gold mines; indeed, in most of the Tibbat territory there is gold. Among these are two wonderful mines. One is in what is called Altun-ci-Tibbat (golden Tibet ?) by the Mughals, in which some septs of the Dolbah Canbahs, or nomads, work, but on account of the excessive coldness of the air they are not able to work more than forty days in each year. The shafts open on level ground in such wise that a person can enter them; they are numerous, and most of them lead one into the other. It is affirmed that as many as three hundred families at a time continue at all times to dwell in these shafts or holes. . . . In them, likewise, they do not burn any oil, only clarified fat of sheep, in which no tallow is contained. They bring the earth in sieves to the mouths of the shafts, and wash it, and it is said that from one sieveful of earth as much as ten misqals on an average are produced." The modern Persian misqal weighs approximately 4·6 ounces, so that either an ancient misqal or one of another locality weighing much less was used. Raverty estimates the misqal at 1½ drams, and this, again, may be either 41 grains or 90 grains, according to whether avoirdupois or

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[a] Raverty, Jour. As. Soc. Beng., LXIV, 1895, p. 92.

apothecaries' weights are indicated. The Mirza goes on to describe the methods : "The same person digs out the earth, brings it out, and washes it himself ; and in the course of a day can fill and wash twenty sievesful. Although this matter has not been verified and tested by me, nevertheless the statement agrees in every way with the reports current in Tibbat, and therefore it has been recorded here. Another territory is Kokah, which contains some two hundred forts. Its length is three days' journey ; and there is gold to be found in every part of it. They dig out a certain quantity of earth, and spread it out on the face of a cured hide, and pick out the gold therefrom, which is in grains. Some of these grains are of the size of lentils or peas, and it is said that nuggets sometimes of the size of an egg and even of the size of a sheep's liver, or even larger, are found."

We have, indeed, in the "Tabaqat-i-Nasiri" a reference to a very large nugget. Among the presents sent to the Sultan Mahommed by Genghis Khan was a nugget of pure gold "as big as a camel's neck, which had been brought from the mountain range of Tamghaz, so that it was necessary to convey that piece of gold upon a cart." Tamghaz is possibly the Kuen-Lun mountain range. To resume the Mirza's narrative : "At the time that I, the writer of these pages, fixed a capitation tax on the Kokah chiefs, they related that only a short time before, a labourer was excavating in a certain part when the implement he was using became so firmly fixed in a place that with all his efforts he was unable to withdraw it again. He removed the earth from around, and what does he behold but a large stone, and embedded in the middle of it was gold, and the spade firmly fixed therein. Leaving it just as it was, he went away, and informed the Hakim, or Governor, of the matter, when that functionary and those then present with him went in a body to the spot, and took hold of the mass, broke the stone, and 1,500 misqals of pure Tibbati gold were extracted from it, each misqal of that part being a misqal and a half of the usual weight. The gold of Kokah which they extract from the earth is, indeed, so pure that however much it may be assayed and tested, the only loss which arises is that of the right of the fire (*i.e.*, what is lost in treating and melting) ; and this fact is considered astonishing and wonderful by travellers and goldsmiths, and probably nowhere else in the world can such a thing be pointed out."

In 1665, François Bernier, who was then in Kashmir in attendance on the Emperor Aurungzebe, relates in letters to Paris a conversation with the ruler of the countries now known as Ladakh and Little Tibet. "I heard him say that his country on the east did confine with great Tibet ; that it was 30 or 40 leagues broad ; that there was, indeed, some little crystal, musk, and wool, but for the rest very poor, and that there were no gold mines as was said"—a most politic statement when made to a Mughal Emperor. To Bernier's fellow-countryman, Jean Baptiste Tavernier, the tattling jewel merchant, we are indebted for much of our information concerning the India of the seventeenth century; but he merely records the rumour of gold in Tibet, incidentally, however, drawing a picture which must have tantalised his fellow jewel merchants in Paris. "Toward the Thibet, which is the ancient Caucasus, in the territories of a Raja, beyond the kingdom of Cachemir, there are three mountains, close by one another, one of which produces excellent Gold, the other Granats, and the third Lapis-Lazuli."

The Jesuit fathers Grueber and d'Orville, who spent two months in Lhassa in 1662, are as silent as Odoric concerning Tibetan gold, as also are two members of the same order, Ippolito Desideri and the Eurasian, Freyre, who resided in Lhassa from 1716 to 1729. The letters of the fiery and unfortunate Francisco Orazio della Penna, the chief of the Capuchin Order in Lhassa during their long sojourn (1716-1780) in that place, contain the earliest definite information we possess. "There are many goldfields in the provinces of U, Tzang, Tang, Khakpo, Khombo, and Kham, and silver (as far as is known) in the province of Kham."

In 1774 George Bogle was sent by Warren Hastings on a mission to the Teshu Lama. In conversation with Tibetan merchants concerning the products of the country, he was told by them that "as to the products of this country, people imagined from gold being produced in it that it was extremely rich; but this was not the case, and that if extraordinary quantities of gold were sent to Bengal, the Emperor of China, who was sovereign of the country, would be displeased at it." On the death of the Lama in Pekin in 1782, Warren Hastings, with characteristic foresight, sent a second embassy to Tibet, in this case under Captain Samuel Turner. The medical officer associated with him was Mr. Sanders, who published mineralogical and other notes on the journey. Of gold he says: "They find it in large quantities, and frequently very pure. In the form of gold dust it is found in the beds of rivers, and at their several bendings, generally attached to small pieces of stone, with every appearance of its having been part of a larger mass. They find it sometimes in large masses, lumps, and irregular veins; the adhering stone is generally flint or quartz, and I have sometimes seen a half-formed, impure sort of precious stone in the mass. By a common process for the purification of gold I extracted 12 per cent. of refuse from some gold dust; and on examination found it to be sand and filings of iron, which last was not likely to have been with it in its native state, but probably employed for the purpose of adulteration." Notwithstanding this most circumstantial account, it is quite certain that Sanders never saw a Tibetan goldfield, and that the information was gained from the Tibetans, but he would, nevertheless, have abundant opportunities for examination of gold dust, which was then the only form of currency in the country.

The brothers Strachey, who visited the sacred Manasarowar lakes in 1846 and 1848 respectively, reported old gold workings in that neighbourhood. It appeared that the fields to the north were let on a triennial lease, and that the farmer or Sarpon paid for the right 17,000 rupees (£1,700) to the Lhassa treasury. He had some 170 miners at work, but the country in which the mines lay was so inhospitable that nearly all supplies (*satu*, *ghiu*, and tea) were sent

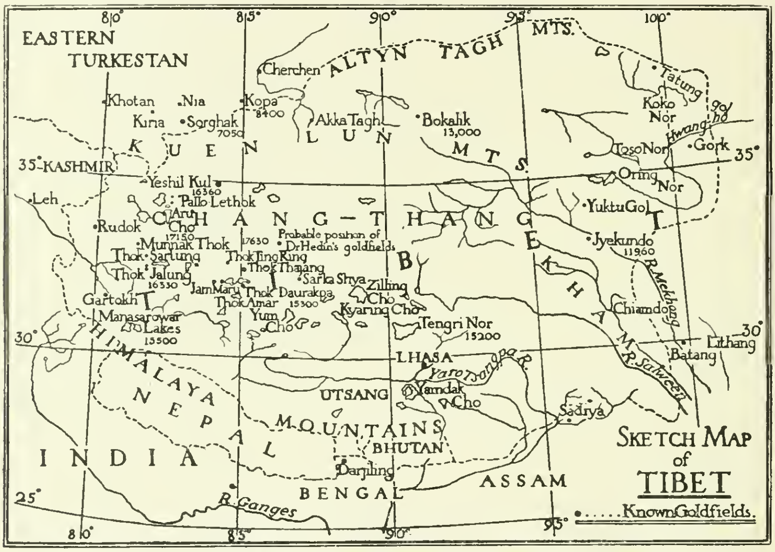

Fig. 89. Sketch Map showing position of Tibetan Goldfields.

from Pruang in Hundes. Occasionally large nuggets were found, and the Lama of Cangri was said to have one weighing nearly 30 ounces.

During 1865 and 1866 geographical explorations of considerable value were carried on by Pandit Nain Singh, one of the most famous of the devoted band of native explorers employed by the Trigonometrical Survey of India to collect information regarding those regions into which a European could not penetrate with safety. Though important geographically, the explorations during these years yield little information for our present purpose. In 1867, however, Nain Singh, together with his brother, who had previously been somewhat of a failure as an explorer, and a third pandit, set out in the guise of Basahris to explore the country along the eastern branch of the Upper Indus. Soon the brother's nerve gave way, and he returned to civilisation and safety. The third pandit went up the Indus, and Nain Singh was now alone. On August 26th of that year, after a most arduous march, he crossed the Chomorang-la (16,670 feet), and finally reached the large camp of Thok-Jalung (Long. 81° 37′ 38″, Lat. 32° 24′ 26·5″), the principal goldfield of the country. He found the camp situated on a wide desolate plain, of a prevailing reddish brown colour. As he approached it his ears were gladdened by the noise of a great number of voices singing together, and on his arrival found that the sound came from the gold-diggers and their families. The goldfield was quite new, and had been worked extensively for some eight or nine years only. According to Nain Singh the workings consisted of a large excavation from 10 to 200 paces in width, and some 25 feet in depth, access to the bottom being by means of steps and slopes, the earth as dug out being thrown up on either side. The excavation was about a mile in length. The digging was carried on with a long-handled shovel, and occasionally with an iron hoe. A very small stream runs through the goldfield, and the bottom of the excavation was consequently rather a quagmire during the day time, but the stream was invaluable for washing. The waters were dammed back, and a sloping channel left for the escape of the overflow. A cloth (felt ?) was spread at (along ?) the bottom of the channel, and kept down by a number of stones, forming an uneven bottom. One man brought earth from the excavation, and sprinkled it over the channel, whilst another drove water down the channel by means of a leather bag. The water carried the lighter soil away, but the pieces of gold fell into the uneven places, and were easily collected in the cloth by lifting up the stones. The yield of gold seems to be large and the finds occasionally very heavy. The pandit saw one nugget about 30 ounces in weight. The diggers say that they can recognise the auriferous gravel at once. The goldfields are carefully watched by the Lhassa authorities and are superintended by a *sarpon* or gold commissioner. The tax levied for the right to dig is one *saršhu*, or about 1 5 ounces (16s.), per digger per annum.

The pandit said that in all his travels he never experienced such intense cold as at Thok-Jalung, owing, he thought, rather to the high wind that was always blowing than to the great elevation (16,330 feet). During the winter the diggers are closely wrapped up in furs, and without them would perish. Their tents, to avoid the wind, are always pitched in pits some 7 or 8 feet below the surface of the ground. Despite the cold, the diggers prefer working in the winter, since then the frozen gravel stands well. The water near Thok-Jalung is so brackish that it cannot be drunk until it has been frozen and remelted. Argols (cattle droppings) are the only fuel. A year after Nain Singh's visit the third pandit travelled to

Rudok, and from thence east to Thok-Jalung. On the way he heard minute descriptions of no fewer than seven separate goldfields—viz., those of Thok-Sarkong, Thok-Dikla, Thok-Ragyok, Thok-Thasang, Thok-Maroobhoob, Gunjee Thok, and Thok-Nainmo, beside those of Thok-Sarlung (Charalung) and Thok-Jalung, which he visited. Thok, it must be explained, is the Tibetan for goldfield. Thok-Sarlung had at one time been the chief goldfield of the district, but had been in a great measure abandoned on the discovery of Thok-Jalung. At the former place the pandit passed a great excavation 30 to 40 feet deep, 200 feet wide, and 2 miles in length, from which the gold had been extracted. At first sight it would appear that this description could fit only the open-cast along the outcrop of a vein, but it is probable that the dimensions of the excavation were governed by the water available, and that the long excavation represents alluvial ground washed on either side of a stream, as apparently is the case at Thok-Jalung.

Nain Singh in a later journey (1873) reached the Thok-Daurakpa goldfields, which were second in importance only to those of Thok-Jalung. The Daurakpa goldfields are 15,280 feet above sea-level, and the diggers dwell in caves called *phukpa*. There were then thirty-two of these, containing each from five to twenty-five individuals. These caves are selected as habitations from necessity rather than from choice, and as a protection from the Khampa brigands, who have an unpleasant habit of cutting down first the tents and then the owners. The caves, on the other hand, are readily defensible. Thok-Daurakpa, unlike Thok-Jalung and Thok-Sarlung, has no long and wide excavations in which all the miners work, but each *phukpa* has its own gold pit. One or two men are generally employed in quarrying the stone in which the gold is found. The pieces of stone are hoisted in baskets to the brink of the pit, and are there pounded into small fragments, which are washed as at Thok-Jalung. From the foregoing description it may be inferred that the Daurakpa workings are in quartz veins, but it is also possible that the gold occurs in a cemented gravel so hard as to require crushing to liberate the gold. Unfortunately, there is no water in the vicinity of the gold mines, and all water for washing is brought from a stream a mile distant in skins on donkeys that are specially kept for the purpose. Nain Singh estimated the value of the gold brought annually into Gartokh at some £8,000 sterling.

Gold mines, generally deserted, have been reported from various places by the explorers who have dashed into Tibet to get as near Lhassa as possible before being stopped and turned back, or who have crossed Tibet to or from China by routes north of Lhassa. These explorers are, particularly, Bower, Carey, Bonvalot, Deasy, Littledale, and Rawling. The diggings visited by the last-named in 1895 were at Pallo Letok (80° 30′, 34° 45′) and its neighbourhood. He heard of a famous goldfield, Munnak Thok (Long. 81° 25′ E., Lat. 33° 10′ N.), which employed 500 miners. In those actually crossed by Captain Rawling, the shallow pits extended for miles in a scene of dreary desolation. They had quite recently been abandoned, for the water races and dams were still clearly and sharply defined.

Of late, attention has been directed to Tibetan goldfields by the report of the discovery of extensive goldfields by the indefatigable Central Asian explorer, Dr. Sven Hedin. An examination of the brief notes supplied by him makes it fairly clear that those newly found are but a northern extension of the already known Thok-Daurakpa and Sarka Shya goldfields. Definite figures for latitude and longitude are not available, but the position of Dr. Hedin's fields is probably about 86° east longitude and somewhat south of the 34th parallel of north latitude.

The most northerly extension of the main Tibetan goldfield is apparently the northern slope of the Kuen-Lun mountains. Gold mining in alluvial deposits has been carried on there certainly for centuries. The principal centres are Sorghak, Kopa, Akka Tagh, and Bokalik. The first of these really lies in eastern Turkestan, and was visited in 1906 by Major C. D. Bruce, during a journey from India to Pekin.[a] Sorghak is described as a squalid place, lack of water and an all-enveloping dust being its chief characteristics. The gravel is worked by circular shafts from 40 to 100 feet deep, apparently, indeed, to "bottom," where tunnels are driven, and the pay gravel sent to surface. Owing to the lack of water Sorghak is a "dry-blowing" field, the sand being winnowed, and the operation finished by blowing the concentrates over felts.

The foregoing auriferous areas are all in Western Tibet. There are two goldfields in Eastern Tibet. The first of these is in the neighbourhood of Koko Nor, in the north-east. According to Mesny, who visited some of these placer deposits, the alluvial gravel is, on an average, 20 feet in depth, but only the bottom gravel for a couple of feet above the rock is worth washing. The gold was coarse, varying in size from that of a turnip seed to that of a pea, while occasionally much larger nuggets were unearthed. The Gork goldfields of Rockhill are also in this neighbourhood (*circa* 101° E. long., 35° 40′ N. lat.). They were discovered about 1888, and were leased by the Hsi-ning Amban (prefect) to a Chinaman for 180 ounces of gold per annum. In less than two years about 3,000 ounces of gold had been taken out. Rockhill records gold also from Yuktu Gol and the Rajong valley south-west of Koko Nor.

[a] Geog. Journal, XXIX, 1907, p. 608.

The Lithang goldfields, also in the east, are not in Tibet proper, but in Chinese Tibet. Here the workings occur along the banks of the Li Chu. About 3,000 ounces are produced annually. The implements used by the washers are very crude, a hollowed-out log serving as a "long-tom." According to Rockhill, the miners make about 3s. 2d. per day, but this is probably too high an estimate.

Between Koko Nor and Lithang is another auriferous area, viz., that of Jyekundo. The washings there are apparently very poor, since one washer obtaining about five-pence worth of gold for four days' work expressed himself to Rockhill as fairly well satisfied.

The outstanding feature of all these Tibetan goldfields is their lack of permanence. Several causes apparently co-operate to cause their desertion. They may be exhausted: new goldfields with greater potentialities may attract the diggers: the fearful influences of *fêng-shui* (*fung-shui*) may be brought into operation: or the diggers may be crushed by the officials. The first and the last of these are probably the most potent. When the Assistant-Commissioner of Kulu visited Thok-Jalung in 1906, he found that field deserted, and was told that all the diggers had gone to Thok-Dalung (*sic*), a day's journey distant. It subsequently appeared, however, that the Jongpen (Revenue Commissioner) of Chaprang had been harassing the diggers at Thok-Jalung. It was his habit to seize all the gold nuggets found, and to pay for them in brick tea at his own valuation. He had even tied up an unfortunate gold digger by the heels, and had him flogged to death.

The reason that for centuries past has been advanced by the Tibetans themselves to account for the desertion of their goldfields is that in each given case the spirits of the earth had been angered and had withdrawn the supply of gold. They have always believed that the nuggets are the roots from which new gold grows, and, according to the lamas, have always replaced some of the gold in order not to deprive the earth entirely of gold seed. The diggers are silent on this last point. The story of the seed gold is first told in detail by William de Rubruquis (1254 A.D.), and has since been repeated by most writers on Tibet. Again, mining in a country hallowed by the graves of their ancestors, is, from the Mongolian point of view, abhorrent to the *fêng-shui*, the spirits of earth and air, who have long been accustomed to certain habitations and will not willingly see them disturbed. Strachey relates that the Manasarowar workings were deserted because a digger there had unearthed a small nugget of strangely human form—clear evidence that the spirits were displeased. Notwithstanding these stories, it may be taken for granted that no really rich field, either in Tibet or in China, is deserted solely from fear of *fêng-shui*.

Of the source of Tibetan gold nothing definite may be said. From the scanty scraps of geological knowledge we possess it may be inferred that the goldfields are associated, as in India, with the Archæan schists and older metamorphics. The strike of the line of goldfields from Rudok to the Zilling Cho, as shown on the accompanying map, would appear to lie northward and parallel to the crystalline axis running through the neighbourhood of Lhassa, as mapped by Hayden when with the 1906 punitive expedition.[a] Again, in the portion of the Western Kuen-Lun mountains known to geologists, the mountain axis is also a metamorphic schist. By the degradation of these older rocks the auriferous gravels have presumably been formed. It has always been a matter of some surprise that, with the drainage from the goldfields apparently falling into the Yaro-Tsangpo, there were no auriferous deposits along that river. The examination of Hayden's concentrates from the Tsangpo,[b] the lack of all mention of gold washings along its course, and the writer's own examination of the river near Sadiya (where it is known as the Dihong) as it debouches from the Himalayas, had sufficiently proved that gold content of the river gravels was unimportant. A new light is therefore thrown on the matter by Dr. Sven Hedin's discovery of a great mountain range between the Tsangpo and the line of goldfields, indicating that the drainage of the latter is toward the great central Tibetan basin and not into the Tsangpo. The eastward trending line of goldfields apparently represents the course of the drainage channel itself.

From the foregoing it will be clear that no opinion may be formed as to the richness or poverty of the Tibetan goldfields. On the one hand, large nuggets are certainly found, and the gold generally appears to be coarse ; but, on the other, the gold diggers are the poorest and most miserable of a poor and wretched people. The gold is certainly widely spread, but the severity of the climate and the difficulties of working are not paralleled even at Nome or at Klondike.

EASTERN TURKESTAN.

Little is known of the auriferous areas of this region. The streams in the neighbourhood of Yarkand, Khotan, and Karakash, all flowing north from the Karakoram mountains, are occasionally auriferous, and give rise to a limited gold-washing industry. The mines of Khotan have already been mentioned under Tibet. They

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[a] Records Geol. Surv., India, XXXII, 1905, p. 160.

[b] Maclaren, loc. cit. sup., p. 173.

are located at Sorghak, Kopa, Chugalak, Charchen, and Karatagh.[a] In 1875 there were said to exist twenty-two places where gold might be found, but of these only the above five were being worked.

In the north-west corner of Eastern Turkestan, gold is found only in the right affluents of the Ili, that flow from the granite ranges of the Dzungaria Ala-Tagh. The Tekes, a tributary of the Ili, is reported to carry a small quantity of alluvial gold.

INDIA.[b]

India offers to the ordinary prospector an extremely uninviting field. Its auriferous deposits, both vein and placer, have been carefully prospected and assiduously worked for at least twenty-five centuries—and that by a people whose skill is noteworthy, and whose patience is monumental. The great spoil heaps of quartz, broken to fragments smaller than a hazel nut, that are numerous in the immediate vicinity of the prospecting works of the ancients, are lasting and sufficient evidence of the great care with which all possibly auriferous quartz outcrops were sampled. No such spoil heaps remain to mark the outcrop of rich veins, for the stone from these was carried away to the nearest water, and, after having been most laboriously reduced to fine powder beneath crushing and rubbing stones, was washed for its contained gold in a rude batea or in a short inclined trough. Prospecting for gold veins in India, therefore, resolves itself into a search for old workings, and in this quest the dolly and pan are useless. An eye keen to detect abnormal depressions in the black cotton soil of the Mysore and Hyderabad plateaux, an ability to trace the schistose belts in which the quartz veins lie, a colloquial knowledge of a Deccan language (preferably Kanarese), and finally sufficient guile to extract information from the unwitting ryot, these are all better aids towards success. Indications of the proximity of gold-quartz veins are sometimes afforded by the presence of the rude stone pestles, mortars, and crushing mills of the ancient miners. The schists in which the veins occur are soft and easily weathered ; often the only hard rock in a schistose region is an intrusive diabase. At points along such a dyke there may be found on its surface numerous cup-shaped depressions, 4 or 5 inches across, and about the same in depth, in which the larger fragments of quartz were broken to the size of a pea before being triturated to dust beneath a stone held in the hand and rubbed backwards and forwards, or beneath great spherical or rudely

[a] Forsyth, "Mission to Yarkand," 1875, p. 475.

[b] Maclaren, Min. Jour., LXXXIV, Aug. 15, 1908, p. 198.

cylindrical rocking stones weighing from a hundredweight to nearly a ton, and worked in all probability by women. The rocking stones leave smooth-faced shallow depressions in the bedrock that are easily recognised by the practised eye. Near Wondalli, in the Nizam's dominions, many huge, rudely spherical, granite boulders that had served as crushing-mills in ancient times were formerly dotted over the quartz-strewn surface. Of these only two now remain, the remainder having been split by unimaginative stone-masons to build the bungalows of a long-defunct gold-mining company. The actual position of the anciently worked vein is often deeply masked. The Southern Deccan, owing to lack of rainfall, is practically treeless, but forms on its surface a thick black soil, commonly known as "cotton soil." From the same lack of rainfall the contour of the surface of the auriferous country where not actually flat is gently undulating, especially when the schists possess no strengthening ribs of hard banded-quartzite to aid them in their struggle against denudation. Under such circumstances, the old pits are soon filled in, and all traces of ancient working are completely obliterated. It was only by noting the existence of a short chain of slight depressions in the cotton-soil that the now well-known Hutti mine was discovered, for over its workings there had been grown many a crop of *jowari* and of cotton. A single depression would have completely escaped notice, and as a matter of fact the chain did not suggest a mine until 1900, although the district had been known to be auriferous, and had, indeed, been prospected for some thirteen years. Even when found the tenor of the quartz in many of the old workings is far too low to justify exploitation under modern conditions, for there can be little doubt that these ancient mines were worked by slave labour. Where, however, the veins were really rich, as at Kolar and at Hutti, they have been followed down for great depths, in the latter case to 620 feet below the surface, probably the greatest depth to which the ancients reached in their search for gold, and a depth the more remarkable in view of the hardness of the rock and of the crude methods of mining and hoisting then in vogue. Fragments of charcoal in old levels and marks of fire on abandoned faces show that the laborious method of "fire-setting" was practised.

India has, through all the ages down to the nineteenth century, been regarded as a land superlatively rich in gold. It was, for example, long thought to contain that Ophir from whence Solomon drew his stores of gold—an assumption considered to be finally proved by various arguments advanced by the most famous philologist of the last century. But these philological arguments are now deemed of doubtful validity, and with every advance on our knowledge of the history of ancient India, it becomes more and more certain that, wherever the ships of Tarshish journeyed, it assuredly was not to the coasts of India. It is highly improbable, considering the comparatively advanced state of civilisation prevailing in Southern India in the days of Solomon, that the voyagers could have landed on its shores other than as mere traders. That they could have occupied the country and worked its gold mines is inconceivable ; and, as traders they could have taken nothing to India with which to appeal to the inhabitants of that self-contained country except gold and silver—the very commodities they are supposed to have brought away. Even four centuries before the Christian era India was famous as an absorbent of gold and silver, and in later centuries even to the present time the flood of gold has always steadily set eastward towards Hindustan—a country, indeed, termed "the sink of gold" by a writer of the Middle Ages. It may be concluded, therefore, that the enormous hoards of gold that have fallen as booty to various conquerors in India, have resulted from the long-continued operations of trade, and are in no wise indicative of rich mines within the country. The Ophir fable, as regarding India, was vigorously exploited from 1877 to 1879, in order to boom the ill-fated mines of the Wainaad, near the Malabar coast, where hundreds of thousands sterling were recklessly squandered in useless work and useless machinery, and millions in promotion money.

Again, India is the home of the gold-digging ants of the Greek historians—a story that, notwithstanding many attempts at elucidation, is to-day an even greater mystery than it was to Herodotus more than 2,300 years ago. For these ants lived in the parched sandy deserts of Northern India, and collected gold in great quantity at the mouths of their burrows ; and so large and fierce and swift were they that the gold they gathered might be collected by the Indians only by stealth and subtlety. Space forbids the discussion of this interesting story, which is repeated, with additions in his own inimitable fashion, by the ingenuous chronicler of the travels of Sir John Mandeville. Notwithstanding the dicta of Professor Schiern and Sir Henry Rawlinson, who place the scene of the labours of the ants amid the snows of the Tibetan plateau, it is considered by the present writer, from the internal evidence furnished, that, if the story is to be accepted at all, its deserts are to be placed, not on the Chang-thang—the desolate wind-swept plateau of Tibet—but in Eastern Turkestan, in the neighbourhood of Yarkand.

From the time of the Greek historians down to the nineteenth century, nothing is known of the history of the gold mines of India. Of all the ancient civilised peoples of the world, the Hindu has proved the worst historian. Possessing several scripts, he nevertheless, as a chronicler falls far behind the Polynesian, dependent only on oral tradition. It was not, indeed, until the advent, about 1000 A.D., of the Musalman conqueror, Mahmud of Ghuzni, through the eastern passes of Afghanistan that historical record lifts the curtain thrown over events in India. But detailed as the subsequent Musalman accounts are, there is in them no mention of the ancient gold mines of Southern India. It is certain that they were being worked in the beginning of the Christian era. Pliny (A.D. 77) says : "In the country of the Nareæ (Nairs), beyond the mountain Capitalia (Mount Abu in Rajputana), there are numerous mines of gold and silver in which the Indians work very extensively"—a description perhaps sufficiently specific to indicate the gold mines of Hyderabad and Mysore.

The first Mahomedan invasion of the Deccan was made by the Khilji emperor, Ala-ud-din, in 1294 A.D., and from thence a fairly connected account of the course of events may be made out from the gossipy chronicles of various writers, and notably from those of the cultured Persian, Mahomed Kazim Ferishta, who wrote at great length in Bijapur about 1600 A.D. Quoting from an old record, he describes the delight with which Ahmed Shah Wully Bahmani in his campaign of 1425 A.D. obtained possession of an unimportant diamond mine at Kullum, but nowhere is there any mention of gold or of gold mines. That this neglect was not due to indifference towards the subject is evident from the fact that he describes the discovery, in 998 A.D., of a now unknown gold mine in far-away Seistan in South-western Afghanistan, and also mentions the trifling gold-washings of Kumaon in Northern India. Further, the great Vijayanagar empire, against which the might of the confederated Mahomedan kingdoms strove so long in vain, and which alone saved Southern India from Mahomedan domination, does not appear to have derived any of its wealth from gold mines. Retaining, as it did, practically undisturbed possession of the auriferous areas of Gadag and of northern Mysore from the beginning of the fourteenth to the middle of the sixteenth centuries, it is in the highest degree improbable that, had the gold mines been worked at any time during the existence of the empire, at least their position would have remained unknown to the rapacious Mahomedan invader. Nor are gold mines mentioned by any of the numerous European adventurers—Nicoli di Conti, Varthema, Federici, Nikitin (1470), or Barbosa (1508)—whose way from Goa to the capital city of Vijayanagar, then at the height of its glory, led them so close to the mines at Gadag. The Vijayanagar empire was swept out of existence in 1565 A.D. at the bloody battle of Talikota, a small village lying some distance across the Kistna river from the Hutti mines. It may, therefore, be finally concluded that the ancient gold mines of Southern India were forgotten by 1300 A.D., thus rendering it probable that they were not worked, at least on a large scale, subsequent to 1000 A.D. At Kolar, however, it is known that pillar-robbing and rooting among the ancient workings was practised in desultory fashion even at the end of the eighteenth century.

Geology.—Except on the edge of the Western Ghauts, the auriferous vein areas of India lie on a broad treeless plateau about 2,200 feet above sea-level. The rainfall varies with proximity to the coast, the central portion of the plateau receiving always less than 20 inches per annum. The known gold belts of Southern India, with one doubtful exception (Wainaad), lie in the Dharwar (Transition) series of Archæan rocks, which rest, so far as can be seen, on a gneissoid granite. The relations of the Dharwar schistose rocks to the granite are far from clear, and are further obscured by the presence of younger granites intrusive both into the gneiss and into the schists, but into the latter generally only along or near their gneiss contacts. Various views have been held as to these relations and the question remains an open one; but the simplest, and the most probable, is that the gneiss is the ancient granite floor on which the lavas and sediments now forming the schistose complex were deposited.

The Dharwar rocks are typically developed as a series of long, narrow, fairly parallel belts, extending from near Belgaum in the Bombay Presidency, and from the Kistna river in the Nizam's dominions, southward through the Mysore State. The northern extension of the Dharwar bands is in nearly all cases concealed beneath Cambrian or pre-Cambrian quartzites, or beneath the Deccan Trap. Five main bands may be distinguished, and are here enumerated in their order from west to east :—

I. The Castle Rock Band.—This band lies along the eastern frontier of the Portuguese territory of Goa, and probably extends towards the south-south-east to join the schist band shown by the work of the Mysore Geological Survey to exist near Honnali. It may also be continuous as far south as the scarp overlooking Mangalore, but very little is known concerning its extension, since it lies in a region of heavy rainfall, and consequently of dense jungle. In the north, however, where it was most closely examined by the writer, it appears to contain the least metamorphosed members of the Dharwar system, viz., dolomitic limestones and quartzites, the latter only occasionally becoming quartz-schists. No auriferous veins have as yet been found along this band.

II. The Dharwar-Shimoga Band.—This band emerges from beneath the Deccan Trap in the neighbourhood of Belgaum, runs south to the station of Dharwar (from which the whole series was named by Foote), enters Mysore territory near Harihar, and passes south by Tarikere until it finally frays out in thin bands. The supposed Dharwar rocks of Coorg and of the Wainaad, are possibly

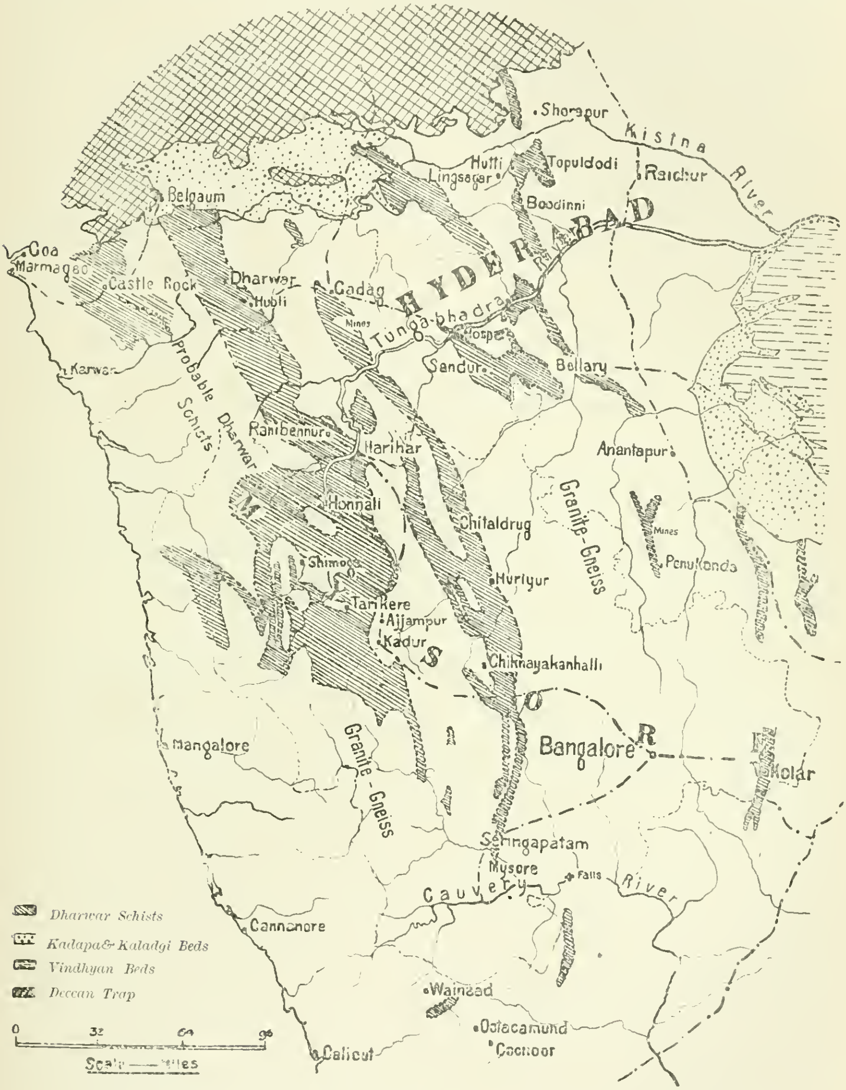

FIG. 90. SKETCH MAP, SHOWING DHARWAR SCHIST BANDS IN SOUTHERN INDIA.

outliers of this great band. Ancient gold workings are known on it west of Ranibennur, and in the Mysore State near Ajjampur. The rocks of the band were, on the whole, evidently original sedimentary deposits, being now mainly chlorite-schists.

III. The Gadag-Seringapatam Band.—This is one of the longest and best-defined of the Dharwar belts. Omitting a small northern outlier at Nargund, it may be said to commence near the town of Gadag, and to have a general south-south-east trend, passing by Chitaldroog and Huriyur, and swinging to the south-south-west as it approaches its southern termination near Seringapatam. Several mining districts occur along the course of this band. The chief is that of Gadag, but numerous old workings are known, and have been re-opened, in the Tumkur district of Mysore. The country of the gold-quartz veins of this belt is an original sedimentary rock, now mainly chlorite-schist and argillite, but associated with boulder beds, and, in the south, with dolomitic limestones. The Nanjangud auriferous area south of Seringapatam is probably on this belt.

IV. The Hunugund Band.—This strikes across the south-west corner of the Nizam's dominions to and beyond Bellary. No auriferous veins are known along its course, although old workings, possibly for gold, occur near Tarwaragheri.

V. The Maski Band.—The Maski belt lies entirely within the Nizam's dominions, between Raichur and Mudgal, and for the most part south of the Kristna river. It comprises three disconnected portions, of which the central one containing the Hutti, Topuldodi, and Wondalli mines, is alone of economic importance. The principal rocks are here hornblende-schists.

In addition to the main bands above outlined there are several smaller bands. The largest of these, in the Sandur State, contains extensive deposits of lateritic manganese. Of the smaller, the Kolar and Anantapur belts are alone of importance. It is from the former, of course, that nearly all the gold obtained in India during the past twenty years has been derived. The main bands and outliers alike apparently represent the bottoms of great earth folds generated by a pre-Cambrian east-north-east—west-south-west compression ; but there is also evidence that some may owe their preservation to faulting down. Speaking generally, the schistosity of the Dharwar belts decreases from east to west ; and, further, on passing from east to west sedimentary rocks assume greater and greater importance, until on the Western Ghauts igneous rocks are rare. Since the work of Mr. R. B. Foote in 1886, and with the exception of a season's work by the present writer in 1904–5, nothing has been done towards demarcating the boundaries within British India of these important belts. In the State of Mysore, however, the disposition and character of the Dharwar bands are well known, owing to the excellent work of the members of the Mysore Geological Survey.

The Dharwar series is a complex aggregate of highly metamorphosed rocks, which are yet not so greatly altered as to render it impossible to discern the original nature of some of its constituents; and a separation into igneous and sedimentary members is often practicable. Of the relative ages of the two little can be said. Among the more easily recognisable sedimentary rocks are boulder-beds or "conglomerates," pebbly grits, quartzites, argillites, chloritic schists, and limestones. The boulders of the boulder-beds are embedded in a chloritic schist matrix, and are seldom so closely aggregated as to deserve the term conglomerate. The quartzites are in places metamorphosed into quartz-schists. They are often, and especially in the Castle Rock Band on the edge of the Western Ghauts, horizontally bedded, but yet, in conformity with the prevailing direction of pressure, they have had impressed on them a distinct north-north-west—south-south-east schistose cleavage. Since the bedding and cleavage are very nearly of equal value in their resistance to weathering, the same bed often shows within a few yards a sudden transition from horizontality to a steep north-easterly dip, the last being that of the foliation. Limestones are not abundant, and reach their greatest development in the dolomitic members of the Castle Rock Band that underlie the above-mentioned quartzites. The limestones contain in places thin interbedded bands of chrysolite, which show by their numerous contortions and intense crumpling that they have yielded by physical displacement to a lateral pressure that, owing to chemical reconstitution of the lime and magnesia carbonates, has left no visible effect on the limestone. Another exposure of limestone occurs at Dodrampur, south of Chiknayakanhalli, in the Mysore State. By far the most characteristic rock of the series, only to be found, as far as the writer is aware, in the sedimentary division of the Dharwars, is a well-banded, generally much contorted, hæmatite-magnetite-quartz rock of obscure origin. This rock, though forming but a relatively small proportion of the complex, yet exercises a most potent influence on Dharwarian scenery. Its superior hardness enables it to form the mountain ridges of the belts while the softer chloritic schists and argillites, with which it is in India invariably associated, sink down to intervening valleys and plains. These hæmatite-quartz rocks, and consequently the mountain ridges, invariably conform to the general strike of the foliation.

The great degree of contortion shown by them indicates that they have shared in all the metamorphism to which the Dharwars have been subjected, and further that if, as has been assumed by some authorities, they owe their origin to silicification along shearing planes, such silicification took place long prior to the period of greatest metamorphic activity. But shearing planes are compatible only with great dynamic movements, such as are known to have taken place in this region long after the formation of the hæmatite-quartz bands. The most reasonable explanation of the origin of these peculiar rocks is that suggested by Van Hise in regard to not greatly dissimilar American occurrences. He supposes that they represent original highly ferruginous shales, that, owing to a re-arrangement of the component minerals proceeding from the natural segregative tendency of iron oxides and of silica, formed, before they were depressed below the reach of oxidising influences, normal ferruginous cherts containing simply limonite and cherty matter, more or less banded. Passing from the upper zone of weathering, and being subjected to the stress of orogenic movements, the bands were contorted and subjected to active dehydration, which converted the limonite into hæmatite. Where pure iron carbonates, such as are now found at the surface in many Dharwarian areas, occurred with the limonite the depression into the region of sulphide waters produced magnetite. Where, however, the descending iron carbonates were not pure, but contained lime and magnesia, and came within the influence of silicious waters, actinolite, grünerite, or kindred minerals were formed. Such, no doubt, was the origin of the gedrite-bearing rocks described by the Mysore Geological Survey. The banding of the quartz-rock is occasionally so fine as to be resolvable only under the microscope.[a] Similar rocks are known in the Archæan rocks of Western Australia and in Rhodesia; they have recently been described from the latter country under the designation of "banded ironstones." In Western Australia they are known as "laminated quartzites."

The members of the Dharwars derived from igneous rocks are mica-schists, hornblende-schists, certain chloritic schists, amphibolites, felsites, and quartz-porphyries, representing probably a succession of fairly basic to acidic rocks, such as may be met with in many a younger volcanic region. The origin of the mica-schists is not clear, but some of the hornblende-schists retain sufficient of the original structure to indicate their diabasic nature, while in some light-coloured varieties the ophitic structure is so clear that the rocks may fairly be termed diabase-schists. Where they have been influenced by the intrusion of younger granites, the hornblende-schists lose their schistose structure, and by reconstitution of their fragmentary felspars and hornblendes, assume a truly dioritic habit. No trace remains of original pyroxene, but certain hornblende-schists, and notably those of Kolar, when near the intrusive granite, contain veinlets of secondary augite, which, in the sections in the

[a] Maclaren, Trans. Inst. Min. Met., XVI, 1907, p. 1.

writer's collection, appear to owe their origin to pneumatolytic action.

Throughout the whole Dharwarian series, as well as through the adjacent crystalline rocks, there ramify numerous diabasic and doleritic dykes that, showing no schistose structure and no trace whatever of deformation, are obviously later than the period of the final metamorphism of the enclosing rock. They may, however, be correlated with some degree of probability with certain lava flows in the Cheyair group of the Lower Cuddapah System. The microscopic characters of these flows have been described with some detail,[a] and their petrographic similarities to the dykes of the Madras Presidency pointed out. Their similarity to the dykes of Western India is no less striking, an augite-diorite lava group perhaps representing best the majority of the western dykes. The determination of the age of these dykes is a matter of some importance, as will be seen later when considering the two periods of Indian auriferous activity.

In India, outside the typical southern areas, the only rocks that may reasonably, on the evidence available, be grouped with the Dharwars, are the auriferous schists and phyllites of Chota Nagpur, and probably also those of the great Araválli system of N.W. India. The Aravállis possess the same general direction of foliation as the Dharwars, and have been apparently subjected to the same compressive force. To the foregoing rocks it may eventually be found necessary to add the schists of Behar and of Shillong, in the north-east of India.

The relations of overlying rocks to the Dharwars are those of absolute unconformity. Where contacts have been observed, the younger Transition beds lie horizontally, or at low angles, on the upturned and denuded edges of the Dharwars. The latter have suffered from long æons of dynamic metamorphism; the former have hardly been disturbed, preserving, for example, at the ancient hill fort of Nargund, even their ripple-markings as clearly defined to-day as when they were first laid down on the shores of a Cambrian sea. An enormous gap in time is therefore indicated by this unconformity.

The younger rocks contain no fossils and are perhaps Cambrian or even pre-Cambrian in age. They are, in the main, slates, conglomerates, and quartzites, the last being occasionally so little compacted as to rather deserve the name of sandstones. In their typical areas they are preserved in broad basins—the chief being the Cuddapah (Kadapa), and the Kaladgi basins. The representatives of these rocks in Northern India must be sought for in the Bijawars (Gwaliors).

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[a] Lake. Rec. Geol. Surv. India, XXIII, p. 259; Holland, Ib. XXX, p. 16.

The auriferous quartz veins of the Dharwars may most readily be divided into two groups : (*a*) those which occur in hornblendic schists, and (*b*) those occurring in argillites and chloritic schists. The best known of the former are those of the Kolar goldfield in Mysore, and of the Hutti field in the Nizam's dominions. The latter division includes those of the Gadag field and the Dharwar belt proper. A closer examination, however, shows that the veins are capable of a genetic, and therefore a better, classification, indicating two distinct and long-separated periods of auriferous activity. The first is to be associated with the period of the general dynamic metamorphism of the Dharwars, and finds expression in the veins of bluish-grey to bluish-black quartz that furnish the gold of Kolar and of Hutti. Microscopic sections of this quartz, especially from the Hutti mine, show that it has been subjected to all the metamorphism that has affected the enclosing rocks. Its structure is decidedly schistose, and its dark colour may be considered to be due to total internal reflection from strain surfaces. Its gold is nearly always internal, a certain proof of contemporaneous deposition of gold and of silica.

The second period of auriferous activity may with equal clearness be associated with the great intrusion of diabasic and doleritic magmas already shown to have occurred in Lower Cuddapah times. The heat furnished by these dykes set in motion siliceous solutions carrying gold, and the white quartz veins of Kolar, Hutti, and Gadag were the result. On the first two fields the white quartz is often found in the same fissure as the older dark variety, doubtless deriving some of its gold from the latter. When examined under the microscope the white quartz shows no trace of schistose structure and no further strain phenomena than are normal in the quartz of ordinary veins.

The veins of both periods show a decided tendency towards lenticular and overlapping structure—the world-wide characteristic of quartz veins in schistose rocks, and indeed the natural result of deposition along foliation planes. On the Gadag field the younger are the more important veins, occurring in a carbonaceous argillite, which is studded, as might be expected, with pyrites. The quartz lenses of the area are connected by graphitic lode-formations, and the main Gadag reef system appears to lie within what was originally a highly carbonaceous band in the argillites. In the older quartz veins the gold-quartz occurs in "shoots," those of the Kolar vein furnishing probably the best example known of this form of aggregation of gold.

No strong or well-defined veins have been found associated with the Dharwars of Chota Nagpur in Northern India. The few that have been determined are small and poor, and evidently fall within the second or younger group, as outlined above. They are associated with a tremendous dioritic outburst not greatly dissimilar from those already described, and which, known as the Dulma Trap, sweeps in an arc of a circle through the Singbhum Division. No auriferous veins are known to occur in the Aravállis of North-West India.

Kolar.—The Kolar goldfield lies about 2,700 feet above sea level, towards the eastern edge of the open grass-covered Mysore uplands. The nearest large town is Bangalore. The climate, though hot, is healthy, and residence there entails none of those trials, amounting at times to positive suffering, that must be endured by unfortunate dwellers in the "plains" of India. The average annual rainfall is 31 inches, an amount very small when the latitude of the field is taken into consideration. Until recently, therefore, there has always been some difficulty in obtaining sufficient water for milling and domestic purposes, since none of the mines make much water. The recent connection of the field with the Betamangalam tank or reservoir, which lies a few miles to the north-east, has now ensured a plentiful supply for the field.

The modern history of the Kolar goldfield opens in 1802 with the examination of the outcrops by Lieut. Warren, of H.M. 33rd Regiment, who was then engaged in surveying the Eastern Mysore frontier. While camped at the Betamangalam tank, rumours of the existence of gold at the small village of Wúrigam (Ooregaum) reached him. He paid a visit to the spot, set a number of women to work, and collected a small quantity of gold. While thus engaged he heard that gold was being extracted from a spot about a mile west of the neighbouring village of Marcupam (Marikuppam). Thither he accordingly repaired, and descended two mines, which were no more than 30 and 50 feet deep respectively. He employed several men in collecting quartz, but obtained only 2 grains gold as the result of two days' labour. As he was dependent on the honesty of native washers, he shrewdly remarks that it was in all probability not a true return. According to the natives, these mines had been known for many years, and had indeed been tried by Tippoo Sahib, who abandoned the experiment after a few weeks' work. The trial, however, appears to have been conducted in a very perfunctory manner, for the Brahmin in charge of the workmen never visited the scene of operations. Lieut. Warren also made numerous trials in the sands of the watercourses, in nearly all cases obtaining a few fine colours of gold. For many years after Warren's visit fugitive references to the gold of Mysore, mainly quotations from his description, appear in the publications of the period. It appears that the natives at Marikuppam continued to burrow among the old workings until 1859, but so crude and so dangerous were their methods that, in their own interests, they were finally prohibited from working underground by Sir Mark Cubbon, then Commissioner of Mysore. About the same time a syndicate of Bangalore military residents obtained a concession and commenced to work at Ooregum. Their operations were unsuccessful.

The pioneer of the present industry was undoubtedly M. F. Lavelle, a retired soldier, who had served with his regiment during the Maori war in New Zealand, and had there also learned something of gold-mining. In 1873 he applied to the Mysore Government for the exclusive right to prospect in the Kolar district, mainly for coal. Whether the mention of coal was merely a finesse or not is now not clear, but at any rate his attention was soon turned towards gold. He commenced operations in 1875, and in 1876 handed over his concessions to a small syndicate that imported two Australian miners, but spent its small capital (£5,000) with little or no return. Fresh capital was obtained, and in 1879 a little gold quartz was obtained, the find resulting in the formation of a small company (the original Ooregum Company of Madras) with a capital of Rs. 100,000 (£10,000). Further discoveries of gold-quartz in 1880 brought several mining engineers from the Wainaad, then in the throes of a vigorous "boom," and the concession was promptly purchased for £75,000. The first crushing took place in December, 1880, when 40 tons were treated for 42 ounces gold. The Wainaad boom had now spread to Mysore, and by July, 1881, eleven companies had been formed, with an aggregate capital of £1,216,000, of which no less than £641,000 had been paid to the vendors in cash and shares, but mainly cash. During the height of the boom, the wildest speculations were indulged in. The newspapers of the time contain grave discussions concerning the serious effect on the world's currency of the future gold output of an area that had then produced to European labour and capital certainly less than 100 ounces of gold, and had, as future operations were destined to show, hardly a single ounce "in sight."

On the field itself operations appear to have been attended with considerable lack of management. Large European staffs were imported, suitable quarters for these were built at great expense, costly milling machinery was brought to the field, and the little money thus left for true mining was frittered away in sinking numerous surface shafts. Little or no gold was found, and as the companies approached the end of their resources they endeavoured to avert disaster by rapid changes of management, thus profiting as little as could be by the local experience gained by mistakes. By the end of 1883 nearly all the companies were moribund. In October of that year a meeting was held in London which was destined to affect materially the fortunes of the Kolar field. Of a

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Panoramic View of Kolar Goldfield, India.

capital of £135,000 the Mysore company had but £18,000 unexpended and the point was debated among the shareholders whether it was better to distribute the money or to carry on with what appeared at best to be a forlorn hope. In the end it was decided to continue, the meeting being greatly influenced by the strongly expressed opinions of Captain Plummer and of Mr. W. Bell-Davies, a mining engineer who had not long before visited the field, and also by the fact that a small pocket of gold quartz had a short time previously been found in the Balaghat mine. Captain Plummer took charge, and concentrated his forces on a shaft 173 feet deep, near very extensive old workings at Marikuppam. Driving in a direction opposite to that favoured by most of his predecessors, he soon came on the reef, but amongst ancient workings. Fortunately, some pillars of quartz worth 4 ounces to the ton had been left in the old stopes, and an effort was made to bottom the old workings, resulting in the discovery of stone of equal richness. By the end of 1885 the Mysore mine had yielded 6,099 ounces gold, worth £24,000. This success naturally galvanised the adjacent companies into fresh life, and the Ooregum, Nundydroog, and others found fresh capital. The general features of the auriferous deposits were now being recognised, and from 1886 onward the history of the field has been one of unvaried success and prosperity. Neither in mining nor in milling have any serious difficulties presented themselves. The dip of the lode (about 55°) greatly facilitates the former, and since the gold is free milling, the simplest of methods suffices for the latter. A notable factor in the reduction of mining and milling costs was introduced in 1902. Fuel had always been expensive, the necessary coal being brought either from Singareni, 600 miles distant by rail, or from Barakar, 400 by rail and 1,000 by sea. In that year electric power was substituted for steam, electricity being generated at the Cauvery Falls, 92 miles by air-line from Kolar. The cost at first was high—£29 per horse-power per annum—but as the capital outlay was recouped the Mysore Government reduced charges to £10 per horse-power per annum. Prior to the introduction of electricity the steam charges had been £30 per horse-power per annum.

The geology of the Kolar field warrants some detailed mention. Its schist belt is about 50 miles in length, reaching from Shrinivaspur in the north, to four or five miles north of Krishnagiri in the Madras Presidency. The fundamental granite-gneiss rocks are separated by Dr. Smeeth of the Mysore Geological Survey as a grey gneiss, an older porphyritic granite, and a younger intrusive granite, the last being certainly later than the schists.[a] The rocks of the schist belt are also divided into three series: (*a*) The conglomerate series;

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[a] Rep. Dep. Mines, Mysore, 1899.

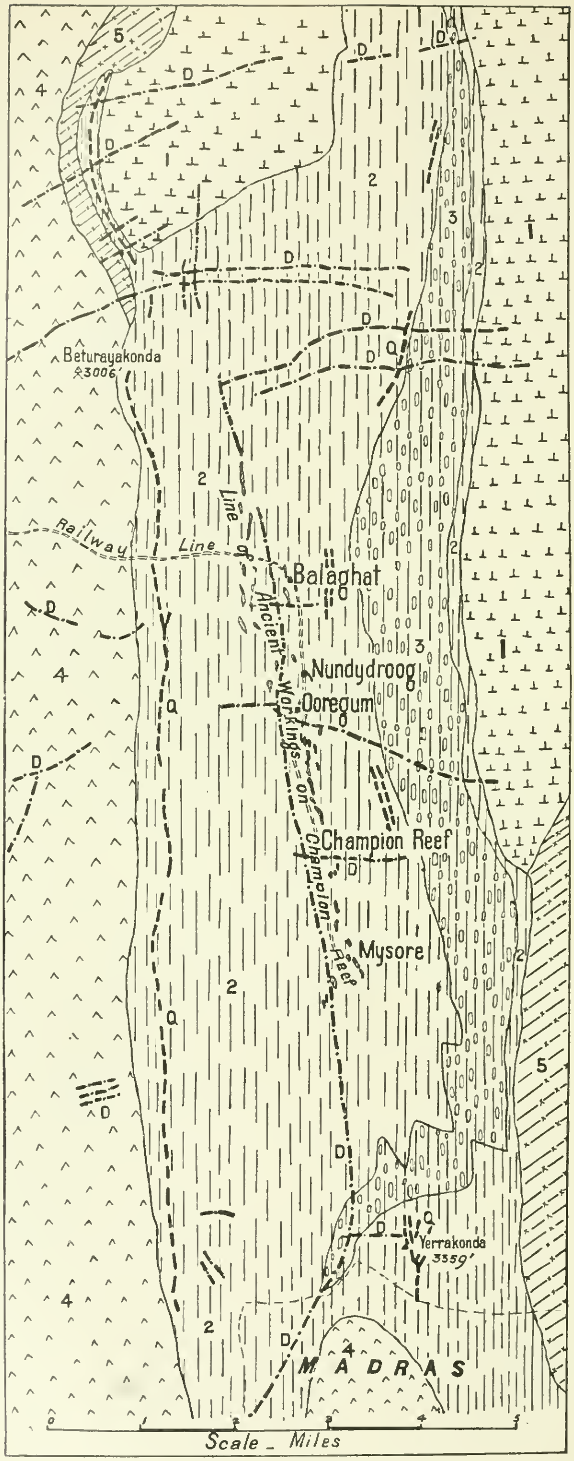

FIG. 91. GEOLOGICAL SKETCH MAP OF THE KOLAR GOLDFIELD, INDIA (*Smeeth*).

1. Newer Granite. 2. Hornblende-schist. 3. Conglomerate series. 4. Older Porphyritic Banded and Gneissose Granite. 5. Granitic Gneiss. *D*. Basic Dykes. *Q*. Ferruginous Banded Quartzite.

(*b*) hornblendic schists; and (*c*) ferruginous quartzites. The conglomerate series should, perhaps, be named the pseudo-conglomerate series, since the structure is autoclastic and is derived by simple crushing and squeezing *in situ* of granite veins in a hornblende-schist matrix. This series is developed along the eastern margin of the belt. The hornblende-schist which makes up the greater portion of the belt appears to have originally been a complex of lavas of intermediate or basic composition, and, as at Gadag, there are traces of original diabasic structure. Though the beds on either side of the belt possess dips converging towards the centre there is no clear evidence of regular synclinal arrangement, and there is, indeed, some ground for the belief that the Champion Lode occupies the position of a thrust plane along which the Dharwar rocks have overridden. The quartzites are of the type already

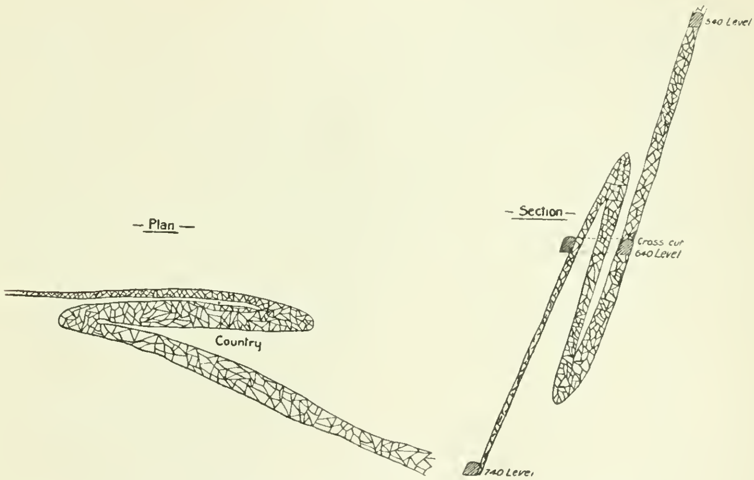

FIG. 92. "ROLLS" IN CHAMPION REEF, KOLAR, INDIA (*Hatch*).

described, and are developed as a low serrated ridge on the western side of the belt. Several diabasic dykes occur, the largest in the auriferous area being fairly parallel with the foliation of the schist. Others are, however, transverse to the foliation.

Several parallel quartz lodes are known on the Kolar field, but of these only one, the Champion Reef, has as yet proved of economic importance. From it, the gold yield of the field, and practically of India, is derived. It carries five large mines (Mysore, Champion Reef, Ooregum, Nundydroog, and Balaghat) along its strike, and is payable for at least four miles of its length. It has been followed to a depth of 3,740 feet in the Mysore, and

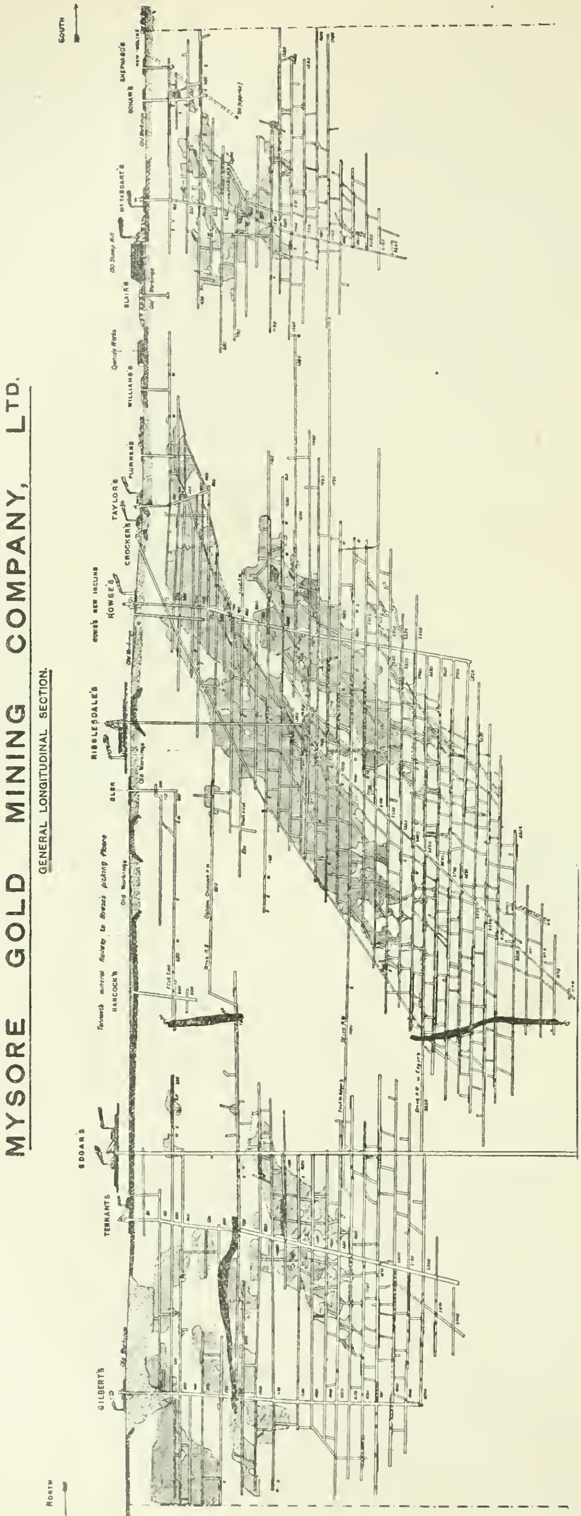

FIG. 93. SHOWING WORKINGS, PITCH OF SHOOTS, AND BASIC DYKES, MYSORE MINE, KOLAR, INDIA.

3,520 feet in the Ooregum mine. In the northern end of the field the reef becomes disordered and no stable mines have been developed beyond the Balaghat ; south of the Mysore mine the reef is also ill-defined. Its average width is perhaps 4 feet and its dip is with the foliation of the enclosing hornblendic schists, viz., about 55° west. Owing to its interfoliation with the schists there is a tendency to form lenses of quartz, but this feature is not nearly so well marked as on most schistose fields. The walls are, as a rule, well-defined. A notable feature is an occasional puckering and folding back of the vein on itself forming in places great masses of quartz usually of high grade. The axes of the folds generally have a pitch to the north in the plane of the vein. This structure is not uncommon in quartz veins in dynamically metamorphosed rocks, and has been recorded, for example, from Nova Scotia (p. 464) and from California. In the case of the Kolar country subsequent mineral reconstitution near the lode has largely obliterated the parallel puckerings and foldings of the hornblende-schist. Two types of quartz occur, both being auriferous. The older is dark bluish-grey, with a vitreous lustre, the younger, due to the intrusion of diabasic dykes, is white and opaque. The gold occurs for the most part in the former, and in characteristic shoots that have a constant pitch to the north within the vein. The shoots are generally well separated by stretches of barren or very low-grade quartz, or by " pinches " in the lode-fissure carrying no quartz at all. The rich shoot in the Mysore mine had been worked to a depth of 236 feet by the ancients, who had apparently grasped the intricacies of Kolar gold-deposition. This great shoot had a stoping length of 800 feet with a maximum width of 35 feet. Its average width was, however, about 4 feet. It has maintained its general width and value for a depth on its pitch of more than 4,000 feet, and is certainly the most notable shoot known in the history of gold-mining. To 1907 the average tenor of the ore crushed on the Kolar field was more than an ounce per ton over a quantity of more than 6,000,000 tons.

In addition to gold, the quartz contains pyrite, pyrrhotite, arsenopyrite, blende, galena, and chalcopyrite. The amount of sulphides present is, however, very small. An interesting occurrence is that of veinlets of tourmaline. These are certainly to be ascribed to the granite intrusions, that as have already been seen, are common on the borders of the schist band. As might have been expected, some of the acid intrusions have passed along favouring fissures, and occur as aplitic dykes in the Ooregum mine. The diabasic dykes of much later age have apparently exercised no appreciable effect on the distribution of gold, their influence being restricted entirely to the white quartz of younger generation.

The following table shows the yield of the principal mines of the field from the commencement of mining operations to the end of 1907 :—

Mine.	Tonnage Crushed.	Crude Ounces Gold.	Value Sterling.	Dividends Paid.*
Mysore	2,012,289	2,544,108	£9,937,542	£5,234,288
Champion Reef	1,730,448	2,053,203	7,796,016	3,481,633
Ooregum... ...	1,360,972	1,212,007	4,537,338	1,501,950
Nundydroog ...	783,730	803,278	3,015,711	1,340,077
Balaghat ...	317,191	285,050	1,099,194	227,800
Total... ...	6,204,630	6,897,646	£26,385,801	£11,785,748

* To April 8th, 1908.

Gadag.—Attention was first directed to the Gadag field by the report of gold-washings in the Dhoni and Shirhatti streams. The district was visited by Newbold in 1842 and by Aytoun ten years later, but the numerous pits were definitely recognised as ancient workings only in 1874 by the veteran Indian geologist Bruce Foote, by whom the foundation of our knowledge of the Dharwar belts has been laid. It was, indeed, his description written at that time[a] that led to prospecting in the Gadag district some 26 years later, and eventually to the establishment of the present mining companies. It is interesting to note here that the discovery of all the ancient mines of southern India, with the exception of those of Kolar and the Wainaad, has been a direct result of his geological work. It was his published description, for example, that induced the late Mr. T. W. Hughes-Hughes, also a member of the Geological Survey of India, to examine the Maski band, a search that eventually yielded the dividend-paying Hutti mine.

The rocks of the auriferous portion of the Gadag band, crossing from east to west, are hornblende-schist, chlorite-schist, argillite, felsite, and massive gritty schist. Two main reef series may be made out. The eastern lies entirely in a long, narrow band of argillite, and follows a highly carbonaceous band in the argillite. The total length of the auriferous area is about 8 miles, extending from near the village of Nabapur in the north, to the Sangli mines in the south. Along its length are scattered numerous old workings, the majority of which are now being vigorously prospected. The reefs are permanent, but vary locally both in width and in value. They show the lenticular, *en echelon* structure characteristic of veins in schistose rocks. The quartz is typically associated with graphitic "pug," the graphite being obviously derived from the enclosing carbonaceous argillite. Pyrite is naturally abundant in the

[a] Rec. Geol. Surv. India, XXI, 1886, p. 40.

Dharwar Schists, Sangli, India.

[illegible]

country of the veins. The principal mine on the band is the Dharwar Reefs, near Kabligatti village. It has reached a depth of 940 feet, bottoming the ancient workings at 250 feet. It is the only producing company on the field, commencing crushing with a 20-stamp mill in February, 1907. From that month to April, 1908, it had crushed for the fifteen months 15,739 tons ore for a yield of 7,302 crude ounces, worth about £27,700. The tailings, which were still to be treated, contained about 4 dwts. gold per ton. The other mines on the belt, including those of Sangli, are still in the prospecting stage.

Four miles west of the foregoing is the Hosur series of reefs. So far as may be made out, for the surface is largely covered with

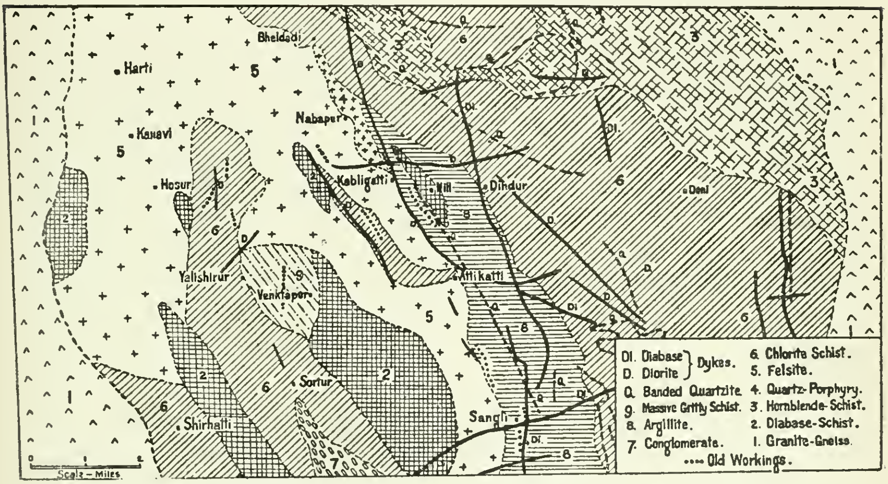

FIG. 94. GEOLOGY OF THE NEIGHBOURHOOD OF THE GADAG MINES, INDIA.

cotton soil, these lie in chlorite-schist and massive gritty schist near felsite. These mines carry no graphite, and are still in the development stage. Hornblende-schists similar to those of Kolar occur on the eastern side of the belt, but are not known to carry auriferous veins.

Hutti.—The Hutti mine lies within the boundaries of the Maski band, as first described by Foote. This schist belt lies south of the Kristna river in the Lingsugur division of the Nizam's Dominions. Its auriferous veins were discovered by Mr. T. W. Hughes-Hughes in 1887, his search, as already mentioned, being based on Bruce Foote's geological work. In 1887 the rights to the minerals within the Hyderabad State were bought by the Hyderabad (Deccan) Company. From first to last, this company, together with a subsidiary company (Wondalli), expended some £400,000 on gold-mining in the district. Numerous ancient workings were discovered and a few were opened up. The Wondalli veins a few miles from Hutti were taken over and operated by the above-mentioned subsidiary company and gold to the value of £60,000 was won, all of which went back into the mine. No profit was made, and the company ceased operations in 1900. Its most productive year had been 1899, when 18,970 tons were crushed for a yield of 7,822 ounces. The whole history of gold-mining by these companies was characterised by extravagance and general disregard of mining economics. A mine opened at Boodinnie, south of Wondalli, was worked long after it should have been obvious that the stone obtained was too poor to pay even milling expenses. The quartz was nevertheless crushed.

The bright page in the history of the field was opened with the formation of the Hutti company with a capital of £55,000. Mining at Hutti commenced in 1901, and crushing in February of 1903. Its career has been uniformly successful. To the end of 1907 the 30-head mill had crushed 104,065 tons quartz for 56,894 crude ounces worth £216,927, and had paid dividends of £29,902 and royalties of £11,000. It will, from the foregoing figures, be obvious that, considering the high mining costs due to the distance (45 miles) of the mine from the nearest railway station (Raichur), the quartz must be regarded as low-grade. All fuel and mine-supplies are carried by bullock-cart over ill-made sandy and stony roads.

At Hutti the deepest modern workings have reached 1,440 feet. The ancient workings were finally bottomed at 620 feet.

Of late years several prospecting companies have been formed to work neighbouring veins at Topuldodi, south-east of Wondalli, and in the Shorapur district across the Kristna river, but in no case have the results obtained been sufficiently encouraging to warrant the formation of mining companies with large capitals, and prospecting has now practically ceased.

The Maski band of Dharwar schists in which the Hutti mine lies, is some 7 to 8 miles in width, and stretches in an approximately meridional direction for about 45 miles across the Raichur Doab. The chief members of the schistose series are hornblende-schist, altered diabase, chlorite-schist, and acid schistose rocks, the last possibly representing altered porphyries. The whole complex is crossed by younger diabasic dykes, while along the northern boundary the schists have been attacked by granite intrusions. Along the eastern border of the belt are pebbly conglomerates and other original sedimentary members.

The veins of the Hutti, Topuldodi, and Wondalli mines are in a hornblende-schist precisely similar to that of the Kolar field. The Boodinnie vein lay, however, in a soft chlorite-schist. The Hutti vein, the only one of present importance, lies near the western border of the belt and strikes parallel with the line of contact of granite and schist. In it vein-quartz of both older and younger generation are found, the older dark chalcedonic bluish-grey variety being auriferous, the younger white form poor or barren. The last is especially abundant near a diabase dyke crossing the north-west end of the Hutti lode-channel. The vein conforms with the schistosity of the country, dipping at a high angle to the west. The quartz is disposed in lenses of an average diameter of perhaps 100 feet, and a maximum thickness of 5 feet. Their edges overlap *en echelon*, both laterally and vertically. The ore, therefore, lies rather in a lode-channel than in a continuous quartz vein.

Anantapur.—The schist belt in which the Anantapur mines are situated was discovered by Mr. E. W. Wetherell, of the Mysore Geological Survey in March, 1902. It lies in the Madras Presidency about 9 miles from Nagasamudram station on the Southern Mahratta railway. Prospecting here was commenced in April, 1906. Old workings are fairly numerous on the three main reefs of the central portion. So far as is yet known, the ancients do not appear to have reached a greater depth than 118 feet.

Tumkur.—The Bellara and Bodimardi veins, in the Gadag-Seringapatam belt near Chitaldroog, lie either in diabase or in a chloritic-schist with which are associated argillaceous and ferruginous schists and some limestones and conglomerates. The quartz is generally small and of low-grade, but may rise in width to 3½ feet, with a value of ½ to 1½ ounces per ton. Numerous old workings have been prospected in this neighbourhood, but none have yielded a mine, though a depth of 380 feet was reached in the Bellara property.

Coimbatore.—Numerous old native workings for gold occur in the Kollegal and Satyamangalam taluks of the Coimbatore district; but the veins are small and unimportant. Considerable unsuccessful prospecting work has been carried on at the Haddabanatta and Bensibetta. The rock in which the veins lie is schistose, and is probably to be correlated with the Dharwars.

Wainaad.—This field demands mention rather from its past history than for the value of its gold-quartz veins. It lies to the west-north-west of Ootacamund on the slopes of the Western Ghauts. Its gold veins and the alluvial deposits derived therefrom have been worked for many centuries by native methods. They appear to have attracted the attention of Europeans about 1793, and from thence to 1865 they were the subject of various recommendations and reports. During the earlier years of the nineteenth century they had been worked by slave labour. With the abolition of slavery and the demand for labour on the coffee plantations of the vicinity, work in the mines ceased almost completely. In 1865 the field was visited by Australian miners, and a little prospecting, resulting in the erection of a quartz-mill, undertaken on the gold-quartz veins. These early explorations met with little or no success. Nevertheless, from 1879-81, the field was the scene of one of the most extraordinary "booms" of modern history. Numerous companies, with an aggregate capital of no less than four millions sterling, were called into existence. The proportion of the subscribed capital that did not go into the pockets of promoters was squandered mainly in expensive and useless machinery, little of which was put into actual operation. The slump that followed the "boom" was complete. From time to time, however, efforts have been made to reopen some of the mines, but these have met with little success. Expert examination has shown that the veins are low-grade, but occasionally carry rich pockets, too small to exercise any notable effect on the general tenor of the quartz, but sufficient often to raise futile hopes in the breasts of shareholders. An extended examination of the better-known veins was made in 1900 by Dr. Hatch and Mr. Hayden, of the Indian Geological Survey, with disappointing results. The general average of numerous samples was only 2 dwts. per ton over a width of 5·4 feet.[a]

The country of the veins is biotite-gneiss, which, together with other metamorphic types, occurs with dubious Dharwarian rocks, all being penetrated by basic and acid intrusives. The veins run obliquely to the foliation of the gneiss, and are occasionally of considerable width. They are often pyritous, furnishing pyrite, marcasite, mispickel, &c. The pyrite is the chief source of the auriferous values; and the free gold occurring is derived from its decomposition. The figures of the crushings in bulk uniformly bear evidence of the low grade of the veins. Thus up to the beginning of 1883, some 3,597 tons had been crushed for a yield of only 482 ounces, or nearly 2·7 dwts. per ton.

Elsewhere in India, vein mining has been carried on far to the north of the Dharwar belts shown in the accompanying map. The chief district was at Sonapet in Bengal, in the Chota Nagpur Dharwar schist area. This was the scene of a notable "boom" in 1891-2, that caused considerable, but unfortunately unjustifiable, excitement in Calcutta. Only a few ounces of gold were obtained from the principal

[a] Mem. Geol. Surv. India, XXXIII, 1902, p. 30.

mine, and it is doubtful whether even these few were the natural product of the mines. Despite the lack of gold, companies with an aggregate capital of a million sterling were formed. In this district gold-quartz veins will probably yet be discovered near Raigara, in the jungles west of Chakhardhapur, on the Bengal-Nagpur railway, since numerous crushing and rubbing stones have been found there, recalling those known from the outcrops of the gold-quartz veins of southern India. Occasional small patches of gold, generally associated with galena in cavities in a porous quartz, have indeed been found in the Chota Nagpur area. Of these, the largest was at Pahardiah, near Manharpur. It yielded a few pounds only of very rich "specimen" stone, plentifully bespattered with gold.

Alluvial Gold.—In few countries is alluvial gold more widely distributed, and in few countries also does it show less tendency to aggregation under the influence of running water. Regarded as a whole, the seasons of India may, from the alluvial miner's point of view, be divided into dry and wet. The duration of the latter is about four months, and nearly the whole of an abundant rainfall takes place in that time. In consequence, the rivers are, during the monsoon, raging floods that change their direction across their flood plains from day to day. The gravel deposit of one day is therefore either broken up and its gold widely dispersed by the flood of the next week, or it is covered by the next flood with many feet of fine sand. The only concentration possible under these conditions is that of the flaky flood-gold which, as the river is falling, is caught in the natural riffles provided by the stony gravel bars and beaches formed at the head or at the tail of an island, at the lower end of a long pool, or on the convex curve of an ox-bow in the river. The deposition of gold on a bottom is generally impossible. On the other hand, in the central Deccan, where auriferous schist belts occur, the rainfall is too slight (below 20 inches), under the tropical conditions prevailing, to permit of aqueous concentration of gold in quantity; further, the change from regions of low rainfall to those of high monsoon fall is confined to bands of only a few miles in width, parallel to the coast, and situated at the edge of the Ghauts.

Alluvial gold is, nevertheless, found in minute quantities wherever streams drain areas of the old schist rock, and wherever they at the same time have a grade suitable for the carriage and deposition of gravel. Such conditions obtain in many streams in Mysore, Madras, Bombay, Hyderabad, Central India, and Chota Nagpur, but in no case, so far as is yet known, are the gravels sufficiently rich to warrant European examination, though in many places they afford a few weeks' employment during the cold weather to the native washer, who is content to work for a return of 1½d. to 2d. per day. In the west of Chota Nagpur a few men are employed at gold-washing all the year round, but ordinarily they combine with the pursuit of gold-washing, one or more of the more menial occupations of the Indian village. Where the gravels are very poor, the work of washing is left entirely to women and children. A very small quantity of gold is thus annually obtained, and seeing that climatic conditions have not varied greatly during the historial centuries, it is exceedingly improbable that the yield of alluvial gold in India was ever extensive.

From a metalliferous point of view the Himalayas are singularly barren. There has never been manifested in this uplift that extrusion of igneous magmas of which metalliferous impregnation appears to be an inevitable concomitant. The streams flowing from and through this great range are therefore as a rule devoid of gold. Above Attock, and in the upper waters of the Indus, and in the Alakananda are small gravel banks that are even now worked. Much of this gold is probably derived from the Tibetan plateau, since many of the Indo-Gangetic streams have pushed through the main range and captured some of the drainage channels of that region. In Upper Assam also, streams that flow from the north into the Brahmaputra, as the Subansiri, carry small quantities of gold. One small bar near the mouth of the Subansiri gorge yielded on examination at the rate of more than a pennyweight per cubic yard. The quantity of gravel available was, however, very small. It is probable, also, that some of the gold of this region is derived by a re-wash of the Tipam (Siwalik) sandstone that wraps round the Brahmaputra Valley, both on the north and on the south. For the gold of the Lohit (or sacred) branch of the Brahmaputra, a source must be sought in the metamorphic rocks of Miju ranges in the headwaters of that river.[a]

The methods of the native washers of India are extremely primitive. Their implements are the wooden batea or a short inclined trough, with rude sieves and scrapers. In the use of these they are, however, extremely expert, since they have had always to deal with flaky flood gold that necessitates extreme care in its use. Like native washers in Sumatra and in Colombia, the Kols of Chota Nagpur use the soapy juice of the leaves of a tree (in this case a creeper, *Combretum decandrum*) to facilitate the separation of the fine gold from the associated black sand left behind in the batea as the last residue on washing.[b]

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[a] Maclaren, "Auriferous Occurrences of Upper Assam," Rec. Geol. Surv. India, XXXI, 1904, p. 179.

[b] Maclaren, Ib., XXXI, 1904, p. 66.

The total gold yield of India during the present century is shown in the attached table :—

Year.	Crude Ounces.	Value, Sterling.
1901	531,766	£1,930,737
1902	517,639	1,970,230
1903	603,787	2,303,144
1904	618,746	2,366,079
1905	630,817	2,416,966
1906	581,545	2,230,284

CEYLON.

The existence of alluvial gold in Ceylon has been known for many years. Search was made for it under the direction of Sir Samuel Baker in 1854, and by others in later years. In 1902-3 Mr. C. G. Dixon reported it to be widely distributed in small quantities in the central, western, and southern portions of the island. Dr. A. K. Coomara-Swamy in 1905 directed prospecting operations, finding a little gold at Niriella, Weralupe, Marapona, and Dombagammana in the Kalu-ganga, or in the We-ganga, its principal tributary. These localities lie about 40 miles east-south-east of Colombo. Gold also occurs in the head-waters of the Welawe-ganga, especially near Balangoda, about 60 miles from Colombo in the same direction as the foregoing. Other localities at which gold is occasionally met with in the search for gems are the Pellawatta-ganga and the Moon Plains, near Nuwara Eliya.[a] In no case was gold found in sufficient quantity to warrant dredging. The grains obtained were exceedingly fine, the largest in the possession of the Ceylon Mineralogical Survey coming from Balangoda, and weighing no more than 6·4 grains (·415 gramme). Native washers work the gravels by a rude method of stream sluicing, finishing the concentration in a wooden *batea*, or even in a cocoa-nut shell. The gold would appear to be derived from the ancient metamorphic rocks of the island.

BURMA.[b]

Burma has long enjoyed the reputation of possessing rich and extensive auriferous deposits. It formed the northern portion of the Chrysê of Pomponius Mela—the Golden Chersonese of Ptolemy. As such there was written across it on mediæval maps, " Here is much gold "—that alluring legend attached to so many far eastern and little known countries. In recent years the pan and the assay

[a] Ceylon Administration Reports, 1905, Mineralogical Survey, E. 5.

[b] Maclaren, Min. Jour., LXXXII, 1907, p. 113.

balance of the prospector have gone far towards dispelling the time-honoured illusion. Nevertheless, gold is widely distributed throughout Upper Burma and those parts of Lower Burma immediately adjacent to the mountain ranges. Few gold-quartz veins have been brought to light. Those discovered lie either in the Tertiary andesitic country between Wuntho and Banmauk in Upper Burma, or in the gneissic ranges south of Nam-Kham on the Shweli river.

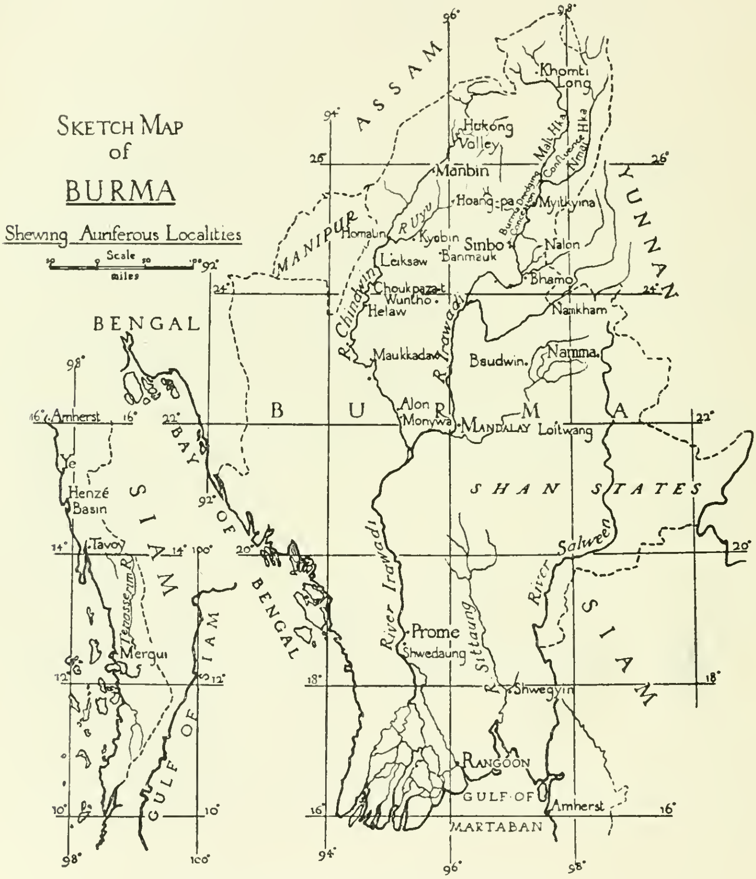

Fig. 95. Distribution of Gold in Burma.

The Choukpazat (Kyoukpazat) veins have furnished the only gold mines yet worked in Burma. They lie 26 miles north of Wuntho and 11 miles from Nankan, the nearest railway station. The region is covered with dense jungle, and its rocks are overlain by a heavy soil-cap that, together with the jungle, renders geological exploration most difficult. The rocks are consolidated and fairly well stratified tuffs and breccias of andesitic facies, intruded in places by quartz-diorites.[a] Veins similar to those at Choukpazat occur at and near Legyin, 11 miles further north, and also in the neighbourhood of Banmauk. The Choukpazat veins were discovered by Kadu Shan washers when following up auriferous shoadings, and were worked by them to a depth of 8 to 10 feet. They attracted European capital in 1894, and were developed for a couple of years with results sufficiently encouraging to warrant the erection of a light 750-lb. 10-stamp mill, to which a cyanide plant was eventually added. Work was vigorously and efficiently carried on until 1903, when the auriferous shoot, upon which mining had been concentrated, pinched out. After considerable exploratory work, unfortunately fruitless, the mine was abandoned and the machinery dismantled. It is difficult to obtain accurate figures relating to the Choukpazat output, since they seem not to have been preserved in the records of the Indian Mines Department, and, moreover, where they have been supplied by the company they refer often to a financial year terminating differently from that officially adopted. The following figures are probably as close an approximation to the truth as is now possible :—

Year.	Tons Crushed.	Yield from Plates. Ounces.	Yield from Cyanide. Ounces.	Total. Ounces.
1894–5	686	103·0	......	103·0
1895–6	1,918	540·6	......	540·6
1896–7	2,692	925·1	......	925·1
1897–8	2,366	958·7	......	958·7
1898–9	3,025	1,357·9	......	1,357·9
1899–1900	1,747	639·8	33·0	672·8
1900–1*	1,477	595·2	604·9	1,200·1
1902	......	......	......	1,984·0
1903	......	......	......	......
				7,742·2

* October to March 31st only.

The total output was therefore presumably a little more than 8,000 ounces, of a value of, say, £31,000. The highest yield was obtained during 1902, when 1,984 ounces, valued at £7,606, were produced. The average gold per ton for the seven years available is 8·3 dwts.

Generally speaking, the veins of this andesitic region are highly pyritic and low grade. The Choukpazat vein was proved to a depth of 420 feet, but the valuable portion appears to have been above the 310-feet level. The length of the ore body was about 240 feet, the vein being cut off to the south-west by an intrusive

[a] Gen. Rep. Geol. Surv. India, 1899-1900, p. 63.

dyke. On the north-west it pinched out in the country. Its thickness varied from 2 inches to 10 feet, with an average of 3 feet 6 inches. Below the 310-feet level the quartz was associated with calcite. It was occasionally clean, but more often was well mineralised, carrying 5 per cent. of chalcopyrite, pyrite, galena, and franklinite (oxide of iron, manganese, and zinc). The last, when separated, contained as much as 7 ounces of gold per ton of concentrate, the copper and iron pyrites from 2 grains to 18 dwts. per ton, while the galena carried nothing. An excellent indicator for gold was altaite, the somewhat rare telluride of lead.[a] Most of the gold was extremely fine. The bullion from the plates averaged 850 gold. Total costs were about 14s. per ton, labour being cheap and fairly efficient. The only other gold-quartz veins reported from Burma are those in the gneissic range lying south of the Shweli river in the Northern Shan States. These veins are large and heavily mineralised, but of very low grade.

Taking the great Irawadi river first, as its importance naturally warrants, poor-gold gravels occur near Prome and at Shwedaung, where desultory washing has long been carried on. The next auriferous occurrence is 400 miles farther up the river at Shwegu. In the Mozit Chaung, near the mouth of the Second Defile, the fine gravels appear to be faintly auriferous. From Sinbo, at the upper entrance to the Third Defile to the confluence of the Irawadi is a distance of about 100 miles. This stretch of river is held by the Burma Gold Dredging Company, with head-quarters at the riverside station of Myitkyina, the British administrative post farthest up the Irawadi. The history of the company dates back to 1900, when the question of the practicability of dredging the Irawadi gravels was first taken up. Vigorous prospecting during the season of 1900-1 showed that dredging was feasible, and in 1902 a small dredge, bought and dismantled in New Zealand, was re-erected at Myitkyina. In October of that year dredging operations were commenced. The dredge was small and, being square-ended, not altogether suited to the conditions obtaining on the Irawadi. Nevertheless, it did most useful prospecting work until March, 1904, when a sudden rise in the river brought down so much floating débris to be piled against the dredge and head-line that the latter parted and the dredge was capsized and lost. It had during its prospecting career recovered 441·69 ounces of gold, of a value of £1,680. 5s. Three large dredges were at work on the concession in 1907. They are fitted with the abnormally powerful winches necessitated by the great length of head- and side-lines, the width of the river occasionally requiring as much as 300 yards of the latter, with

[a] Louis, H., Trans. N. Eng. Inst. M.E., XLVI, 1897, p. 129.

a correspondingly long head-line. The banks of the river are low, and there is therefore no possibility under ordinary conditions of keeping the lines clear of the water. Every rise of the river brings down great quantities of floating timber, constituting one of the chief obstacles to dredging when the rainy season is approaching. Dredging time is largely broken by the "rains," and may be reckoned at eight months in the year. The "wash" itself is coarse gravel, with the gold fairly well disseminated throughout. There is therefore little or no stripping. Its treatment when raised presents no technical difficulties. Small quantities of platinum and platinoid metals are recovered with the gold. The returns of the company are private, those available from official sources being as follows :—

	Ounces.	Value.		
		£	s.	d.
1903	370·05	1,401	6	7
1904	214·30	826	16	4
1905	621·00	2,418	10	8
1906	2,301·00	8,855	6	8
	3,506·35	13,502	0	3

The Mole Chaung, after meandering across the old flood-plain of the Irawadi, joins that river a little above Bhamo. At its debouchure from the hills near Nalon gravels were found which were for a time considered to promise payable results. They have since been thoroughly prospected with a Keystone drill, and are now considered to be valueless. The Nalon gravels are possibly a re-wash of ancient high-level Irawadi gravels, the great river having flowed here under the Chinese frontier hills before it forsook its broad flood-plain to flow through the narrow Third Defile. A little desultory washing of no importance is carried on near Myothit on the Taiping river east of Bhamo.

The great western tributary of the Irawadi, the Chindwin, carries a little gold wherever gravels occur along its course. In one spot alone—viz., Helaw, are the gravels sufficiently rich to attract more than passing attention from even the native washer, who is, in Burma, generally a woman. Near Helaw the Chindwin widens, and its waters, on a low river, divide to form a long gravel island. The island is swept by the great floods of the rainy season, and the sand carried away, exposing the larger stones that then act as an excellent natural riffle-bed in which the gold is caught. As the waters subside and uncover the head of the island, the Burmese washers attack the gravel exposed, taking only the surface covering to a depth of about a foot. During most seasons the results are poor, even from a native point of view, but occasionally a lucky concentration takes place. The apparatus of the native washer is extremely simple, consisting only of a shallow wooden sluice-box in which rough concentration is effected, and a wooden batea in which the gold is finally separated from the black sand. The average earnings of the washers are probably less than four annas (fourpence) per day.

A concession of that portion of the Chindwin lying between Minsin and Homalin—about 180 miles—was granted to the Mandalay Dredging Company. After some preliminary prospecting a dredge was obtained, erected at Rangoon, towed up the Irawadi to Pakokku, and thence up the Chindwin to Maukkadaw, where it was unfortunately stranded. Before it could be refloated the company had gone into liquidation, and the dredge was eventually sold to be dismantled to go to South America. The Chindwin gravels, therefore, remain virgin ground.

The Upper Chindwin, from Homalin to Manbin, 130 miles farther up, has been examined from time to time by various prospecting parties, but, since no concessions have been applied for after prospecting, it has apparently been considered valueless.

At Kyobin, on the Uyu river, a tributary falling into the Chindwin below Homalin, old high-level, false-bedded, auriferous gravels occur. These have for some generations been worked by the Burmese by a rude method of ground-sluicing. They also have attracted the attention of prospectors, but, since no serious work has been done on them, are presumably too low in value to return interest on the capital necessary. The gold of these gravels is brought from the south to its present position by the Chaungyi Chaung. This stream drains the andesitic country from Banmauk to near Choukpazat, and its gold is derived from the degradation of the small pyritic gold-quartz veins already described as occurring in that area. The higher reaches of the Uyu as far as the military outpost of Hoang-pa have also been prospected, but with little success. The Chindwin and its tributaries have, therefore, during the past five years, been fairly closely examined, and have, on the whole, been considered too poor for further exploitation. Natives still wash along the Chaungyi Chaung: at Kyobin: and at Leiksaw, but their earnings are in all cases certainly small.

In the Northern Shan States, on the eastern frontier of Burma, there occur numerous short, narrow, but deep valleys opening into the Salween gorges. Some of these carry auriferous gravels. The Nam-Hsawm, one of the longest on the right bank of the Salween, was in former days worked by Chinese, and was taken up in 1905 by the Namma Gold Dredging Company, with capital raised mainly in Rangoon. After preliminary exploration the gravels were considered sufficiently rich to warrant the erection of a dredge on the ground, an end effected only after overcoming numerous difficulties, of which the formation of a road 40 miles long to enable the machinery to be placed on the ground was by no means the least. After a short run it was found that the value of the gravel had been over-estimated, and the dredge was abandoned. It was, in 1908, being worked by Chinese. South of Namma, near the Loi-Twang mountain, are native gold washings. These have been exhaustively investigated by the Geological Survey of India,[a] and have been proved to be of no commercial value. According to the Burmese and the Shans, the streams of the Wa country across the Salween opposite Namma are highly auriferous. More particularly is this so in the case of the Shwe-Thamin-Chaung (the Stream of the Golden Deer). Yet the only expedition that has entered this country failed to find gold in this valley. It is true, however, that the expedition halted only for two or three hours at the stream, and that it had no gold-washers with it. In the Wa country the King's writ does not run, and as the wilder Was are inveterate head-hunters, requiring, indeed, fresh heads every spring to ensure the success of the crops of the forthcoming season, the potentialities of wealth concealed in their valleys have hitherto failed to attract the private prospector.

In Lower Burma the gravels of the Sittaung at Shwegyin were formerly washed by the natives. These washings, though poor, are of great antiquity, and were farmed out by the kings of Burma prior to British occupation. In the Tenasserim province gold is reported from the Ye river, and also from the Henzé Basin, in the latter place occurring with the tin-wash. The various tributaries of the Tenasserim river, besides carrying tin, are more or less auriferous. One of these, the Khamaungthwé, about 30 miles east of Tavoy, has been granted to a syndicate, by whom a considerable sum has been spent in prospecting operations.

Of regions now inaccessible to the ordinary prospector, the Hukong Valley, at the head of the Chindwin river, and Hkamti-Long at the head of the Irawadi, are the most noteworthy. Coarse gold has been known for many years to exist in the former valley. There it is worked by the Kachins, mainly with slave labour. The richest streams are reported to be the Kapdup and the Nam Kwan. The Hkamti-Long country, on the other hand, promises deposits rather in veins in the older metamorphic rocks of the Miju and the Zayul ranges than in the alluvial of the rivers. So far as is known, gold is not sought for in Hkamti-Long.

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[a] La Touche, Rec. Geol. Surv. India, XXXV, 1907, p. 102.

To sum up the history of gold exploration in Burma : Gold-quartz veins have been found, but have proved small in extent and erratic in value, while of all Burma's numerous auriferous alluvial deposits none have been considered worthy of extended trial except those owned by the Burma Gold Dredging Company above Myitkyina. There three dredges were at work in 1907 with results considered so satisfactory that a fourth dredge of greater capacity than any of its predecessors was being built.

CHINESE EMPIRE.

Chi-li.—Numerous gold deposits, both vein and alluvial, are known to exist in the mountainous portion of the Chi-li province lying north and north-west of Pekin. The vein deposits appear to be confined entirely to the Archæan and Cambrian (Sinian) system of plutonic and metamorphic rocks, occurring indiscriminately in amphibolitic schists, quartzites and limestones. Intrusive volcanic rocks (basalt, andesite, and rhyolite) occur in scattered areas.[a] So far as they are known, the gold-quartz veins of Chi-li are, with few exceptions, very thin and small. Perhaps the most notable exception is the gold vein of Chin-chang-kou-liang (Long. 119° 56′ E. ; Lat. 42° 20′ N.), 40 miles north-west of Chau-yang. It has been worked for many years, and has indeed been driven on for 4,000 feet. The vein is from 4 inches to 3 feet in width, and may occasionally widen to 6½ to 7 feet. The oxidation zone reaches a depth of 200 feet. The values occur in shoots. The ore is highly pyritous, carrying 10 per cent. of sulphides (galena, chalcopyrite, pyrite, and blende). Nevertheless, 60 per cent. of the gold is free-milling. The country is amphibolite-schist, resembling very closely an altered diabase.[b] The production of the mine in 1901 was about 200 tons per month, the ore averaging an ounce per ton. In six years it had yielded to native workmen 43,000 ounces gold from 39,000 tons ore.

Near Chuan-shan-tsze (Long. 119° 12′ E. ; Lat. 42° 26′ N.) is another of the exceptions to the general rule of the smallness and poverty of Chi-li veins. The mine lies in amphibolite-schist about 3 miles (8 li) east of the village. The vein is 4 inches to 3 feet wide, and is composed of pyritous quartz. The ore-shoot appears to be about 300 feet in length. According to Vogelsang, it has been opened to a depth of 1,100 feet. The ore is raised by a horse-whim. On the surface it is heated to make it brittle, is quenched with water,

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[a] Hoover, Trans. Inst. Min. Met., VIII, 1900, p. 324.

[b] Vogelsang, "Reisen im nördlichen und mittlern China," Peterm. Mittheil., LVII, 1901, pp. 245 *et seq.*

broken to nuts with a hammer, and ground between stone rollers. Fifteen such rollers are used, each actuated by two mules. The capacity of each mill is 400lbs. (300 catties) in 24 hours. Concentration is effected on sloping tables and the final separation is performed in the batea. The average tenor of the ore is one ounce per ton. The annual production is 700 ounces. About 200 workmen are employed. Six per cent. royalty is charged by the Tu-tung (prefect) of Jehol. Near Yü-erh-yai (Long. 118° 27′ E. ; Lat. 40° 34′ N.) small gold-quartz veins lie at the contact of metamorphic limestone, with a granite. Other veins are known in the Jehol prefecture in a gabbroid rock, in diabase, and in granite.

In few places in Chi-li has gold-quartz mining been profitable to the native owners, and despite the fact that the country has obviously been most carefully prospected, few important auriferous vein occurrences are known. The placer deposits of Chi-li, on the other hand, are comparatively rich, and indeed furnish the greater proportion of the gold obtained from the province. The vicinity of Ching-chang-kou-liang, mentioned already as possessing a rich quartz vein, was especially productive, as is evidenced by the fact that the Chinese have driven a tunnel 3,000 feet in length, to drain a buried alluvial basin. General depression of the country has hidden much of the ancient river-channel system beneath great thicknesses of alluvium and of loess. The total gold production of Chi-li in 1898 was estimated at 50,000 ounces.

Shantung.—The geology of the Shantung province, so far as it concerns metalliferous deposits, is identical with that of Chi-li. Gold-quartz veins are, however, not so widely distributed, nor is the yield of gold so large, being for 1898 only 6,000 ounces. The principal gold mine appears to be the Chow-yen (Mountain of Gold), 40 miles from Chefoo, discovered and worked as long ago as 1620 A.D. Its vein is of great width, ranging from 30 to 90 feet for a length of a mile. The ore occurs in indefinite shoots, and carries from 15 to 20 per cent. pyrites, the latter often occurring in great masses. The ore is distinctly low-grade. Forty per cent. of the gold is free.[a] The mine is estimated to contain about 200,000 tons available ore, worth about £2 per ton. It is owned by Chinese.[b] Gold mines were opened at P'ing-tu, also in the Shantung province, in 1884. The ore is highly pyritous, and the lode has been worked down to the sulphide-level. The concentrates from the primitive stamp mills are sold, after treatment and re-treatment, to native farmers, who carry them home and occupy their leisure time in the winter months

[a] Hoover, loc. cit. sup.

[b] Curle, "Gold Mines of the World," London, 1905, p. 216.

in fine-grinding and re-panning the pyrites. Other auriferous occurrences are known and have been mentioned by various writers, but none appear to be of sufficient extent or value to warrant detailed description.

Weihaiwei.—Mining operations, both on placers and on veins, have been carried on in the vicinity of Weihaiwei for many years by the Chinese. Vein-mining was, however, confined to the outcrops and oxidised zones of the reefs, where the gold was free and easily saved. In 1902 the Weihaiwei Gold Company was formed to work a vein, the outcrop of which had already been attacked by the Chinese. The mine lay among low hills at an altitude of 5,000 feet above sea-level, and at a distance of 10 miles from the port of Weihaiwei. The country of the vein is gneiss, traversed both by acidic and by basic dykes, the acidic (aplite and pegmatite) being crossed by the basic intrusives. The ore-body was some 20 feet in width, and gave an average assay value of 37s. 6d. over the whole width.[a] Free gold, to the extent of 25 per cent. of the total yield, was accompanied by auriferous pyrite, galena, and chalcopyrite. The quartz of the vein appeared to largely replace an original dyke. The company erected a 20-stamp mill, and for some time treated 2,500 tons

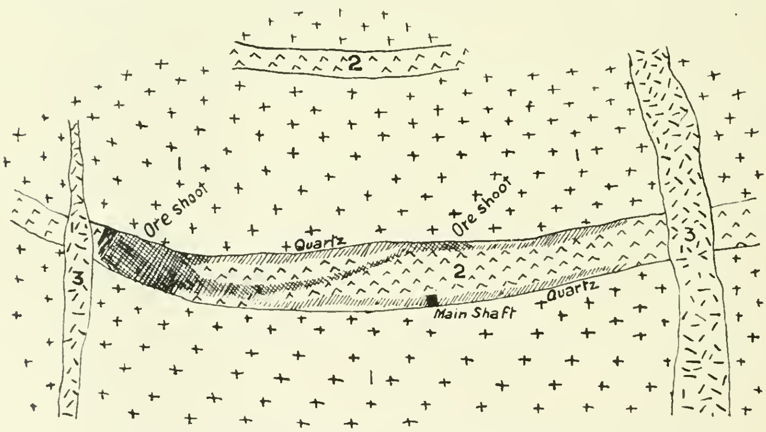

FIG. 96. ORE-SHOOTS IN APLITIC DYKE, WEIHAIWEI (*Verschoyle*).
1. Gneiss with pegmatite veins. 2. Aplitic dykes. 3. Diorite dykes.

of $5\frac{1}{2}$ dwt. ore per month, but considerable difficulty was experienced in treating the sulphide ores, which were eventually shipped to smelters in America for treatment. Operations were never very profitable and eventually ceased in 1907.

Szechuen.—Little is known of the auriferous occurrences of Szechuen province. The beaches of the Upper Yang-tse in several

[a] Verschoyle, Eng. Min. Jour., Nov. 17, 1906, p. 919.

places afford a scanty livelihood to gold-washers, who work over the gravels renewed from year to year by the floods of the wet season. The only gold mine of any size known to Europeans is at Maha (Long. 102° 05′ E.; Lat. 28° 15′ N.) Although alluvial gold has been recovered from this neighbourhood for many years, the gold-quartz veins of Maha have been worked only since 1880. At one time no less than 15,000 men were employed. The ore is crushed partly by Huntington mills and partly by 80 primitive Chinese stamps actuated by 40 overshot wheels. The mine is situated at an altitude of 10,000 feet.[a] Alluvial gold in small quantity is reported also from Kai-ja, 25 miles south-west of Maha; from Yen-Ching (Long. 101° 45′ E.; Lat. 27° 25′ N.); and from the sands of the Fu above Kiating.

Deserted gold mines are known near Fêng-ko on the Upper Yangtse (Long. 100° 30′ E.; Lat. 27° 45′ N.); the Muli (Tibetan) country further north on the Lithang river produces considerable quantities of gold-dust.[b]

Yunnan.—In Yunnan numerous small gold mines occur along the north- and south-running geomorphic folds developed by great Miocene movements.[c] The gold-quartz veins have been exposed only by native labour, and no foreign work has as yet been permitted. The only mine actually producing gold in 1907 was that of Ta-lan (Talangting), famous throughout Yunnan. Its glories have been depicted in glowing terms to the present writer even in a region as far distant from Ta-lan as the Shan States. Ta-lan is situated exactly on the Tropic of Cancer in east long. 101° 45′. The mines lie nine miles from the town in the hills to the north-east, and are at an elevation of some 7,300 feet above sea-level. Here intrusive volcanic rocks have broken through the Palæozoic shales, slates, sandstones, and limestones of the Yunnan plateau. Throughout the intrusive rock are fine veins of quartz. The auriferous area is said to cover about a square mile. Some 3,000 men are employed, and work in the crudest fashion. The output is nominally about 3,000 ounces per annum, but is probably much more. The mines have been worked for some 60 years, the Chinese Government receiving a royalty of 18 per cent. The ore is broken up with hammers and then pounded fine in an ordinary self-acting paddy (rice) mortar. It is then washed over grooved tables. The loss is evidently great, as many men make a livelihood by collecting and re-washing the tailings. The gold is apparently unevenly distributed in the veins, and rich pockets are

[a] Jack, "The Back Blocks of China," London, 1904, p. 101.

[b] Johnston, "From Peking to Mandalay," London, 1908, p. 238.

[c] Leclere, Ann. des Mines, Ser. 9, XX, 1901, p. 445.

occasionally met with. A yield of an ounce to the ton (5 fen to 100 catties) is considered to be the lowest payable return. The oxidised zones yield occasionally as much as 20 ounces per ton. Owing to the crude methods of working the total output of quartz per miner is probably a little more than two tons per annum. It is probable that the Ta-lan intrusive rock is an andesite of the same character as that which occurs sporadically in Burma.

At Kin-kiang, about 60 miles from Tali-fu, and at the spot at which the Blue river takes the name of Kin-cha-kiang, are rich conglomerate beds, perhaps 100 yards in thickness. Their tenor is unknown, but 500 gold-washers are engaged in working on them. The washers use wooden trays much like those in vogue in India and Burma. Their earnings are certainly small, perhaps no more than 3d. to 6d. ($1\frac{1}{2}$ to 3 grains gold) per day. These workings have been known since at least the 24th year of Kang-hi (1685 A.D.).

Jack[a] heard of gold mines, both in quartz and alluvial, two stages from Manwyne, on the Shweli (Loonkiang) river; and also of gold-quartz veins in the mountains between the Mekhong and the Salween at about 27° 20′ north latitude.

Garnier[b] heard of four gold mines in Yunnan, viz., that at Kin-cha-kiang, above-mentioned; at Ma-ku (opened in 1730 A.D.), on the borders of Yunnan, and near Linngan; Ma-kang (opened 1744 A.D.), south of Tchong-tien, and west of the famous silver mines of Ngan-nan; and Houang-tsao-pa to the west of Teng-yueh. The last is possibly that mentioned by Jack as lying two marches from Manwyne, though the positions given do not exactly coincide.

Fo-Kien.—A valuable goldfield is said to exist in the Shao-wu (Cha-oo) district of Fo-Kien province. Shao-wu lies about 150 miles north-west of Foo-chow, and is on the eastern flanks of the Yung-ling mountains.

The total gold output of China cannot of course be estimated with an approach to accuracy, but may be considered to range between £300,000 and £400,000 per annum.

MANCHURIA.

Liau-tung Peninsula.—The auriferous deposits of the Liau-tung Peninsula are divided by Bogdanovitch[c] into four classes: (*a*) Those in existing stream beds: These are of little importance. The Chinese wash the annually formed surface deposits from year to

[a] Loc. cit. sup.

[b] Voyage d'Exploration en Indo-Chinie, 1867, I, p. 230.

[c] Materialen zur Geologie Russlands, XX, 1900, p. 240.

year, and always, of course, at the same spots in the stream beds. (*b*) Pleistocene high-level gravels : These are worked east of Laio-tie-chan, near the village of Chandze-toun (121° 12′ E. ; 38° 43′ N.) to the south-west of Port Arthur. The pay-gravel is extracted by sinking closely adjacent pits through the overburden and enlarging these at the bottom when the pay-streak is reached. The overburden is only from 5½ to 7½ feet thick, while the pay-streak is from 6 to 8 inches deep. The tenor of the latter is from 9 to 14 grains per metric ton. (*c*) Ancient valley alluvials : Four pits sunk on the eastern slope of Laio-tie-chan proved the presence of an auriferous gravel bed. Its thickness varied from 2 to 4 feet, while that of the barren overburden was from 9 to 27 feet. The Chinese dug to bed-rock, finding fairly coarse grains of gold on the bottom. The tenor of the pay-streak was from 7 to 14 grains per metric ton. (*d*) Auriferous marine placers formed by the concentrating action of the sea waves and currents on the gravels brought down by the streams from the above-mentioned deposits : the Chinese work these placers during ebb-tide, the greatest width of beach exposed being some 60 yards. The thickness of the black-sand beds thus rendered accessible is about a foot. They lie on the upturned edges of argillaceous strata. The Chinese gather the sand as far seaward as possible, since the further out, the fewer pebbles there are. Fifteen Chinamen can recover 2½ tons of sand mixed with pebbles in one ebb-tide. On washing, this quantity yields 2·6 ounces (81 grammes) gold in grains and slugs of a fineness of 869. During two ebb-tides at the end of November, and under the above conditions, Bogdanovitch collected 5·3 ounces (166 grammes), in which was a slug of 1·77 ounces (55·4 grammes). The old gravels near Pei-lien-tsa were discovered about 1874 and the marine placers much later. Very low-grade thin gold-quartz veins traverse the quartzose and argillaceous schists of the neighbourhood, and the degradation of these has probably furnished the gold of the auriferous sands and gravels.

Both recent and high-level gravels occur in the neighbourhood of Port Arthur, and also to the east at Siao-pin-tao (Long. 121° 30′ E. ; Lat. 38° 49′ N.). Here also there is a marine placer, at the base of which pebbles containing gold are occasionally found. Elsewhere in the Liau-tung peninsula gold is found to the east of Port Adams near the lake Gou-tsia-pao-tsi (Long. 122° 02′ E. ; Lat. 39° 24′ N.), where the Chinese have exploited deep placers. Auriferous veins occur in the neighbourhood of the lake in the Taku-chan series of rocks. Similar auriferous alluvial deposits occur near the temple of Youhon-din-miao, and near the village of Chou-tsia-toun-pei-gu, about 15½ miles south-west of Pi-tsze-wo. These lie on amphibolitic schists and gneisses, that are intruded by pyritous granite-porphyry closely resembling the beresite (microgranite) of the Urals. Assays of adjacent veins gave from 1 to 5 dwts. gold per metric ton. The pyrites was also auriferous, averaging in tenor about 1 dwt. gold, though exceptional assays showed results as high as 32 ounces per metric ton.[a]

In Northern Manchuria several rich gold deposits are believed to exist. Von Cholnoki[b] reports an auriferous bed in the basin of the San-tao, originating apparently from the degradation of gold-quartz veins in granite and gneiss. At Tsi-tz'-Kouho, near Kirin, such veins have been worked. The basin of the Au-hao carries gold, as also do the gravels of the Great Chingan, though in both cases in small quantities. The gold mines of the province of Cheilun-tzian (Heilungchiang), which since the Boxer troubles had been seized by the Russians, were restored to the Chinese in 1907. Three mines are known: Quan-in-chan, Mo-che, and Quan-che. These were, after their resumption by the Chinese, worked directly by Chinese officials, but, the venture proving unsuccessful, they were handed back to the native Manchurian miners, the Chinese Government taking a substantial royalty.[c]

KOREA.

The median chain of the Korean peninsula is composed of ancient crystalline schists and granites through which recent volcanic rocks have been intruded. The general altitude of its higher peaks, situated in the north of Korea, where are also the gold-mining districts, is from 5,000 to 6,000 feet. The placer deposits of Korea have long been worked by the natives and are, or were, until the establishment of the Japanese protectorate, the property of the Imperial household. In 1898 concessions to foreigners were granted, one to each foreign nation then interested in Korean affairs. They were given for a term of 25 years on condition of a payment to the Emperor of a royalty of 25 per cent. of the net profits. Four such concessions were taken up: one each by Americans, British, Germans, and Japanese. The last proved worthless. The German concession lay at Tank-kogae, some 100 miles north-east of Seoul, and in the centre of a flourishing placer industry that had been in existence for 50 years, and where at one time 20,000 men had been employed. An extension of a year

[a] Pervinquière, Rev. Scientif., Ser. 5, I, 1904, p. 547.

[b] Földtani Közloni, XXIX, 1900, p. 289.

[c] Min. Jour., Nov. 2, 1907.

was given to the native miners to work out their holdings, and when the Germans finally took possession, much of the richer pay-dirt had been exhausted. The maximum thickness of the overburden above the pay-streak is estimated at 75 feet. The alluvial gold is fairly coarse, and nuggets of half-an-ounce in weight are not rare. The fineness is about 920.[a] Extended prospecting, both in the alluvial gravels and on the adjacent quartz veins from which the alluvial gold had been derived failed to yield any deposit of economic value, and the concession was abandoned.

The British concession was located at Yuen-san, where a rich ore-shoot was worked for some time. On its exhaustion, and on the failure of the subsequent endeavours to find new ore-bodies, this concession also retroceded to the Korean Crown.

The American grant, on the other hand, has been profitable from the commencement of mining operations. It lies at Unsan in the extreme north-west of Korea, near the Manchurian frontier. (Long. 126° 10′ E.; Lat. 40° 02′ N.). It has an area of 400 to 500 square miles, containing three distinct groups of mines separated by distances of some 20 miles. The groups are Chittabalbie and Maibong; Kuk San Dong; and Tabowie and Taracol, forming together the Oriental Consolidated Mines. Gold occurs here in banded quartz veins in granite. The veins contain a good deal of country, which is, as a rule, highly graphitic. The total quantity of sulphides present in the ore amounts to 10 per cent. The sulphides are pyrite, galena, and blende; of these the two last are considered certain indications of rich ore. The gold is fine and is seldom visible in the quartz.[b] There are five separate stamp-mills in operation, one at each of the above-mentioned mines, and in all 220 stamps are at work. To July, 1906, about a million tons of ore had been crushed, for an average recovery of 33s. 4d. per ton. Another million tons, worth about £1 per ton, was available. The total costs per ton in 1906 were 9s. 3d. The original royalty of 25 per cent. of the profits has been modified to an annual payment of £2,500. The annual produce of these mines is about £250,000.[c]

In addition to the foregoing, numerous placers are known at Chungkeung (near Kaichchou), Kalmoru (43 miles north of Changjim), at Kangwöndo, &c., and in Hpyengan-To generally. These are still being worked in native fashion, and yield large quantities of alluvial gold. In 1894 the production of gold in

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[a] Hamilton, Min. Jour., June 28, 1902; Bauer, Zeit. für prakt. Geol., XIII, 1905, p. 69.

[b] Speak, Trans. Inst. Min. Met., XII, 1903, pp. 237, 427.

[c] Curle, Eng. Min. Jour., Aug, 18, 1906, p. 296.

Korea was £195,844 (4,896,120 francs); by 1900 it had risen to £844,879 (21,121,989 francs).[a]

Recent returns are :—

	Kg.	Ounces.	Value, Sterling.
1905	3,892	124,933	£531,528
1906	3,488	111,965	476,334

JAPAN.

The long isolation of Japan from the Western World since the early years of the seventeenth century is doubtless responsible for the general neglect to recognise that Empire as one of the chief contributors to the flood of gold that poured into Europe during the sixteenth century. European trade with Japan opened with the appearance on its shores in 1542 of Mendez Pinto, the Portuguese adventurer, to use no stronger term. By 1600, the export of gold had assumed enormous proportions, and thousands of natives were engaged in exhausting the more accessible auriferous deposits. In 1611 the first signs of revolt against Portuguese domination were evinced, and by 1624 the last Portuguese had been expelled after an arduous struggle. A few Dutch were permitted to remain and to trade, but under the most humiliating conditions. The following is the estimated amount of gold exported from the country by the Portuguese and the Dutch respectively during the period of intercourse :—[b]

Portuguese	1545–1598	£6,000,000
	1599–1625	54,000,000
		£60,000,000[c]
Dutch (Gold alone) ...	1611–1646	£9,400,000
	1647–1706	4,600,000
	1707–1840	1,000,000
		£15,000,000

Since the present yield of Japan is only some £350,000 per annum, it is probable that the above sums represent the exhaustion of the placers and the enriched vein outcrops.

Yezo (Hokkaido).—The island of Yezo carries the most important placer deposits in Japan. The source of the gold is quartz veins in the Palæozoic formations. The most celebrated locality is Esashi (Lat. 44° 55′ N.; Long. 142° 30′ E.), the Klondike of

[a] Pervinquière, Revue Scientifique, Paris, 5, I, 1904, p. 545.

[b] Del. Mar, "History of the Precious Metals," London, 1880, p. 134.

[c] Gold and silver, of which probably £20,000,000 was gold.

Japan. At Esashi in 1899 there were collected 14,358 ounces (119,082 momme) including one nugget of 23·9 ounces (198 momme) in weight. During 1902 the principal alluvial mines in Hokkaido yielded :—[a]

	Ounces.
Shintotsugawa	6,616
Usotannai...	4,074
Peichan	2,196

Numerous alluvial gold occurrences are found in the provinces of Kitami, Teshio, Teshiro, Ishikari, Hidaka, Iburi, Shiribeshi, and Oshima.[b] In Ishikari and Hidaka platinum and osmiridium occur with the gold. The following table shows the value of the placer-gold output of Yezo during recent years :—[c]

	Sterling.		Sterling.
1898	£5,100	1903	£48,863
1899	48,643	1904	14,173
1900	111,143	1905	11,805
1901	101,080	1906	8,142
1902	63,367		

The only gold-quartz mine of importance in Yezo is the Pońshikaribets mine, lying about 7¼ miles (3 *ri*) south of the Yoichi, Shiribeshi Province. The country is a Tertiary volcanic tuff often intersected by andesite dykes. The veinstone is rhodochrosite and quartz, and the accompanying sulphides are auriferous argentite, galena, chalcopyrite, and zinc blende. The reefs vary in width from 5 inches to 30 feet. The gold yield from this mine for the three years 1898-1900 was 115,580 ounces (957,009 momme).

Honshū (Hondo).—Honshū, next to the south, is the largest island of the Japanese group. It contains several placer deposits of no great importance. Their gold content is derived mainly from the degradation of quartz veins in Tertiary andesitic tuffs and lavas.

In the Ugo province in the north of Honshū the chief gold-quartz veins are at the Matsuoka and the Ōkuzu mines. In the former the auriferous deposit is a stockwork at the contact of liparite, with Tertiary strata. The sulphides are argentiferous galena, zinc blende, and pyrite. Its produce is small, being for the three years 1898-1900 only 95·6 ounces (794 momme).

[a] Weigall, Trans. Inst. Min. Met., XV, 1906, p. 206.

[b] "Geology of Japan," Tokyo, 1902, p. 130.

[c] Gordon, Cons. Rep., 1907.

The Ōkuzu mine is 8½ miles south-west of the town of Hanawa. Its veins were discovered in 1604. The country is Tertiary tuff and augite-andesite. The width of the veins varies from a few inches to 2 or 3 feet. Chalcopyrite and pyrite and, rarely, sphalerite are the associated sulphides. The yield of this mine from 1896 to 1900 was 1,227 ounces (10,157 momme).

In the Ugo province the Innai mine, one of the most famous silver mines of Japan, produces some 3,000 ounces of gold annually, in addition to 400,000 ounces silver.

In the Iwashiro province some distance north of Tokyo and towards the eastern coast, are several gold mines. The Handa mine, about a mile west of Kori railway station, is believed to have been worked for at least 1,000 years. Its veins run through Tertiary strata and liparite, and vary in thickness from 3 to 10 feet. The veinstone is principally quartz associated with calcite, the former being sometimes amethystine in character. The accompanying sulphides are auriferous argentite, together with sphalerite and minor quantities of galena, chalcopyrite, pyrite. Native silver is occasionally found. The gold yield from 1896 to 1900 was 2,351 ounces (19,469 momme). The Takadama mine, 2½ miles from Atami station, is supposed to have been first worked in the ninth century A.D. Its yield is very small, and in its geological character it is similar to the Handa mine.

The Hashidate mine is situated in Echigo province, 7½ miles south-west of Itoigawa, on the west coast. Its values are believed to lie in quartz veins in Palæozoic rocks.[a] The gold yield for 1896 to 1900 was 8,043 ounces (66,601 momme).

The Kaga province, immediately to the south, furnishes two gold mines, the Kanahira and the Kuratani, the latter being 14 miles south of Kanazawa. The country in each case is liparite and Tertiary tuffs, traversed by numerous small veins. The veinstone of the former mine is barytes and quartz; of the latter, rhodochrosite, barytes, and calcite. Associated with the gold are galena, sphalerite, and pyrite. The yield of the Kanahira veins from 1896 to 1900 was 3,443 ounces (28,515 momme), and of the Kuratani for the same period was 8,314 ounces (68,843 momme).

In the Kai province, west of Tokyo, is the Ho mine, which has been worked since 1681 A.D. The quartz veins of this mine contain native gold in Palæozoic clay-slate and sandstone.

The most important mines of Honshū are probably those in the Tajima province, north-west of Kioto. The Kosen mine lies

[a] Loc. cit. sup., p. 124.

near the coast, 10 miles north-west of Toyooka, the principal town of Tajima province. Its rock is granite, traversed by propylite dykes. Two principal mineral veins are found in the granite, but the occurrence is evidently closely related to the younger intrusive rocks. The gold occurs with quartz, argentite, pyrite, and galena. The Ikuno mines, further south and near the town of Ikuno, are perhaps the most famous in Japan. They are said to have been discovered in 807 A.D. The three principal mines are the Tasei, Kanagase, and Kasei. At the Tasei the country is liparite, propylite, and Tertiary volcanic tuffs. Similar rocks occur at Kanagase but there they are traversed by basaltic dykes. At the Kasei the country is diorite, intersected by liparite and propylite dykes. The gangue of the lodes generally is quartz, calcite, and rhodochrosite, and the gold occurs with argentite, pyrite, chalcopyrite, bornite, fahlore, galena, stibnite, pyrargyrite, and sphalerite. The veins, as a rule, are very large and of great length. The Kasei lode, for example, is 5,300 feet long and nearly 50 feet wide. The yield of these mines from 1896 to 1900 inclusive was 16,449 ounces (136,202 momme).

The only other gold mine requiring notice in the main island is the Ōmori, in the Iwami province, due north of Hiroshima. This mine was opened about 600 years ago. Its rocks are hypersthene-quartz-andesite lavas and agglomerates, with which are associated Tertiary sedimentary strata. Its deposits fall into two groups: The Eikyū, in the solid hypersthene-quartz-andesite, and the Hontani stockworks and impregnations in the agglomerate. In the former group the veins are 1 to 2 feet thick, and consist of quartz and pyrite. The gold is associated generally with chalcopyrite. In the Hontani type the ores are native silver, argentite, siderite, and malachite. The yield of recent years from this mine has been small.

Sado.—The Aikawa mine, famous in Japanese annals, is near Aikawa, on Sado island, which lies off the north-east coast of Honshū. The veins were discovered in 1600 A.D., and yielded enormously for many years. They traverse augite-andesite tuffs and Tertiary shales. Three principal veins are mined, occasionally for great widths, the Aoban, the southernmost, attaining a working width of 100 feet. The Torigoe vein, the northernmost, varies from 5 to 50 feet, and the Ōtate from 2 to 10 feet in width. The two outer veins have a length of at least 4,000 feet. The veinstone is mainly quartz and calcite, at times carrying pearl-spar and gypsum. Native gold and silver occurs with argentite, chalcopyrite, pyrite, blende, and galena, together with occasional specimens of stephanite, pyrargyrite, marcasite, and arsenopyrite. The gold yield from 1896 to 1900 was 33,851 ounces (280,292 momme).

Kyūshū (Kiushiu).—The Kyūshū island is the most southerly of the large islands of the Japanese group. Its principal mines are in the Chikugo and Satsuma provinces. The Hoshino mines, 12 miles east of Fukushima, in the first-named province, are in augite-andesite, intrusive through Palæozoic rocks. The veins are 10 to 20 feet wide, and are impregnated with pyrite, and more rarely with sphalerite. The most productive are the Komuro and the Yamo. In the Satsuma province, in the south-west corner of the island, are the Serigano, Yamagano, and Kago mines. The first is 24 miles north of Kagoshima. It was discovered in 1652, and has since been worked almost continuously. The country is augite-andesite, and the veins vary in thickness from a few inches to 9 feet. Pyrite and chalcopyrite are usually associated with the vein-quartz. The yield of the Serigano mine from 1896 to 1900 was 2,052 ounces (16,991 momme).

The Yamagano mine lies 17 miles north of Kajiki, the principal town of Ōsumi province. It was discovered about the same time as the Serigano mines, and is said in one year (1659) to have yielded about 60,000 ounces of gold. The rocks of the neighbourhood are Tertiary shales and sandstones intruded by augite-andesite. The andesite is traversed by numerous auriferous veins, the thinner veins forming stockworks particularly rich at the intersections. The larger veins are often 20 to 30 feet in thickness. The veinstone is quartz with calcite and pyrite. Native gold occurs with argentite, or, more rarely, with chalcopyrite. From 1896 to 1900 these mines produced 11,932 ounces gold (98,801 momme).

The Kago mines are in the extreme south of the Satsuma province, and 31½ miles south of Kagoshima. They were discovered in 1683. The country is Mesozoic clay-slate and sandstone intruded by Tertiary quartz-porphyry and andesite dykes, which do not, as a rule, appear at the surface. The gangue is quartz and clay. The production of these mines is small, not amounting to more than 700 ounces per annum.

From the foregoing it will be seen that the majority of the gold-quartz veins of Japan have been worked for many generations. In these cases the gold of the zones of oxidation and secondary enrichment may be expected to have been exhausted, leaving only the poorer sulphide zones. In nearly every case it may be noted that the gold-quartz veins are associated with Tertiary andesitic intrusions.

During recent years the gold yield of Japan, exclusive of that of Formosa (given in another place), has been as follows :—

	Crude Ounces.		Crude Ounces.
1881–1890	146,062	1904	88,719
1891–1900	345,287	1905	95,173
1901	75,591	1906	95,747
1902	95,670	1907	88,653
1903	100,774		

FORMOSA (Taiwan).

Formosa, in common with other Eastern countries, has been represented by early European travellers as a repository of untold riches. Many of these voyagers, as Ogilby (1671) and Benyowsky (1771), enter into most elaborate details concerning the auriferous wealth of Formosa. Yet the knowledge of the sites of the old workings had, up to 1890, been completely lost. In that year flakes of gold were discovered during the construction of a railway in the extreme north of the island. Thousands of Chinese, many of whom had worked placer deposits in Australia or America, flocked across to the new find. At first, individual miner's rights were issued by the Chinese authorities, but in 1893, in order to lessen the expense of administration, the fields were farmed out for 18 months to four wealthy Chinese for the sum of £7,500 (75,000 yen).[a] In that year a rich placer deposit was discovered in the Kyu-fun mountains, and the fortunate monopolist who possessed that portion is believed to have obtained several hundred pounds sterling daily for a considerable period. The number of washers engaged was very large, and it is estimated that in one year (1893 to 1894) as much as £200,000 was recovered. In 1894 gold-quartz veins were discovered at Kyu-fun by a Chinese miner, who had obtained some experience in California, and in the same year, the Chinese authorities, in view of the flourishing state of the industry, resumed direct control. The island passed to Japan in 1895.

The principal alluvial fields are along the upper waters of the Kelung river, for 20 miles above the village of Suihenkiaka (Long. 121° 39′ E. ; Lat. 25° 05′ N.). Several streams flowing north-east to the coast from the Kyu-fun hills also yield alluvial gold. Zui-ho, 9 miles from Kelung, is practically the centre of the alluvial district. Only the long-tom and the cradle have as yet been used by the native washers. Other auriferous gravels or veins are known along the precipitous and dangerous east coast, access to which is equally difficult by sea or by land. These are in the Giran

[a] Davidson, "The Island of Formosa," London, 1903, p. 439.

(Gilan) district ; in the Buroko district, 12 miles south of Giran ; near Shinjio, 35 miles south of Suao ; near Shukoran, and in the extreme south-west of the island in the Fuko (Hongkong) hills. A reference to a geological map of Formosa shows that the above-mentioned localities are more or less coincident with exposures of Tertiary andesitic rocks.

The only vein mines now being worked are in the immediate vicinity of Zui-ho. The country is composed of Tertiary sedimentary strata intruded by andesitic dykes.[a] Three Japanese companies, the Fujita, Tanaka, and Batanko, are at work. The Fujita mines are at Kyu-fun, several hundred feet above sea-level. The ore occurs in a highly-decomposed zone, and is so soft that stamps have not hitherto been found to be necessary. The zone has been traced for 2,500 feet and varies from 2 to 7 feet in width. Within 60 feet of the ore body are seams of workable coal in the Tertiary sedimentary rocks. Similar coal seams are worked in the neighbourhood to furnish motive power for the mines. The rainfall of the district, 150 inches per annum falling on 219 days, is, however, so great that abundant electric power is readily generated from the numerous waterfalls. The mill of the Fujita is on the coast, 6,000 feet distant from the mine, and is connected with it by an aerial tramway. In 1906 the monthly output was some 2,700 tons for a yield of 2,150 ounces bullion, 700 fine in gold.

The Tanaka mines are two in number, one at Kinkwaseki, and the other at Batanko. The output is about 2,000 ounces per month.[b] The Kinkwaseki mine is in an area of Tertiary sandstone and shale intersected by a large dyke of quartz-andesite running north and south. The vein occurs on the east side of the dyke and sends small veinlets into it. The thickness of the vein is in places not less than 20 feet.

A little to the south of the two principal mines the Botanko mine lies in similar rocks. In 1906, 1,000 tons per month were being treated for 1,100 ounces bullion, 900 fine, but the output was shortly to be increased. The following table shows the yields of the respective Formosan mines from 1903 to 1905 inclusive :—

Year.	Fujita (Kyu-fun).		Tanaka.			
			Kinkwaseki.		Botanko.	
	Ounces.	Value.	Ounces.	Value.	Ounces.	Value.
1903	8,272	£26,172	12,559	£50,836	8,774	£32,940
1904	21,360	64,730	14,341	53,375	12,641	47,738
1905	25,800	73,014	24,800	85,312	12,130	43,473

[a] "Outlines of Geology of Japan," Tokyo, 1902, p. 129.

[b] Crowe, Consular Reports, Foreign Office, May, 1906, No. 649.

Year.	Placer.		Total.	
	Ounces.	Value.	Ounces.	Value.
1903	9,239	£28,976	38,844	£138,924
1904	5,126	16,500	53,468	182,343
1905	3,447	11,030	66,177	212,829

The total yield of Formosa from 1897 to 1907 inclusive is :—

Year.	Quartz.	Alluvial.	Total Ounces.	Year.	Quartz.	Alluvial.	Total Ounces.
1897	...	278	278	1903	29,605	9,239	38,844
1898	1,322	867	2,189	1904	48,342	5,126	53,468
1899	4,077	878	4,955	1905	62,730	3,447	66,177
1900	11,087	1,136	12,223	1906	48,051	1,712	49,763*
1901	18,735	15,409	34,144	1907	42,229	1,328	43,557*
1902	27,893	20,424	48,317				
							353,915

* Value about 75s. per ounce.

FRENCH INDO-CHINA.

Tongking.—Gold is very sparsely distributed in Tongking, and its recovery is practised only on the smallest of scales. The gold occurrences are mainly placer. They are situated at Cam-Lan (Sontai province), Nhat-Son (Lao-kay province), at various spots in the Tuyen-Kwang province, and at Mai-duc (Phuong-Lam province). The last alone calls for further mention. It lies some distance south of Hanoi, on the southern border of the alluvial delta of the Red river. It is in a region of low hills composed of slates and schists, through which small gold-quartz veins run. These last occasionally assay as high as 26 dwts. gold per ton. Their degradation has furnished alluvial deposits containing very fine gold, which were long worked by the Chinese. Since the occupation of the country by the French the placers have been abandoned.[a]

Annam.—As in Tongking, the auriferous occurrences of Annam are of little present importance, and may, with two exceptions, be dismissed with the mere indication of their respective localities. They occur at Tuong-Dong (Hatinh province); to the south of Turan (Kwang-Nam province); in the Mai-Leng region (Kwang-Tri province); and at Kim-Son (Binh-Dinh province).

[a] Pelatan, "Les Richesses Minerales des Colonies françaises," Paris, 1902, p. 238.

Of these, the Kwang-Nam occurrences are alone of importance. Gold is found both in veins and in alluvial gravels.

The actual localities at which gold is or has been worked are Vinh-Ninh, Than-Hoa, Vinh-Muy, Tai-Yen, and Bong-Miu. At the last-mentioned mines the ancient workings are very extensive, stretching on some of the veins for a mile in length. These mines were taken up by a French company (La Société des Mines d'Or de Bong-Miu) in 1896. Their mills in 1902 were treating from 50 to 60 tons quartz per day. The residues were being cyanided. The country is a micaceous schist in which several bands have been mineralised (with pyrite and galena) to breadths of 1 to 6 feet. The bands are locally lenticular. The gold occurs either free or contained in pyrite and galena. Chalcopyrite is occasionally present. The average tenor of the ore is said to be 9 dwts. per metric ton, while the total costs are given at 12s. per ton. Silver to the extent of 3 to 16 ounces per metric ton is also present. In 1902 no less than 745,000 tons ore were said to be in sight.[a]

A second auriferous region in Annam is that which lies in the upper basin of the Se-San, an eastern tributary of the Me-Khong, and falling into it at Stung-Treng. Here are numerous alluvial deposits that have for centuries been exploited by the Laos. The alluvial pay-streaks are rarely more than a yard in thickness. They are occasionally very rich, and some have a local value of 2 to 2½ dwts. per cubic yard. The general tenor, however, appears to be from 3 to 15 grains per cubic yard. As a rule, the gold is fine, but nuggets have been reported. One, indeed, is said to have weighed 65 ounces. Native washing is carried on in bateas, the gravel being extracted from the pay-streak by numerous pits placed close together. Quartz-mining in the old schists of this district is conducted by a French company at Ruhleville on pyritous gold-quartz veins carrying also galena.

The gold yield of French Indo-China is small; during 1906 only 1,412 ounces (44 kg.), worth £5,960, were produced.

SIAM.

The mountain ranges that separate the valleys of the Me-nam and the Nam-mun tributary of the Me-Khong contain the few known gold occurrences of Siam. The principal mines are those of Sara-buri, Bu-Khanun, Kabin, Srakeo, Watana, Chentabun, and, further to the east, Sesupon. All are therefore grouped about

[a] Pelatan, loc. cit. sup.; Saugy, Bull Soc. de Geol. Comm. de Paris, XXII, 1900, p. 626; Id., Bull. Com. de l'Asie française, X, 1902, p. 346.

the 102nd meridian of longitude, and to the east and south-east of Bangkok.

The Bu-Khanun mines, south-east of Korat, are in alluvial gravels that rest on sericite-schists. Srakeo, midway between Korat and Chentabun, contains veinlets in granite that have so far yielded most disappointing results to the French company working them. The Watana mines are also worked by a French company. They were first opened as placer mines, but in 1894 an exceedingly rich pocket was found in a quartz-vein in the eruptive porphyries that traverse the crystalline schists of these mountains. Since that time further rich pockets have been encountered, but, taken as a whole, the deposits offer little encouragement to systematic exploitation. The veins of Chentabun are also in decomposed eruptive rocks. They have been worked by the Siamese, and even of late years have yielded rich gold-quartz. They are now abandoned. Similar veins occur at Sesupon, which is situated on a river flowing into the great Tonle Sap lake. The Kabin mine, midway between Pachim and Watana, formerly produced more than 2,000 ounces gold per annum.

The climate of the Siamese gold districts is one of the most deadly and most malarious in the world, and even a short sojourn often proves fatal to native and to European alike. This fact, of course, militates greatly against the development of the mines.

FEDERATED MALAY STATES.

In this portion of the Malay Peninsula a belt of auriferous country extends northwards from Mount Ophir into Kelantan. Along the belt all the peninsular goldfields occur, but in sparse and irregular distribution. The country of the goldfields is essentially the Raub series of shales and limestones, which appear to correspond very closely with the Upper Productus beds of the Salt Range in India,[a] and are therefore of Permo-Carboniferous age. They may, however, on examination be found to be more closely allied to similar beds in the Shan States of Burma.[b] Interbedded with the limestones and shales of the Raub series are tuffs and ash-beds, which are often highly sheared. With these latter may possibly be connected basic dykes that are found cutting through the granite. The dykes are both diabasic and doleritic. The igneous members of the Raub series are sometimes metamorphosed into hornblendic and augitic schists. Garnetiferous phyllites are also found.

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[a] Scrivenor, Progress Rep. Geol. Surv. Fed. Malay States, 1907, p. 25.

[b] Middlemiss, Ann. Rep. Geol. Surv. India, 1900, p. 138.

Kelantan.—The semi-independent State of Kelantan, ruled by a Mussulman sultan, lies in the Malay Peninsula, in the extreme south of Siam. It is now to be considered, together with the adjacent Trengganu State, as a portion of the Federated Malay States, the transfer from Siam having been effected in 1908. Its auriferous districts, indeed, lie on the northern slopes of those mountains from which the Plus and the Kintra rivers flow to Perak. The best known of the gold mines are situated at Kundor (Long. 101° 55′ E.; Lat. 4° 54′ N.) on the left bank of the Galas river, a short distance from Pulai, and within a few miles of the Pahang border. These mines have been worked for generations by the Chinese and Malays, who, however, devote the whole of their energies to the placer deposits of the neighbourhood.[a] Successful dredging on the Kelantan river has been carried on since 1904 by the Duff Development Syndicate. The attempts of this company to discover gold-quartz veins of economic value have so far met with failure. During 1904-5 this company produced £4,931 ($42,264), and in the following year £8,900 ($76,290) gold, all derived from the dredges. In 1906–7 the dredging companies obtained 6,461 ounces gold.[b]

Perak.—In Upper Perak, Batang Padang, and Kuala Kangsar, gold is found in limited quantities with the tin "wash." Near Tapah, in Batang Padang, a gold-quartz vein, Bukit Mas, has been worked in phyllite. In 1897 it produced 1,100 ounces gold from 5,250 tons ore. It has since been abandoned.[c] Perak, in 1905, produced 1,799 ounces (fine) worth £7,196, and in 1906, 1,057 ounces (fine) worth £4,228.

Negri Sembilan.—Gold is found along the eastern portion of this State from the borders of Malacca, in the Tampin district, to the boundary of Pahang, in the Kuala Pilah district. Batu Bersawah, lying a little to the north of Mount Ophir, is the only gold-quartz mine now being worked in Negri Sembilan. Its returns are very small, being in 1906 only 434 (fine) ounces. It appears to be in sheared and altered diabase near its junction with the Raub shales.[d] The veinstone is quartz, and the gold occurs with pyrite and blende. The auriferous occurrence at Pasoh in the north of this State is interesting since the country is a sheared granophyre. There is no defined lode, and from the fact that the richest patches were obtained in vughs with pyrites, it would appear that the

[a] Clifford, Geog. Jour., IX, 1897, p. 33.

[b] Graham, Cons. Rep., 1907.

[c] Belfield, "Handbook of Fed. Malay States," London, 1907, p. 69.

[d] Scrivenor, loc. cit., p. 25.

free gold obtained was derived from the decomposition and removal of pyritous impregnations.

Pahang.—Alluvial gold in small quantities is widely distributed throughout Pahang. None of these placer occurrences appear to be worthy of the attention of the European miner. At the present time gold-quartz veins are worked in this State only by the Raub-Australian Gold Mining Company, which controls the three mines, Bukit Koman, Bukit Malacca, and Stope. The rocks of these mines are the shales of the Raub series, here almost vertical. With the shales, which are often calcareous, are associated calcareous crush-conglomerates. There are no well-defined veins, but the ore is obtained from irregular lenticular bedded veins and stringers, the value being highest where there is a considerable admixture of pyritous country. At Bukit Koman, when the quartz is massive and in bulk, its average value may be 2½ to 3 dwts. When, however, the ore-body becomes a mass of quartz veinlets and stringers its value rises to 12 to 20 dwts. per ton. At the Stope mine scheelite occurs with the gold quartz. The Raub mines and mills are worked by electricity generated at the Senjam river. The latest available returns from these mines are :—

Year.	Tons Ore.	Ounces Gold.
1905	60,905	7,879·227
1906	69,139	9,995·192

or an average return of 2·75 dwts. per ton ore.

Gold-quartz veins have from time to time been worked in other parts of the State, at Silensing, Tui, Punjom, and Kechau. At Tui the veins occur with calcite in a light-grey limestone ; at Punjom in a nondescript rock resembling a greisen ;[a] and at Kechau, 40 miles north of Raub, the hanging-wall was hard black limestone, while the footwall was a sheared ash-bed, probably of the Pahang Volcanic Series. Between these clearly-marked walls were scattered masses of low-grade ore. A crushing of 1,380 tons from Kechau yielded 581·503 ounces, equivalent to 8·42 dwts. per ton.

The output of gold from Pahang from 1890 to 1906 inclusive was 241,358 ounces, of an approximate value of £965,000. From the four States comprising the Federated Malay States there were produced during 1905 and 1906 :—

Year.	Ounces.	Value.
1905	11,453	£45,812
1906	11,580	46,320

[a] Scrivenor, Pahang Gov. Gazette, July, 1904, p. 5.

EAST INDIAN ARCHIPELAGO AND POLYNESIA.

PHILIPPINE ISLANDS.

Gold-mining is a very ancient industry in the Philippines, and gold has long been exported from thence to China and Further India. The export naturally attracted the attention of both the Spaniards and the Portuguese, who hoped to find there a second Inca hoard, and many were the futile endeavours made by them to discover the supposed rich deposits. As far back as 1572 the well-known mines of Paracale and Mambulao in Camarines Norte were examined by Latin adventurers. It follows, therefore, that the more accessible alluvial and vein gold-deposits are now exhausted, leaving only those which, from difficulty of access or of working, were beyond the reach of the native miners, who, as in the case of the northern Igorrotes, indeed displayed no mean skill in vein-mining.

In the island of Luzon are two main auriferous districts. The northern field lies in the neighbourhood of Mount Data and in the country of the Igorrotes in the provinces of Abra, Bontoc, Lepanto, and Benguet. The region is one of crystalline schists and old massive rocks. The placers of Nueva Ecija lie north of Manila and east of the Rio Grande de Pampanga. They have long been worked by the natives, but were only recently known to Europeans. The auriferous gravels lie on sedimentary rocks, but hornblende-andesite and gneiss are known in the neighbourhood. The pay-gravel contains large pebbles and masses of chalcedony and jasper. The gold is very pure, but is small and flaky. The presence of clay and the lack of a regular water-supply tend to hinder the exploitation of these placers. Platinum, and possibly iridium, are associated with the gold.[a] The southern field is in the province of Camarines Norte, to the east of Manila. Here also the region is gneissic and schistose. The gold-quartz veins carry, in addition to gold, pyrite, chalcopyrite, galena, and sphalerite, with occasionally a little lead chromate (crocoisite). At Dagupan, south-west of Mambulao, are numerous gold-quartz stringers in black clay-slates, the whole being strongly reminiscent of the Southern Appalachian quartz veins in saprolite.[b]

[a] Goodman, Min. Jour., Oct. 26, 1907.

[b] Becker, 20th Ann. Rep. U.S. Geol. Surv., 1899-1900, Pt. III, p. 576.

At Paracale, the rock appears to be granitic, and the veins are sometimes 20 feet in width. From 1893 the "Philippines Mineral Syndicate" worked the historic Mambulao mines, but apparently with little success. Numerous placer mines, and also beach sands, are worked in the Camarines Norte province, but their production is diminishing from decade to decade, and they present no features of special interest. Gold dredges were operating in 1907 on the placer deposits of Paracale.

On Masbate Island both quartz veins and placer deposits are being worked. At Arroroy, a 10-stamp mill was erected to crush gold quartz. Two gold dredges are also in operation, one on the Lanang river and the other on the Guinibattan river. Both are working regularly.[a]

In the province of Capiz, Panay Island, several alluvial deposits are worked. The best of these appears to be at Astorga, Dumaráo (Lat. 11° 16′ N.). Others are near San Enrique and Barotoc Viejo in the province of Ilo-ilo. In the island of Cebu are abandoned mines, in which pyritous veinlets in diorite had been worked. Gold occurs at Pambujan, in the island of Sámar. Pyritous gold-quartz veins are also known at Pinutan in the small island of Panaón, lying between Leyte and Mindanao. The wall rock is "greenstone-porphyry." One vein of a tenor of 25s. to 30s. per ton, 6 feet wide, and carrying pyrite, galena, and zinc-blende, had been worked to a considerable extent.

Like Luzon, Mindanao possesses two distinct auriferous regions, one immediately south of the Bay of Macajalar, in the province of Misamis (Lat. 8° 20′ N.; Long. 120° 40′ E.), the other including the east-coast range of the province of Surigao. The Misamis deposits include veins, placers, and river sands. The veins are mainly in the Pigholugan region, where the two principal mines are the Abaca-an and the Pigholugan. Both are working in a soft grey argillaceous slate, where numerous narrow quartz-stringers, rarely more than an inch wide, form stockworks. The gold occurs in "pockets," mainly at the intersections of these veinlets, and the method of working is governed entirely by the manner of occurrence.[b] The river sands of the region are little worked, and the bulk of the gold comes from old high-level river gravels, of which the more important are those of the Iponan, Rio Cagayán, Bigaan, and Cutman (Kugman), all rivers flowing into the Bay of Macajalar. The pay-streak in the gravels runs from 18 inches to 10 feet in thickness, and appears to average about 5 feet. According to Abella, the pay-streak contains as much as 27 grains fine gold per

[a] Eng. Min. Jour., July 21, 1906, p. 102.
[b] Nichols, Trans. Inst. Amer. M.E., XXXI, 1901, p. 612.

cubic yard,[a] yet those engaged in washing earn only from 6d. to 1s. per day. Nichols[b] estimates the value of the dredging area of the Iponan, below the Pigtao, as worth from 7½d. to 12½d. (15 to 25 cents) per cubic yard.

In the Surigao province the eastern mountains are reported to be auriferous from their northern extremity as far south as Carga (7° 12′ N.). The northern portion appears to be the richer, especially in the neighbourhood of Surigao, Placer, Mainit, and Taganan. The gold-quartz veins of this area are pyritous (pyrite, chalcopyrite, galena, and blende), and lie in a metamorphic slate. They are small and pockety, resembling greatly those of Pigholugan described above. Beside the foregoing there are numerous auriferous occurrences, both in veins and in gravels, but none appear at the present time to be of economic value or of scientific interest.

Gold has recently been found about 25 miles north of Zamboanga, at the westernmost extremity of Mindanao. It occurs in a yellow clay arising from the decomposition of a schist, the original locus of the gold being quartz-stringers in the schist.[c]

BORNEO.

British North Borneo.—Gold has been known since 1883 in the gravels of the Segamah river on the east coast of North Borneo. Silam, in Darvel Bay, is the nearest port to the locality. Exploration in the neighbourhood has hitherto failed to prove the existence of gold in payable quantities. Beach gold is also reported from Marudu Bay.

Sarawak.—The gold deposits of economic importance in this State lie to the south-west of Kuching, the capital. They were worked both for alluvial gold and for lode gold by the Chinese. The placer gravels are now more or less exhausted. It was from Krian, near Bau, that the largest nugget found in the Borneo drifts was obtained. Its weight was 7 ounces (218 grammes).[d]

Gold is won from the matrix at Bau, Bidi, and Jambusan, about 15 miles south-west of Kuching. The Bau mines were primarily worked for antimony. The general geology of the country is simple. A conformable series of stratified rocks lies approximately horizontal. The basement rock is a Middle Oolite limestone, which is overlain by thin marl beds, often very local in development. The marl, where it occurs, is overlain by a series of shales, sandstones, grits, and conglomerates. The whole series is greatly broken by

[a] Becker, loc. cit., p. 581.

[b] Loc. cit., p. 616.

[c] Min. Sci. Press, Jan. 1, 1908.

[d] Posewitz, "Borneo," Trans. F. H. Hatch, London, 1902, p. 318.

block-faulting, and is extensively intruded by quartz-porphyry dykes.[a] The igneous rocks also occur as sills and as nondescript masses or stocks varying in character, according to Scrivenor,[b] from a hypersthene-gabbro to a quartz-diorite. All are probably segregations from an andesitic magma.

The main gold-bearing belt of Upper Sarawak may be said to extend from south-west to north-east through Bau and Bidi. The ore occurs: (*a*) As irregular masses in limestone, and (*b*) as impregnations or disseminations in shale. The former are as a rule richer and more pyritous than the latter. At Bau the workings are all open-cast, and are scattered over a wide area of low-lying land. The ore is a dark breccia of shale, sandstone, and limestone cemented and often largely replaced by silica. The minerals associated with the gold are strikingly characteristic of andesitic influence. They are mispickel, galena, proustite, cinnabar, native arsenic, realgar, native antimony, stibnite, senarmontite, valentinite, jamesonite, and bindheimite (lead antimoniate). The gold (as at Coromandel, New Zealand) is often associated with native arsenic, while the stibnite contains little or no gold. The pyritic ore from Su San Shien, Bau, yielded on analysis (Geikie):—

Sulphur	31·75	Zinc	14·32
Arsenic	20·32	Cobalt	·30
Iron	27·86	Silica	·84
Copper	·04	Oxygen and Loss	·11
Lead	4·10		
			99·64

At this mine it has been noted that where intrusive sills occupy a horizontal position in the shales, mineralisation is wholly confined to the underlying beds of shale. While the shales overlying the limestone are often auriferous, the marls that have already been mentioned as having a local development are always barren. The gold comes from the pyrites in the shales, no free gold being seen, even in panning rich ore. Silicified shales furnish the great bulk of the ore milled. In these, the impregnation, as might be expected, is extremely irregular in value. Average analyses of silicified ore gave the following:—

Silica	76·82	to	85·59
Arsenic	1·14	,,	14·84
Antimony	·50	,,	1·50
Iron	·94	,,	2·05
Sulphur	·54	,,	1·75
Lime	·89	,,	5·60
Carbon di-oxide	·70	,,	4·44
Gold	8 dwts.	to	35 dwts. per ton.
Silver	20 ,,	,,	40 ,, ,,

[a] Geikie, Trans. Inst. Min. Met., XV, 1905, p. 63.

[b] "Geology of Sarawak," Sarawak Gazette, 1905, p. 102.

At Taiton the ore occurs in fissures in the limestone, but mud, clay, and soil have also been worked. There would appear to be often a secondary enrichment near the surface, probably effected in this case by the removal of matrix and base matter.

At Jambusan, 2 miles east of Bau, the ore occurs as irregular masses or pockets in the limestone. The ore-bodies have no well-defined limits, and their exploitation is guided entirely by the tenor of the rock. The ore is a hard, black, cherty rock, containing 87 per cent. silica and 11 per cent. stibnite. The gold is coarse and free, varying in amount from 5 dwts. to 20 ounces per ton of ore. Numerous dykes and intrusive sheets occur in this neighbourhood, and it is evident that the mineralisation throughout this field is closely dependent on these igneous rocks. Near Bau, a quartz-porphyry dyke yields from 1½ to 2 dwts. per ton, and there are several similar dykes in the neighbourhood whose gold content appears to be associated with wad and manganiferous clay.

At Tai Parrit, about 100 acres are silicified and mineralised, carrying small quantities of gold throughout. Shales, limestones, and marls are confusedly thrown together, and the whole is intruded by numerous dykes. In some cases brecciation is due to removal of the underlying limestone, in others, it is apparently due to faulting. As a rule, the deposits are small, scattered, and shallow, but at Jambusan one deposit has been proved to a depth of 120 feet.

Since mining is open-cast the costs are low. Mining and transport amounted in 1905 to 2s. 6d. per ton, while the total costs were 10s. 4d. per ton.[a] From November, 1898, to July 31st, 1904, no less than 448,319 tons ore had been treated at Bau for a yield of 87,182 ounces fine gold, equal to a return of 3·88 dwts. per ton. In 1905, two mills, at Bau and Bidi, were in operation, the former treating 10,000 and the latter 8,000 tons per month. The output of fine gold in 1905 was 44,299 ounces, 39,186 ounces in 1906, and 41,751 ounces in 1907.

DUTCH EAST INDIES.

Dutch Borneo.—Gold has for centuries been worked in Borneo by the Chinese, who operated, generally with great success, in small working syndicates. In the early part of the nineteenth century the Chinese industry was in a highly-flourishing condition, and Chinese miners were possessed of considerable political influence, the exercise of which eventually brought them into conflict with

[a] Scrutton, Trans. Inst. Min. Met., XV, 1905, p. 144.

the Dutch authorities, and engendered a long war that ended only in 1854 with the complete subjugation of the Chinese. During the struggle the gold-mining industry suffered severely, and has never indeed regained its former position. In Dutch Borneo, gold occurs both in the parent rock and in the gravels of the streams, nearly all of the latter containing a little gold. Three main auriferous districts may be made out: a western, including the so-called "Chinese districts" in the neighbourhood of the Sambas and Landak rivers; a central district covering the country at the heads of the Kahajan and the Kapuas rivers; and a south-eastern district including the Tanah-Laut and the Kusan countries. The line of auriferous country in Borneo would therefore appear to strike from Western Sarawak south-east across Central Borneo to Tanah-Laut, a line coinciding very closely with the distribution of the Tertiary eruptive rocks, as shown on Posewitz's geological map.[a]

No gold-quartz veins of importance have yet been found in Dutch Borneo, though many have from time to time been worked by the Chinese. The western district contains the majority of those known. There, Von Schelle found numerous vein-like impregnations in the phyllites, slates, and sandstones of the "Old Slate" (Devonian ?) formation, or in the older igneous rocks (granite and porphyrite). The latter, as well as the former, are often highly metamorphosed. The more noteworthy of these occurrences of the western district are in the Skadau mountains;[b] in the Udu mountains, further to the south-east near Melassam; near Sjui-Tsiët on the northern slopes of the Pandan mountains; near Mandor in the Han-ui-san and Snaman mountains; and near Sikarim. Both the older sedimentary rocks and the intrusive granites and diorites are traversed by younger apparently Tertiary dykes of andesitic facies. The occurrence of gold is more or less restricted to the igneous rocks, to their contacts, or to the slates near the point of contact.[c] The period of auriferous deposition generally would seem to be post-Eocene and to have been dependent on the early Tertiary eruptions. A vein near Budok is especially interesting, in that it contains sylvanite (telluride of gold and silver), the only occurrence of this mineral yet reported from Borneo. The usual associates of the gold are pyrite, chalcopyrite, and galena. The alluvial deposits of the western district have derived their gold directly from the denudation of veins and veinlets similar to those above described. The deposits in the lowest portion of the beds of the present rivers have not yielded much to the native worker

[a] "Borneo," Theodor Posewitz, Trans. F. H. Hatch, London, 1902, p. 312 *et seq.*

[b] Loc. cit., p. 334.

[c] Truscott, Trans. Inst. Min. Met., X, 1902, p. 58.

owing to the great quantities of water encountered. They may be found to be well adapted for dredging. Native alluvial workings have been mainly carried on in the older drifts where the gold has been found associated with diamonds, platinum, and cinnabar. These older drifts are probably Quaternary. The soil of the hill-slopes also furnishes gold that, in this case, is liberated from the matrix by the decomposition of the rock *in situ*. Such deposits are of course poorer than those on which the concentrating power of running water has had some play. Native washing is effected with rude ground sluices and bateas. Chinese washing is much more advanced, water-wheels and chains being used, and long water-races dug to bring in water to command the gravels.

The central auriferous district lies, as has been stated, towards the head-waters of the Kahajang and the Kapuas. The Kahajang mine is the most noteworthy. It is at the contact of a quartz-porphyrite with the "Old Slate" formation, both having been fractured and impregnated with silica and auriferous pyrites.[a] The quartz of the porphyrite is blue or purple, and, with the felspar, often assumes a peculiar lenticular shape, the result apparently of pressure. The main Kahajang veins are about 212 feet apart, with several small veinlets in the intervening country. The quartz assays about an ounce gold and 12 dwts. silver per ton. A small trial crushing of 139 tons gave 260 ounces bullion, 780 fine. Other quartz-veins in the neighbourhood are in quartz-porphyrite or felsite dykes, and from the degradation of these the alluvial gold appears to have been derived. As in the western district there is a great development of Tertiary andesites, dacites, rhyolites, and basalts. These are especially well developed in the Müller mountains, where they appear to be disposed along a line of fracture.[b] Auriferous impregnation here also is apparently dependent on the volcanic rocks. The alluvial deposits of the Kahajang Valley appeared to Truscott to afford scope for dredging.

In the south-eastern district no quartz veins have been located, but the alluvial gold, especially near Amuntai, appears to have been derived from an altered andesite. On the whole, the Tanah-Laut district in the extreme south-east of Borneo has furnished the richest alluvial deposits.

The gold yield of Dutch Borneo is insignificant, being only 1,990 ounces (62 kg.) in 1905, and 1,059 ounces (33 kg.) in 1906.

Celebes.—Gold-mining on the island of Celebes is at present confined to the narrow east and west peninsula in the northern

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[a] Truscott, loc. cit. sup.

[b] Molengraaff, "Geological Explorations in Central Borneo," London, 1902.

extremity of the island. Here natives and Chinese have long carried on the industry in the usual crude eastern fashion. As in Sumatra and Borneo, auriferous deposition appears to be closely connected with rocks of andesitic facies. The most westerly field on the north coast is that of Palehleh. These mines were taken up by Europeans in 1892, and eventually passed to the Nederland-Indische Gold-mining Company. The main ore-body consists of veins and stringers of auriferous sulphides in augite-porphyrite breccia.[a] Not far to the west are older slates intruded by porphyrite dykes. The slates are the Dolakapa series of Molengraaff.[b] The porphyrite dykes are pyritous, and are occasionally auriferous to the extent of 1 to 1½ dwts. per ton. The ore-body carries three or four parallel sulphide veins separated by country through which smaller stringers ramify. The width mined varies from 1 to 20 feet and will probably average about 6 feet.[c] The sulphides of the ore-body are pyrite, galena, sphalerite, and chalcopyrite, with small quantities of antimony and arsenic, the two last appearing only in chemical analyses. The country itself is also thoroughly impregnated with pyrites, and is, within the lode limits, auriferous to the extent of 2 dwts. per ton. The sulphides themselves carry :—

Gold	4½ ounces per ton.
Silver	12 ,, ,,
Lead	8·5 per cent.
Copper	1·5 ,,
Zinc	3·5 ,,

The value of the ore, owing to the large admixture of country, is generally however about ½ ounce gold per ton associated with 8·5 per cent. sulphides. The gold is, on the whole, coarse, and lies upon, rather than in, the pyrites crystals, from which the bulk of it may be separated by grinding and washing. A proportion seems to be more closely associated, since the pyrites thus washed away possesses a constant value of an ounce per ton. The Palehleh ore-bodies appear to be disposed at intervals along a fracture plane, the length of ore-bearing shoots being more or less equal to that of the intervening barren rock. A similar occurrence to that of Palehleh lies to the south near Pagoeat.

Forty miles west of Palehleh, at Soemalatta, also on the north coast, lies a similar occurrence. Here the ore-body, rich in the andesite, decreases appreciably in value as it passes into the adjacent Dolakapa slates. The eruptive rocks enclosing the ore-bodies

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[a] Bücking, "Beiträge zur Geologie von Celebes," Petermann. Geog. Mittheil., XLV, 1899, p. 276.

[b] Zeit. für prakt. Geol., 1902, p. 250.

[c] Truscott, loc. cit. sup., p. 64.

are diabase- and augite-porphyrite breccia, termed by Molengraaff the "Wubudu eruptive breccias."[a] Three main-reef systems occur at Soemalatta: the North Reef, South Reef, and the Veta Nueva. Ten miles to the west, beyond Soemalatta, is a vein in the eruptive andesitic breccia of Denuki Bay. The lode-matter is a brecciated rock with a siliceous cement, highly pyritous, but of low value.

On the opposite coast and east of Soemalatta is Totok, perhaps the most interesting of North Celebes auriferous deposits. Here the gold occurs in quartz blocks embedded in a tough clay contained in a limestone resting on porphyrite (altered andesite). The igneous rock is possibly an intrusive sill, while the clay represents the decomposition product of brecciated andesitic dykes that have passed upward through the limestone. Decomposition has been largely accompanied by silicification. The gold is found as specks or leaves between the larger quartz crystals, or as moss- or wire-gold on the smaller crystals. Quartz veinlets ramifying into the limestone are small, but are often very rich. There is a complete absence of sulphides, and these veins therefore are in marked contrast to other North Celebes occurrences. From the geological evidence afforded at Totok the general period of andesitic eruption and of auriferous impregnation is almost certainly Tertiary.

Six miles south-west of Totok is the Kotaboenan field, where the gold occurs associated with veinlets and impregnations of quartz and sulphides in decomposed andesite.[b] Except for the greater abundance of quartz at Kotaboenan, the geological conditions resemble those of Palehleh. Minor occurrences are found at Pinogo and Gorontalo further to the south-west.[c]

In 1906 the Celebes goldfields produced 25,038 ounces (780 kg.) fine gold, Totok yielding 11,716 ounces (365 kg.), Palehleh 9,598 ounces (299 kg.), and Soemalatta 3,724 ounces (116 kg.).

Sumatra.—From the remotest times Sumatra has been famed for its gold. Even in the Ramayana, one of the two great Sanskrit epics of the Hindus, Yawadwipa (Sumatra), "adorned by seven kingdoms, the gold and silver region rich in gold mines" is mentioned. Yet, at the present day, only one goldfield is certainly known to merit the application of modern methods. This is the Radjang-Lebong field, 100 miles from Bengkoelen on the south-west coast. Ancient workings were discovered in 1896, and work has since been profitably continued. The Radjang-Lebong lode consists of

[a] Loc. cit., p. 276.

[b] Truscott, loc. cit. sup.

[c] For detailed information concerning the gold deposits of the Dutch East Indies, v. Jaarboek van het Mijnwezen in Nederlandsch Oost-Indie, Batavia, 1895-1906.

five well-defined seams separated by highly-silicified altered andesite. A blue quartz vein, 2 feet wide, on the footwall carries 1 to 2½ ounces gold. Then a band of silicified andesite 18 to 25 feet wide, assays 6 dwts. throughout, and above the broad band of country come the minor seams.[a] The average width of the ore-body for a distance of 1,000 feet has been stated at 17 feet.[b] In 1908 the ore reserves were said to be 265,000 tons of an average assay value of 21 dwts. gold per ton. The gold is finely disseminated throughout the mass and can rarely be seen on panning. The common sulphides are pyrite and chalcopyrite. Pyrolusite, wad, and chalcopyrite also occur. The bullion contains (as at Waihi, New Zealand) a notable proportion of selenium, an analysis giving :—

Gold and Silver ...	91·52	Zinc	·48
Selenium	4·35	Iron	·14
Copper	1·82		
Lead	1·65		99·96

No tellurium has as yet been detected either in the bullion or in the ore. The ratio of silver to gold in the bullion is often 10:1.

At Lebong Soelit, 5 miles west of Redjang Lebong, is a very similar occurrence. Four outcrops, suggesting separate parts of a faulted vein, have been worked by the natives. The total length of outcrop thus indicated is 2,000 feet, over which the reef has an average width of 8 feet and a value of 20 dwts.[c] Assays of the enclosing andesitic country have yielded a little silver but no gold.

A third gold-bearing ore-body lies 7 miles west of Lebong Soelit. The three occurrences, Redjang Lebong, Lebong Soelit, and the third unnamed, lie along an east-west line 12 miles long.

The following shows the output of the Redjang-Lebong mines during the years 1906 and 1907 :—[d]

	Gold. Ounces.	Silver. Ounces.	Tons Crushed.
1906	45,479	248,240	......
1907	59,926	327,584	59,208

In 1907 a dividend of 71 per cent. on a capital of £208,333 (florins 2,500,000) was paid.

The Ketahoen mines are also in the Lebong district in the south-west of Sumatra, and about 80 miles north of Bengkoelen.

[a] Ivey, Trans. Inst. Min. Met. XII, 1903, p. 340.

[b] Truscott, ib., X, 1902, p. 53.

[c] Truscott, loc. cit., p. 55.

[d] Min. Jour., Feb. 29, 1908, p. 250.

Like the Redjang-Lebong they have proved extremely profitable. During 1906 and 1907 they yielded gold and silver to the value of £64,710 (florins 783,000), and £83,718 (florins 1,013,000) respectively.

A minor auriferous area is the Oembilien goldfield in the neighbourhood of Fort de Kock and Soepajang, in the middle of Sumatra. The country here is also andesitic, but the quartz-veins yet found have been of very low grade. In the old schists of Moera Supongi (Tapanoeli), Western Sumatra, Hundeshagen[a] found gold in a grossularite garnet deposit with wollastonite. Black augite-diorite occurs to the west of the deposit, which was not improbably originally a limestone band in the schists, was subsequently metamorphosed to garnet and wollastonite and mineralised by solutions carrying gold, copper, and platinum. Selected samples of bornite assayed from ½ ounce to 75 ounces gold per ton.

NEW GUINEA.

British New Guinea.—The great mountain chain of New Guinea is formed by Archæan crystalline schists and metamorphic rocks, and is continued from the mainland south-east through the islands of the D'Entrecasteaux and of the Louisiade groups. An immense area, extending from near Port Moresby to the German frontier (Lat. 8° S.), is occupied by these rocks. Another similar area occurs further east near Mount Suckling (11,226 feet), and the intervening Owen Stanley range may be conjectured to be also of Archæan schists.[b] It is these ancient rocks that furnish the gold of New Guinea either in veins *in situ*, or detrital in the river valleys. Quartz veins have not been worked on the mainland, except at Gibara, near Milne Bay. The Gibara veins were small and were soon abandoned. More or less successful vein-mining has, however, been, carried on since 1900 on Woodlark Island (Murua), 180 miles north-east of Samarai, which is now the principal port of New Guinea. Woodlark is an upraised island with coral reefs elevated 150 feet above sea-level. The gold-bearing formation at Kulamadau, the principal centre, is merely an impregnated band in the country, 14 feet wide, and defined by clay walls.[c] Both clay and lode-formation carry about 2 per cent. pyrites. Irregular pockets or bunches of calcite occur throughout the formation, and contain veinlets of galena

[a] Trans. Inst. Min. Met., XIII, 1904, p. 551.

[b] Maitland, West Aust. Nat. Hist. Soc., 1905, p. 23.

[c] Pinder, Trans. Inst. Min. Met., X, 1902, p. 87.

that are invariably rich in gold. The principal company operating on Woodlark Island had in 1906 reached a depth of 435 feet. The return from the veins of the island for that year was 10,527 ounces, valued at £33,549. The average yield of the quartz crushed was 17 dwts. 21 grains gold per ton ore.[a] Other mining centres on the island are at Karavkum and Busai. At the latter place alluvial washing has been carried on in deposits containing fossil bones. The yield of alluvial gold from Woodlark Island for 1906 was 1,608 ounces. Mining operations on Sudest (Tagula) and St. Aignan (Misima), islands of the Louisiade group, are confined to gravels.

On the mainland of British New Guinea all the active goldfields, Milne Bay, Keveri, Yodda, and Gira, are placer fields. The Milne Bay field is in the extreme south-east of the mainland, while the Yodda and Gira fields, the most important, are on the Kumusi, Mambare, and Gira rivers, in the north-east portion of British territory. In the early years of prospecting in New Guinea, from 1889 to 1898, very rich pockets were discovered on these rivers. The Mambare is believed to be adapted in places for dredging, but no attempt has as yet been made in that direction. The prospector in New Guinea has many difficulties with which to contend. The climate is extremely malarious, provisions are extraordinarily dear, while the jungle is dense and the natives are dangerous. Hence New Guinea has never experienced the "rush" that its earlier-worked rich deposits would have engendered elsewhere. The estimated yield of the mainland goldfields for 1906 was 12,000 to 13,000 ounces gold, the Yodda and Gira fields each producing about 6,000 ounces.

Official returns from 1888, when mining was commenced, to 1907 inclusive, give the amount of gold exported as some 258,622 ounces, worth £935,831. These figures by no means comprise the total amount produced, For example, while the estimated yield for 1906 was 24,227 ounces, only 14,633 ounces were entered for export in that year. The returns for the last three years available are :—[b]

Year.	Ounces.	Value, Sterling.
1904-5	22,729	£82,736
1905-6	24,227	87,869
1906-7	16,103	58,886

[a] Commonwealth Reports, 1907, British New Guinea, p. 70.
[b] Murray, Aust. Min. Stand., 1907, Ap. 1, 8, pp. 331, 358.

The total yield to 1907 of the various fields since the commencement of placer mining in New Guinea is estimated as below :—

Field.	Crude Ounces.	Value, Sterling.
Louisiade	19,147	£68,376
Murua (Woodlark Id.) ...	110,512	386,791
Gira	51,122	191,707
Milne Bay	13,231	46,310
Yodda	60,940	228,525
Keveri...	3,670	13,763
Total	258,622	£935,471

German New Guinea (Kaiser Wilhelm's Land).—Gold is found in this colony mainly in the extreme south-east, adjoining British territory. The Waria, Wiwo, Morope, Pajawa, and Majama, in fact, all the large streams along the coast from the British boundary to Cape Longuerue, carry a little gold. The Waria and the Wiwo are the richest, but their head-waters and most valuable portions are in British New Guinea. Gold also occurs in the sands of the Ramu, the largest river in Kaiser Wilhelm's Land.[a] Veins are as yet unknown, but they probably occur in the "diorite" of the higher mountains, since gold in trifling quantities is found scattered over the slopes of these ranges.

NEW CALEDONIA.

Numerous occurrences of gold in small quantities have been reported from New Caledonia. Nearly all these are along the Diahot Valley in the extreme north-western portion of the island, but one, that at Mont d'Or, lies a short distance north of Noumea, the principal port.[b]

In the neighbourhood of the Diahot river are the only gold-quartz veins yet worked. The oldest of these is the Fernhill, near Manghine. This vein was discovered by Australian prospectors in 1870, flourished for three years, and has since been spasmodically worked. Its output for the first three years was 4,134 2 ounces (128·576 kg.), and from 1876 to 1878 was 2,712·9 ounces (84·373 kg.), worth £11,200.[c] The vein was very irregular in value and in extent, yielding as high as 5 ounces per ton. The early workings exhausted the oxidised zone, which persisted to a depth of 90 feet, and which was succeeded by highly pyritous, lower-grade, ore.

[a] Schmeisser, Zeit. für prakt. Geol., XIV, 1906, p. 79.

[b] Pelatan, "Les Richesses Minérales des Colonies françaises," Paris, 1902, p. 4.

[c] Glasser, Ann. des Mines, Serie 10me, IV, 1904, p. 507.

The Fernhill ore-bodies lie near the contact of the dark schists of the left bank of the Diahot with the mica-schists that are more or less confined to the right bank. The dark schists are somewhat slaty and are seamed with veinlets of milky quartz. The mica-schists are of an ordinary type with a white sericitic mica. The strike of the foliation of the schists (N. 35° E.) is that of the contact and of the ore-body. The last appears to consist of a zone, from 3 to 4 feet wide, of hyaline quartz grains. Gold is also obtained from silicified bands in the schist, these being as a rule highly pyritous.

Gold-quartz veins have also been worked in the mica-schists of the Tiari mountains, immediately to the north of the Diahot streams. Here are situated the Rose and the Berthe veins. The former was discovered in 1890, and its line of vein-country extends eastward continuously for some 6 or 7 miles. Along this line the band is more or less auriferous, possessing veins and shoots in which a limited quantity of quartz has yielded 1 to $1\frac{2}{3}$ ounces (30 to 50 grammes) gold per ton. The mica-schists of this region are sericitic, and contain as accessory minerals, pyrite, almandine garnet, rutile, and abundant glaucophane. Other deposits *in situ* are in the dark schist of Pouembout, the melaphyre of Tongoué, and the ophite (diabase ?) of the Queyras mine near La Foa.

Alluvial gold is nowhere abundant. The richest deposit appears to be near Galarino, on the coast at the foot of the northern slope of the Tiari range. It is an extensive deposit, but is of exceedingly low grade. It appears rather to be the result of surface decomposition than a true alluvial deposit. As a rule its gold is fine, but a nugget of 25·7 dwts. (40 grammes) has been obtained. The sands of the Diahot contain a little gold with occasional grains of platinum. Other occurrences are in the Nakety river and in the Grosses Gouttes circle. In the latter case the gold appears to be associated with granite massives.

On the whole, the auriferous deposits of New Caledonia appear to offer little encouragement for the investment of capital, or even for further prospecting.

FIJI.

Gold in water-worn quartz has from time to time been obtained from the upper reaches of the Rewa river, north of Suva, on the island of Viti Levu. Such gold may have been derived either from the basement Palæozoic metamorphic schists or from the widely-spread intrusive Cainozoic andesites. In the latter case the occurrence would resemble those of the Hauraki Peninsula of New

Zealand. Specimens seen by the writer were thought to indicate an andesitic origin. No gold-quartz veins have yet been discovered on the island. Fiji being, however, a portion of that ancient continent of which New Caledonia, the Solomon Islands, and New Guinea are all fragments,[a] its basement metamorphic rocks may well be expected to yield similar veins.

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[a] Woolnough, Proc. Linn. Soc. N.S.W., XXVII, 1903, p. 457.

AUSTRALASIA.

NEW ZEALAND.

Prompted by the discoveries of rich gold in Victoria and New South Wales in 1851, vigorous search for similar deposits was made in New Zealand. In the following year, 1852, gold-dust and gold enclosed in quartz was found in the Kapanga Creek at Coromandel Harbour, about 40 miles from Auckland in the North Island. Owing, however, to the fact that the alluvial deposits were small and of little value, and also to the increasing hostility of the natives, this field was abandoned after having yielded some £1,200 gold. The next gold-find in New Zealand took place in 1857, in the Collingwood district in the Nelson province of the South Island; the next and the first of real importance as affecting the history of the Dominion, was that, in 1861, of the rich placers of Gabriel's Gully, Otago. The news of these finds, supplemented by extraordinary reports of the richness of the placer deposits of the West Coast of the South Island, precipitated a series of "rushes" from the New South Wales and Victorian alluvial fields, already past their zenith. With the advent of the Australian diggers, the valley-gravels of Otago, Southland, and the then hardly accessible West Coast district, were thoroughly prospected, and placers of great value, especially along the beaches of the Molyneux (Clutha) and Kawarau rivers in Otago, were discovered. No gold-quartz veins worthy of more than passing attention were known until the purchase from the Maoris in 1867 of the Thames goldfield, some 50 miles from Auckland. Here were discovered near the surface some of the rich bonanzas that are characteristic of the northern and central portions of the Hauraki Peninsula. For the next 20 years gold-mining in New Zealand underwent many vicissitudes, and it was not until 1893 that the development of the now famous Waihi mine and the opening up of similar large bodies of low-grade quartz at Waitekauri and Karangahake in the southern portion of the Hauraki andesitic area, combined with the steady progress of the dredging industry in Otago and Westland in the South Island, placed the industry on a sure industrial foundation.

New Zealand therefore possesses three well-defined and well-separated auriferous areas: (*a*) the Hauraki goldfield on the peninsula of that name on the north-east coast of the North Island; this area contains valuable vein deposits, but no placers; (*b*) the West Coast area, lying along the western slopes of the Alps of the South Island in the provinces of Nelson and Westland; in this area the vein and alluvial occurrences are of equal importance; and (*c*) the Otago area, in which the auriferous alluvial placer gravels are of importance and the few known gold-quartz veins of little economic value.

The following table shows the annual export of gold from New Zealand since 1857:—

Year.	Gold.		Year.	Gold.	
	Ounces.	£		Ounces.	£
1857	10,437	40,422	1884	229,946	921,797
1858	13,534	52,464	1885	237,371	948,615
1859	7,336	28,427	1886	227,079	903,569
1860	4,538	17,585	1887	203,869	811,100
1861	194,031	751,873	1888	201,219	801,066
1862	410,862	1,591,389	1889	203,211	808,549
1863	628,450	2,431,723	1890	193,193	773,438
1864	480,171	1,856,837	1891	251,996	1,007,488
1865	574,574	2,226,474	1892	238,079	954,744
1866	735,376	2,844,517	1893	226,811	913,138
1867	686,905	2,698,862	1894	221,615	887,839
1868	637,474	2,504,326	1895	293,491	1,162,164
1869	614,281	2,362,995	1896	263,694	1,041,428
1870	544,880	2,157,585	1897	251,645	980,204
1871	730,029	2,787,520	1898	280,175	1,080,691
1872	445,370	1,731,261	1899	389,558	1,513,173
1873	505,337	1,987,425	1900	373,616	1,439,602
1874	376,388	1,505,331	1901	455,561	1,753,783
1875	355,322	1,407,770	1902	508,045	1,951,433
1876	322,016	1,284,328	1903	533,314	2,037,831
1877	371,685	1,496,080	1904	520,320	1,987,501
1878	310,486	1,240,079	1905	520,486	2,093,936
1879	287,464	1,148,108	1906	563,843	2,270,904
1880	305,248	1,227,252	1907	508,208	2,027,490
1881	270,561	1,080,790			
1882	251,204	1,002,720			
1883	248.374	993,352		18,218,678	£71,528,978

In addition to the foregoing, silver to the value of more than a million sterling has been recovered, mainly from the gold-quartz veins of the Hauraki Peninsula, and this sum is therefore to be placed to the credit of gold-mining.

Hauraki.—The Hauraki Peninsula is the most northerly gold-mining area in New Zealand. Its auriferous rocks extend for a total length of 120 miles north and south, with an average breadth of some 15 miles. They are continued to the north in the Great Barrier Island, which is geologically a continuation of the peninsula.

The oldest rocks of the area are Palæozoic and Lower Mesozoic unfossiliferous slates and sandstones. With these are associated more or less contemporaneous volcanic rocks that are pre-Jurassic in age. Apparently resting on these, and only recently distinguished as a result of the work of the Geological Survey of New Zealand,[a] are conglomerates, grits, grauwackes, and argillites. Fragmentary fossils from the conglomerates have been identified as *Inoceramus hastii* and *Belemnites sp.*,[b] thus indicating an Upper Jurassic horizon. The pre-Jurassic and Jurassic rocks are known only in the north and north-west of the peninsula, with the single exception of a minute exposure a few miles north of Thames on the south-west coast of the peninsula. In the northern portion of the peninsula is a small area of Cretaceo-Tertiary sediments, which, from stratigraphical evidence, appear to be older than the andesitic eruptive rocks that cover the greater portion of the peninsula. The latter may be broadly divided as hereunder :—

(*a*) Upper Eocene (?) : "Auriferous Series" of andesitic and dacitic flows, breccias, and tuffs ; all much propylitised.

(*b*) Miocene : Beeson's Island group of andesites and dacite-breccias and tuffs.

(*c*) Pliocene : Acid igneous rocks, developed to the east and south of the peninsula, mainly rhyolite, pumiceous agglomerate, pitchstone, &c.

The main "Auriferous Series" covers a great portion of the peninsula and contains nearly all the important gold veins. The rocks of the series have recently been extensively studied so far as their general propylitisation would admit.[c] They are andesites, showing both hyalopilitic and pilotaxitic (micropoecillitic) structure. The chief varieties occurring are pyroxene-andesite, hypersthene-andesite, hornblende-andesite, and hornblende-pyroxene-andesite. With the andesites are associated dacites, that carry hypersthene, or hornblende, or pyroxene, or a combination of any two or of all three, as ferro-magnesian silicates. Both andesites and dacites have been extensively propylitised in many parts of the area to a white, yellow, or bluish-green soft rock with which the auriferous veins, as in Transylvania, are always associated. The processes of propylitisation are indeed here precisely the same as those described for certain andesitic goldfields of Western North America and for the dacites and andesites of Transylvania. The ultimate result is a soft, not greatly coherent rock, made up mainly of quartz, kaolin, chlorite, pyrite, &c.

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[a] Fraser, Bull, IV, N.Z. Geol. Surv., 1907, p. 22.

[b] Thomas, ibid., p. 49.

[c] Sollas, "Rocks of Cape Colville Peninsula," I, 1905, Wellington.

The Beeson's Island group is nowhere known to be auriferous; and microscopic analysis shows its rocks to be andesites and dacites of types not greatly differing from those of the auriferous series. The members of the group are nevertheless easily distinguished in the field, the younger group presenting a distinctly trachytic facies, while the ferro-magnesian silicates are also on the whole more porphyritic.

The younger acid rocks (rhyolite, &c.) of Pliocene age, cover a large portion of the peninsula, especially in the east and south. They do not, as a rule, carry auriferous deposits, but gold-quartz veins have been found in them. It is believed that the Broken Hills mine, Tairua, lies within these rocks.[a] The volcanic activity of Pliocene times has apparently persisted to the present day, since the recent tuffs and lavas of the Hot Lakes region to the south show no vital differentiation either in time or in type.

Speaking generally, the gold-quartz veins of the northern portion of the area are irregular both in extent and in tenor. They have, however, especially when they form a network of interlacing stringers, proved at times exceedingly rich. In the southern areas of Karangahake and Waihi, the veins, on the other hand, are large and well-defined, but are of comparatively low grade.

Dealing in detail with the fields of the Hauraki Peninsula, space can be given in this place for a consideration only of the chief areas, viz., Coromandel, Thames, Waihi, and Karangahake.

The Coromandel field[b] lies some 40 miles due east of Auckland, across the Hauraki Gulf. The basement rocks of the area are the pre-Jurassic rocks to which allusion has already been made. These include ancient volcanic felsitic tuffs as well as ordinary detrital sediments. The andesites and dacites of the "Auriferous Series" here, as elsewhere in the peninsula, are remarkably deficient in amygdaloids, pointing to lavas cooling with sufficient slowness to admit of the complete escape of imprisoned steam.

The reefs of the Coromandel district are exceedingly erratic in course, dip, and tenor. The richest occur in zones or belts of propylitised rock. Three principal reef-channels or lode-zones occur on the Coromandel field: the Hauraki, Kapanga, and Tokatea. There is a possibility that they are merely separated portions of a single zone of solfataric action.

The gold of Coromandel is of higher grade than is usual on the peninsula, being some 750 to 800 fine. In the Hauraki and Kapanga areas crystallized gold is absent, but in the Tokatea area, where

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[a] McKay and Sollas, "Rocks of Cape Colville Peninsula," I, pp. 61, 267.

[b] Maclaren. Ann. Rep. Mines Dept., New Zealand, 1900; Fraser, Bull. N.Z. Geol. Surv., No. 4, 1907.

Coromandel, New Zealand. (Auriferous andesites in middle distance.)

the andesites are only a few hundred feet above the pre-Jurassic rocks, it is the rule to find free gold in vughs and particularly in calcite veins. One remarkable form from the Rainbow Reef, Tokatea, made up of five plates of crystallized gold, simulated to a remarkable extent a butterfly.[a] The form has been described elsewhere in this volume. In most cases in which calcite and quartz occur together in veins deposition appears to have been contemporaneous. A remarkable association of native gold with native arsenic has been met with in the Tokatea area. The arsenic forms hollow geodes with concentric shells that are easily broken off in succession. In the hollow interior are numerous interlacing dendritic threads of gold, which may in the aggregate weigh several ounces. The geodes often weigh several pounds and may be 6 to 8 inches in diameter. Gold is not found in the division planes separating the concentric spheres of growth. In the rich pay-shoots the gold is generally finely distributed throughout the quartz matrix. The associates of the gold are native arsenic, stibnite, pyrite, chalcopyrite, and arsenopyrite. The veins are small and erratic, the richest of recent years being Legge's Reef in the Hauraki area. From this and immediately adjacent reefs a little more than £400,000 gold has been extracted, of which £222,583 has been distributed in dividends. The veins were small, but much of the quartz carried 2 to 6 ounces of gold per *pound* of stone. The total gold yield of the Coromandel area is not certainly known, but to the end of 1906 may be estimated at £1,743,790.[b]

The Thames goldfield lies near the head of the Hauraki Gulf. Its productive area is only a little over a square mile in extent. The country of the veins is entirely andesitic, but the underlying sedimentary pre-Jurassic rocks outcrop as a small exposure some two miles north of the auriferous field. The principal veins run north-north-east and south-south-west, occurring in parallel zones of decomposed rock separated by bands, locally termed "bars," of less decomposed rock. The field is traversed by exceptionally well-defined comparatively recent faults, of which the Moanataiari is the chief. This fault is apparently one of the elements in the formation of the *graben* area of the Hauraki Gulf and its former prolongation, now the swampy plains of the Thames Valley. The trace of the Moanataiari Fault may be followed on the surface for several miles, the downthrow, as indicated by the difference in level, being some 350 feet.[c] The fault hades south-west at 45°. Much

[a] Maclaren, Trans. N.Z. Inst., XXXI, 1899, p. 492, where the crystal faces were figured in error. See Fig. 46.

[b] Fraser, loc. cit. sup., p. 18.

[c] Park, "Geology and Veins, &c., of the Hauraki Peninsula," Auckland, 1897, p. 62.

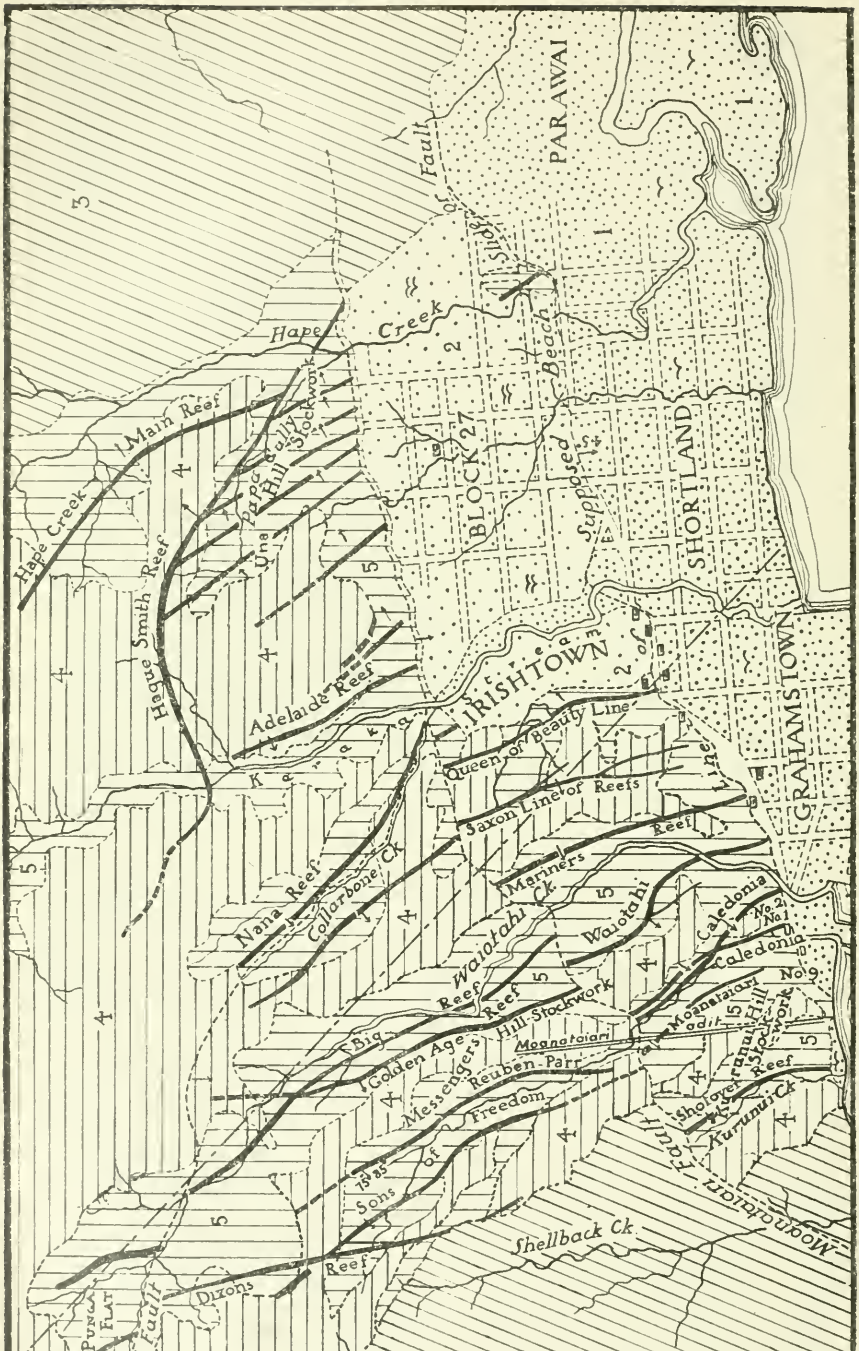

Fig. 97. Geological Map of Thames Goldfield, New Zealand (*Park*).

1. Recent Alluvium. 2. Pleistocene High-Level Gravels. 3. Andesitic Breccias and Tuffs. 4. Hornblende-Andesite. 5. Decomposed Andesite.

of the productive area of the field is on the seaward side of it. Movements have taken place along it at comparatively recent dates, since the slickensided footwall is still well-preserved, and the streams from the footwall side, on crossing the fault, suddenly emerge from the narrow upper valley to the broader portion brought into juxtaposition by downthrow.

The major vein-systems of the field follow a general north-easterly course. The systems are made up, as a rule, of one or two main lodes with numerous irregular branching and cross veins. The veins are celebrated for their bonanzas. Of these the Shotover and Caledonia bonanzas were the richest, the latter producing from a limited area 9 tons of gold in 15 months. The yield of the Thames field has generally depended for any given year on a single mine. Sometimes one and sometimes another has been in bonanza. The steadiest producer has always been the Waiotahi mine, which has consistently paid dividends on a small capital since 1873. From 1905 to 1908 this mine has been in bonanza, as shown in the following table :—

	£	s.	d.
Yield to December, 1904	193,079	6	8
1905	73,918	9	1
1906	223,678	4	3
1907	149,820	12	0
Total	£640,496	12	0

The occurrence of "specimen stone" (containing from 1 to 6 ounces gold per pound of quartz) is characteristic both of this field and of the Coromandel field to the north. The associates of the gold are pyrite, chalcopyrite, galena, stibnite, blende, pyrargyrite, &c. The Norfolk vein in the north of the field has a gangue of quartz which is coloured pink with rhodonite, thus resembling certain veins near the Gold King mine in the San Juan mountains, Colorado, also in andesites.[a]

The main reefs are accompanied by numerous stringers both in the hanging- and foot-walls. These are often mined as a single body. Their intersections within the network are often rich, and it was, in fact, such a stockwork that formed the Shotover and Caledonian bonanzas. The gold is very irregularly distributed, occurring in ill-defined shoots and pockets. The bullion is about 650 fine, but varies considerably from various parts of the field, and even from different parts of the same reef. The rich pay-shoots of the Thames area have hitherto been confined to the

[a] Purington, *in litt.*

upper zones above a depth of 500 feet ; none have been continuous below that level, though independent but lower-grade shoots are known at depths of 640 feet. The continuation of the veins and shoots in depth is a matter that is indissolubly connected with the range of propylitisation of the andesite ; it is also dependent, though in a lesser degree, on the depth at which the floor of pre-Jurassic basement rock may be encountered. Veins do occur in the latter rocks, as at Kuaotunu, on the north-eastern side of the peninsula, and do also continue from the overlying andesite into the pre-Jurassic rocks below, as at the Royal Oak mine, Coromandel, but in neither case have they proved of great value in the older rocks. Considerable analogy in the latter case is shown by the veins of the Vulkoj-Korabia area in Transylvania, where the rich lodes of the overlying dacites are, in the basement rocks, either poor or are entirely barren.

The Karangahake district is, next to Waihi, the most productive of the areas of the southern portion of the Hauraki Peninsula. It is situated at the mouth of the great gorge cut through andesites by the Ohinemuri river at a point some 8 miles west of Waihi. The veins at Karangahake lie in andesitic flows and breccias. Two mines of some importance, the Talisman and the Crown, are working on reefs of the same names. The reef of the former is from 3 to 4 feet in width, with ill-defined foot- and hanging-walls. The quartz shows the peculiar lamellar or platy structure due to the removal of calcite from a quartz-calcite mixture in which the quartz has been moulded on lamellar and rhombohedral calcite. The pay-ore occurs in well-marked shoots, and averages in value from £2 to £3 per ton ; the proportion of gold to silver by weight is 1 : 20. A small branch vein contains rich gold with stibnite, calcite, and siderite. Cobalt is also present, but has been determined only by analysis.

The Talisman Consolidated Mines had produced, to the end of 1907, bullion to the value of £783,334. The output of the Crown Mines had been a little less, viz., £718,767. The present annual value of the yield of the former is about £150,000, and of the latter about £50,000.

Some little distance to the east of Karangahake is an interesting occurrence of cinnabar. The ore is contained in a flat-lying lode or band of hard chalcedonic quartz, through which the cinnabar is disseminated. It is not yet known whether the deposit will prove of economic value.

The Waihi district lying at the base of the Hauraki Peninsula, contains one of the most productive of the world's gold mines. It is situated on a broad, somewhat barren, bracken-clad plain, representing the bottom of an ancient lake basin that now lies nearly 300 feet above sea-level and is almost surrounded by hills. The characteristic topographic features of the Waihi area are the Martha, Union, Amaranth, and Black hills, rising as islands of andesite above the general level of the rhyolite plain. In former days the great outcrop of the Martha lode was a conspicuous feature in the vicinity of the mines. It had indeed been known to prospectors since 1878, and towards 1890 had been worked, but unprofitably, by the pan-amalgamation process. Its true development, however, dates from the introduction of the cyanide process—

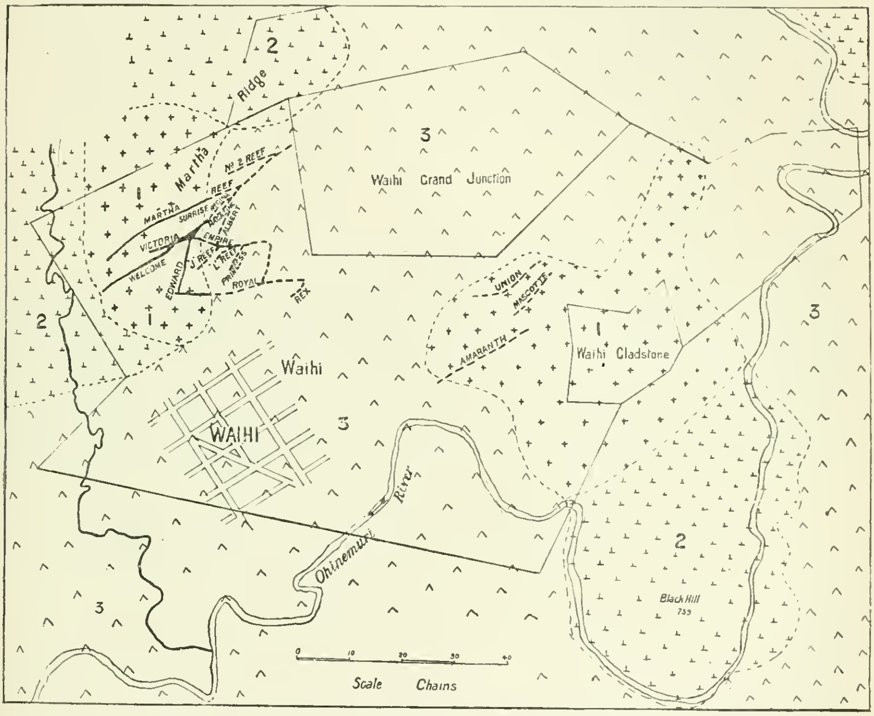

Fig. 98. Geological Sketch Map of the Waihi Mine (*Fraser*).
1. Altered Dacites (vein-bearing). 2. Younger Andesites and Dacites. 3. Rhyolites.

a method of metallurgical treatment that has proved exceptionally well-suited for the recovery of the exceedingly fine gold of the Waihi lodes. The Waihi mine itself is situated at the end of a long, low spur, that juts out southward into the plain from the andesitic ranges in the north. This narrow peninsula is wrapped round on three sides by younger rhyolites. Towards the south-east and some 600 to 700 yards from the Martha Hill, an island of andesitic rock appears above the rhyolite plain, and contains, among others, the Union and Silverton reefs.

In the Waihi area there is no sign of the pre-Jurassic basement rocks that are seen to underlie Tertiary volcanics at Coromandel and at Thames. So far as may be made out at present the country of the Waihi veins is the highly propylitised and weathered andesite of the "Auriferous Series." It has, nevertheless, been apparently originally somewhat more acid in character than the rocks of the already-mentioned goldfields lying further to the north. Rocks from the neighbourhood of the Waihi lodes have been described by Sollas as quartz-hypersthene-andesite and (apparently from much the same locality and horizon) pyroxene-soda-rhyolite, the latter being distinguished by containing a soda-bearing orthoclase, so far as its nature can be judged from the somewhat meagre microscopical and chemical evidence it furnishes. The question

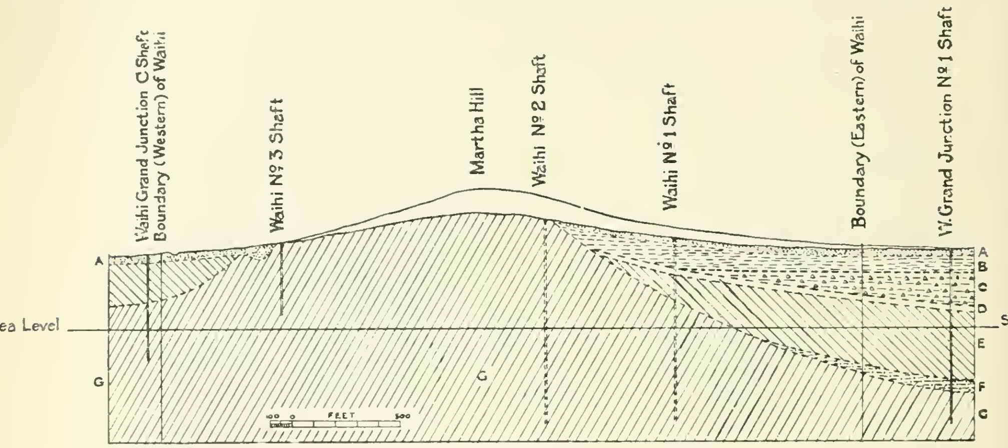

Fig. 99. Vertical Cross-section through Martha Hill (*Fraser*).
A. Surface soils, &c. *B*. Flow rhyolite. *C*. Brecciated flow rhyolite. *D*. Old Land Surface. *E*. Younger andesites and dacites. *F*. Old Land Surface with silicified and carbonized wood. *G*. Altered vein-bearing dacites.

being one of considerable interest, the following description[a] of the acid rocks may be quoted, the rock described coming from the No. 3 level, Waihi mine:—

> **Hornblende-pyroxene-rhyolite.**—"A light greenish-grey rock, with obvious quartz and pyrites. The matrix is granular, polarising, much altered, crowded with felspar laths in stream lines, which are obvious with ordinary light but scarcely visible with cross-nicols, most of them not at all. Irregular quartz grains; Phenocrysts: Orthoclase. Numerous large crystals beginning to pass into muscovite. Some fimbriate at the margin, showing continued growth after extension. Pyrites crystals included in some.
>
> "Hornblende represented by numerous resorption pseudomorphs.
>
> "Pyroxene represented by pseudomorphs in chlorite, small, and not very numerous.
>
> "Quartz: A few corroded grains and bi-pyramids.
>
> "Ilmenite: A few plates in leucoxene.
>
> "Pyrites: Numerous scattered crystals."

[a] Sollas, loc. cit. sup., II, p. 67.

In view of the occurrence of orthoclase (valencianite) in the lodes of Waihi, and of the exceedingly altered state of the country, it is conceivable that the orthoclase found in the above rock may be valencianite due to secondary action; indeed, considerable indication of such a growth is outlined in the foregoing petrological description. It is therefore probable that the highly-decomposed rocks of the Waihi area do not represent original rhyolites, but a local succession of andesites, dacites, and even more acid rocks that have been so thoroughly altered by solfataric solutions that many of their original characters have disappeared. The possibly rhyolitic rocks in this complex must in any case be sharply distinguished from the younger rhyolites that at a much later (Pliocene) stage filled the valleys and depressions caused by sub-aerial erosion in the rocks

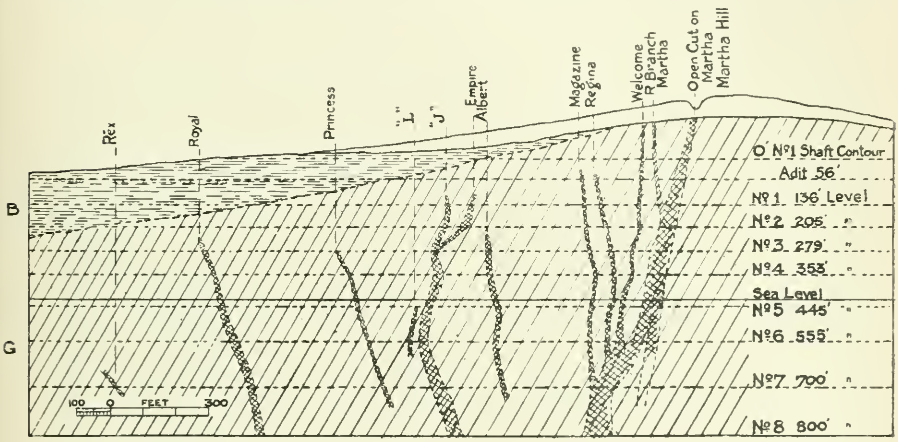

FIG. 100. CROSS-SECTION, WAIHI MINE. SHOWING "BLIND" LODES (excepting Edward vein, parallel to line of section) (*Fraser*).

of the "Auriferous Series." Since the younger rocks contain no quartz lodes it may be inferred that their deposition took place subsequently to the propylitisation of the andesites and dacites.

The vein system of Waihi is somewhat complex, as will appear from the accompanying sketch-map. The quartz reefs are large and numerous (sixteen are known), but are all connected. The principal are the Martha, Welcome, Empire, Edward, and Royal. The Martha is the main lode of the mine, striking north-north-east and south-south-west and underlying south-east at very steep angles. At the surface its width varied from 20 to 60 feet, with an outcrop of over 300 yards. At a depth of 900 feet its range in width is from 70 to 110 feet. As already mentioned, the outcrop showed as a steep bluff, the white quartz of which was visible, especially in the rays of the setting sun, from many miles across the plain. The Martha lode traverses the Waihi mine property from one boundary to the other. The Welcome lode ranges in width from 50 to 100 feet, the Empire lode from 25 to 30 feet, the Royal about 14 feet, and the most recently discovered, the Edward, from 50 to 70 feet. The last at the maximum width has shown assays of £10 per ton. The filling of the lodes is calcitic quartz. The walls are not at all well-defined, and the general appearance of the lodes indicates successive opening along fissures near the surface and successive fillings with quartz along the openings thus formed, together with a very considerable amount of metasomatic replacement of the fissure-walls. The lodes are enclosed in a thoroughly decomposed country highly impregnated with pyrite. The ore is a hard grey to white quartz with calcite ; it is occasionally laminated, the laminations being often rendered apparent by banded inclusions of silver sulphides. Its average value is £2. 14s. per short ton. In the upper levels the development of lamellar quartz from the vein-mixture of quartz and calcite is notable. In this case the calcite is dissolved out by acid waters, the resulting cavities being found partly filled by manganese oxides.[a] The sulphides amount to about 3 per cent. of the ore, and are mainly pyrite and blende. The sulphide ore of the lower levels now furnishes the greater part of the gold, though oxidised ore has been found below 800 feet. Selenium occurs in the ore, but has been met with only in the bullion and has not been identified as a mineral. With this occurrence an interesting analogy is afforded by the Radjang-Lebong mine, Sumatra, also in andesitic rock. Nickel and cobalt have been detected in close analyses, and are apparently associated with the manganese oxides that are found filling the cavities in the lamellar quartz of the oxidation zone. The gold is very finely divided and is rarely visible. The proportion of silver to gold in the ore is about 7 : 1. The rich ore of Waihi is a characteristically banded quartz. The sulphide ore contains both more gold and more silver than the ore of the oxidised zone. There is, indeed, considerable evidence for the assumption of an impoverishment rather than an enrichment of the Waihi lode-outcrops. The uppermost sulphide zone at the base of the zone of oxidation was very rich, averaging from 1 to 2 ounces gold and 30 to 60 ounces silver per ton, while exceedingly rich portions assayed 25 ounces gold and 1,000 ounces silver per ton. Morgan[b] therefore maintains that there has been a definite zone of secondary sulphide-enrichment. The greater part of the

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[a] Lindgren, Eng. Min. Jour. Feb. 2, 1905; Bell and Fraser, Can. Min. Jour., Aug., 1908.

[b] Eng. Min. Jour., May 4, 1905, p. 861.

gold is contained in pyrite, and little is found in the rarely occurring galena and blende.

The Martha lode has been proved for a length of over 3,400 feet in the Waihi Company's mine, and for a depth of 1,000 feet. Many of the other lodes above enumerated have been discovered only by underground prospecting, since the majority, large as they are, are so-called "blind" lodes that do not, as shown in Fig. 100, reach the surface, and therefore show no outcrops.

The Waihi Grand Junction mine is situated on the strike of the Martha lode to the east. The lode is there much smaller. This mine has produced during 1906 and 1907 bullion to the value of £89,626. Its section of the lode is hidden beneath a bed of rhyolite that has filled the ancient valley on the slopes of which the Martha lode outcropped.

At Waihi Beach, 6 miles from Waihi, a secondary auriferous deposition has taken place in spherulitic rhyolites of Pliocene age. The presence of such secondary gold-deposits is not surprising, since hot springs are still sporadic along the eastern coast of the peninsula.

The total output of the Waihi mine from 1890 to the end of 1907 is shown in the following table :—

1890 ...	... ...	... £13,628	1900 ...	112,012 tons	... £317,902
1891 ...	... ...	... 36,458	1901 ...	159,325 ,,	... 461,205
1892 ...	18,297 tons	... 46,219	1902 ...	179,485 ,,	... 521,574
1893 ...	19,805 ,,	... 64,345	1903 ...	231,323 ,,	... 658,393
1894 ...	24,364 ,,	... 83,023	1904 ...	259,978 ,,	... 683,882
1895 ...	33,670 ,,	... 120,335	1905 ..	298,531 ,,	... 728,521
1896 ...	34,410 ,,	... 135,156	1906 ...	328,866 ,,	... 837,927
1897 ...	40,764 ,,	... 144,041	1907 ...	356,974 ,,	... 878,486
1898 ...	77,929 ,,	... 256,494			
1899 ...	102,381 ,,	... 302,525		Total	£6,290,120

To March, 1908, there had been paid in dividends £2,926,215. The total costs of treatment were in 1907 about £1 per ton. Among the other mining camps of the Hauraki Peninsula is the Great Barrier Island, where the reefs are large but of low grade, varying in tenor from 30s. to £3 per ton. The yield during 1907 of the Great Barrier mines was only some £650. At Kuaotunu on the north-eastern coast the veins carry finely divided gold and lie in the pre-Jurassic basement sedimentary rocks. The yield has never been extensive. In the southern area besides the camps of Waihi and Karangahake already mentioned, are the important veins of Komata and Waitekauri. At the former place low-grade veins are on the whole being successively worked. The Komata Reefs mine from its opening in 1900 produced to the end of 1907 bullion of the value of £273,176. At Waitekauri a large reef was worked and yielded considerable quantities of gold, but with a change in the reef in depth from the lamellar quartz similar to that characteristic of the Waihi and Karangahake mines to the original mixture in depth of quartz and calcite, the mine became too poor to work, and was finally abandoned. The Broken Hills mines at Tairua, where gold-quartz veins are being profitably worked at or near the junction of rhyolite and andesite, has produced, from 1900 to 1907 inclusive, bullion to the value of £81,390.

West Coast.—In the middle auriferous area of New Zealand stretching along the western slopes of the mountain ranges of the South Island, both gold-quartz veins and placer deposits derived from them are numerous. In the Nelson and Marlborough provinces the veins are in micaceous schists of indefinite age. The only mine of importance in this area is situated at Taitapu, near Nelson. The placer deposits of these two northern provinces include modern river gravels, high-level gravels, and ancient Tertiary folded sediments.[a]

In Westland, the centre of quartz-mining is Reefton, where veins occur in Palæozoic (Carboniferous ?) strata. The country is grey talcose clayey shales and sandstones. The veins strike with the country and several parallel-bedded veins are occasionally worked as one reef. The quartz-bodies consist of extremely irregular bunches and masses branching in all directions into the country. They are nevertheless aggregated along certain lines, longitudinal connection being made by narrow fissures that sometimes contain quartz, but more often "pug." The narrow fissures occur in the harder parts of the rock, the quartz ore-bodies as a rule in the softer country. Deposition of gold takes place generally on the slaty selvages of the veins and also in quartz containing angular fragments of the argillite or grauwacke of the country. This type of brecciated ore-filling is locally known as "magpie stone." The veins vary in thickness between 4 and 40 feet ; in depth they pinch to mere threads, but often recover their former width with deeper sinking. The average tenor of the quartz raised is 10 to 14 dwts. gold. The gold is of high quality, reaching a value of £4 per ounce. Don[b] has shown that the hard rock at Reefton contains little or no pyrite and is not auriferous, while the softer rock adjacent to the quartz-veins was both pyritous and auriferous. Nevertheless, pyrite taken from slates at points distant from the auriferous lodes carried no

[a] McKay, "Gold Deposits of New Zealand," Wellington, 1903.

[b] Trans. Amer. Inst. M.E., XXVII., 1898, p. 584.

Open-cut, Martha Lode, Waihi, New Zealand.

The Humphrey's Gully Beds, Westland, New Zealand.
Auriferous Gravels overlain by Morainic Dêbris.

gold. The output of the principal mines of the Reefton district is shown in the following table :—

Mine.	Average Value of Ore per Ton.	Value Produced in 1906.	Total Dividends Paid to End of 1906.
	£ s. d.	£	£
Consolidated Goldfields of New Zealand	1 17 5	36,307	137,606
Progress Mines of New Zealand	1 14 5	91,200	261,250
Keep-it-Dark Company...	1 16 10	18,887	154,666

The subscribed capital of the last-named company was no more than £6,208. It has been in successful operation for 33 years; its present total working costs are only 10s. 9d. per ton. In the Reefton district from the 31st March, 1880, to the 31st December, 1906, a total quantity of 1,285,771 tons of ore were crushed for a yield of 687,555 ounces gold worth £2,715,838.

The Lyell goldfield, 25 miles further north, shows similar geological features. Elsewhere in Westland quartz-mining is carried on, as at Boatman's and at Blackwater, in mica-schist.

The majority of the short rapid rivers of Westland carry auriferous gravels. These are attacked by hydraulicing and by dredging. In both respects they have yielded successful mines. Auriferous black sands, consisting largely of magnetite and ilmenite, occur in many places along the west coast of South Island of New Zealand, and are worked, especially after storms, by individual miners. The gold of the black sand is exceedingly fine and presents considerable difficulty in treatment.

Otago.—Numerous gold-quartz veins occur in ancient crystalline quartz-schists and phyllites in the central and north-western portions of the provinces of Otago. The prevailing rock throughout central Otago is mica-schist, which is generally foliated with quartz-laminæ and is interbedded at times with thick bands of chlorite-schist. Quartz-schists are also common, while occasional bands of actinolite-schist may be met with. In most places the schists are sharply contorted and show a silky lustre on corrugated surfaces. Towards the upper part of the series the schists become insensibly less and less altered and pass into argillaceous, arenaceous, and micaceous rocks. So far as is known, igneous dykes are entirely absent from the schist areas, although granites, syenites, and basic dykes form the great mountain complex further to the west between the southern lakes and the fjord regions. The whole appearance of the schists, together with their composition, undoubtedly warrants the assumption that the original unaltered rocks from which the schists have been metamorphosed were sediments and were not igneous rocks.

The quartz-veins in the Central Otago schists are often auriferous but are poor and of low grade. In few places have they been found sufficiently rich to work. The most valuable are those of Skippers, Macetown, and Arrowtown, all lying to the north of Lake Wakatipu in the front valleys of the New Zealand Alpine chain, which here reaches a height of some 10,000 feet. Other reefing areas of less importance are Waipori and Nenthorn, towards the eastern coast, and the Preservation Inlet field in the extreme south-west corner of the island.

At Macetown the Premier forms the principal lode system. It is traceable for nearly 2,000 feet, but the greater part of it is filled with "mullock," or broken schist country, which carries small quartz veins and contains much carbonaceous matter. Here, three nearly parallel veins are met by a cross reef, pay-shoots being formed at the intersections.

At Skippers, which is separated from Macetown by a ridge 6,000 feet high, the Phœnix mine has been most productive. The lodes are three in number and form a parallel system that traverses a well-defined lode channel. As on many other fields characterised by parallel veins, the pay-shoots in the lodes are never opposite one another either vertically or horizontally. At the Phœnix mine, therefore, a pay-shoot on one lode denotes two barren zones immediately opposite. Further, the lodes of Skippers are always poor when their strike is south of west, but their tenor improves when their strike turns to north of west. Don's researches[a] have shown for this region that the quartz folia of the mica-schist are not auriferous when pyrites is absent, and further, that pyrites is present in appreciable quantity only when the quartz laminæ are near an auriferous lode.

The alluvial deposits of Otago are of considerable value. Of the 6,215,914 ounces exported from the province from 1861 to 1906, a very great proportion came from the placers. Much of the placer gold was won by the individual digger working along the beaches of the Molyneux and Kawarau rivers at times of low water, using only the crudest of appliances—the pan, cradle, and long-tom. In later days many attempts were made to recover by machinery the gold inaccessible to the ordinary digger from the deeper waters of these swift-running rivers. It was indeed these attempts that gave rise to the modern dredging methods that now find world-wide application. The early dredges were dippers worked by hand; these after a time were succeeded by current-wheel dredgers, in which

[a] Loc. cit., p. 581.

the motive power that raised the gravel from the river bottom was furnished by the strength of the current. The success of the earlier steam dredges working on the richer bars and ridges was so marked that many dredges were hurriedly built to work in spots from whence there was little hope of remuneration. In 1900 the dredging boom was at its height, but by 1907 only 35 dredges remained in operation in Otago, and eight on the West Coast. In 1906 the Otago dredges produced £415,117 gold, and those of the West Coast £86,082.

The alluvial placers of Otago never attained the importance nor furnished the yield per cubic yard of those of Victoria or of California. Much of the alluvial drift is of Lower Miocene age, though the gravels on which most dredges are now operating are recent, and are often merely a re-wash of the Miocene gravels. No large nuggets have been found in the New Zealand placers, the heaviest on record weighing only 27 ounces. The source of the alluvial gold is the quartz veins and the quartz laminæ of the mica-schists and quartz-schists.[a] These rocks are easily eroded and their constituent minerals are quickly separated in the channels of the rivers in which the waters flow with currents of 6 to even 7 knots an hour, thus forming ideal natural sluices. The rivers have a fairly even gradient, and are subject to periodic floods arising from the melting of the snows. While the floods are not sufficiently strong to scour the bottom or to cut fresh channels for the river, the current is yet adequate to roll over and to triturate the quartz pebbles and to liberate their contained gold. The lighter mica is readily removed by the river currents, even when flowing at speeds much less than their normal.

Numerous high-level auriferous gravels, which are often well cemented, are worked by hydraulicing. Of these the Blue Spur deposits near Lawrence are typical. They lie at the head of the Gabriel's Gully, where the first payable placer gold was found in 1861. The deposit is a great mass of cemented conglomerate which has been preserved by having been faulted down.[b] Its shape is roughly oval, and its original area was some 45 acres. The matrix contains boulders of sizes varying up to 2 feet in diameter. The pebbles are cemented by a light greenish-blue fine-grained cement, from which the designation " Blue Spur " has been derived. The stratigraphical horizon of the Blue Spur conglomerates is below the Pliocene coal measures (lignites) of Otago. In 1906 the Blue Spur Company treated by hydraulic methods over 200,000 cubic yards of cemented gravel, all of which required blasting, for an average yield of 6½d. per cubic yard.

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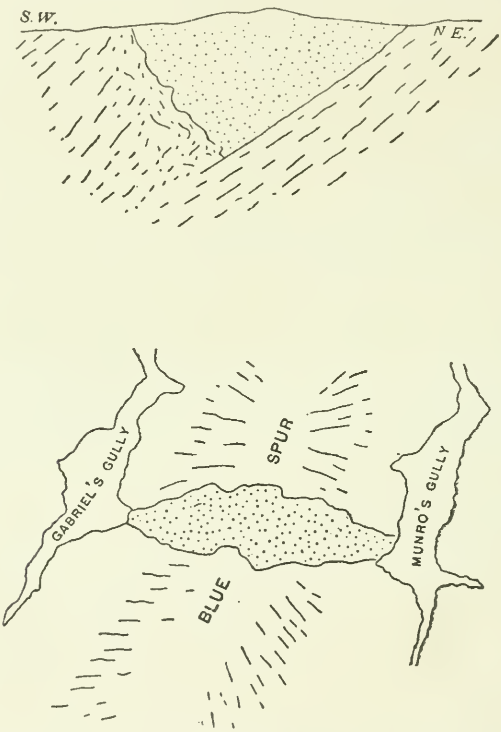
[a] Park, Bull. Geol. Surv. N.Z., No. 2, 1906.

[b] Rickard, T. A., Trans. Amer. Inst. M.E., XXI, 1892, p. 432.

Loose auriferous gravels are worked in Otago at an average cost of $1\frac{3}{4}$d. per cubic yard; in the West Coast district the costs are slightly higher, reaching 2d. per cubic yard.

In addition to the foregoing well-known occurrences small quantities of gold have been reported from time to time from the central active volcanic regions of the North Island. In this connection certain analyses made by the New Zealand Geological Survey may be here quoted as throwing a most interesting light on the deposition of gold.[a] Assays of the sinter of the Whakarewarewa hot springs

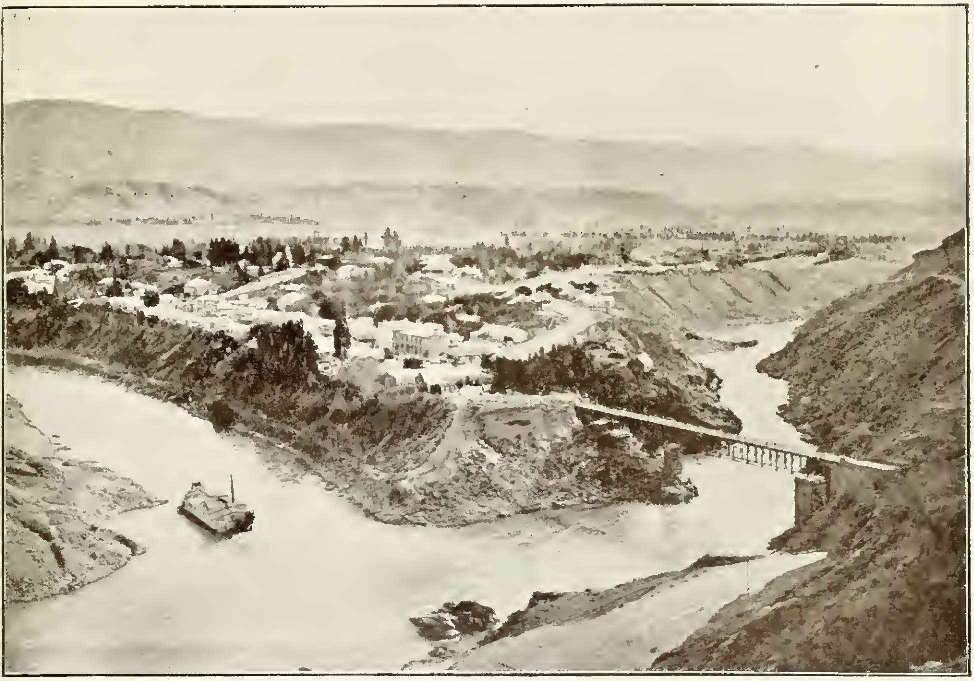


FIGS. 101 AND 102. SECTION AND PLAN OF BLUE SPUR GRAVELS, OTAGO, NEW ZEALAND (*Rickard*).

near Rotorua, yielded silver to the extent of 4 ounces 18 dwts., and gold to the extent of 1 dwt. 4 grains per ton. Again, mud, composed mainly of quartz, amorphous silica, and a little felspar, from the famous Waimangu geyser, perhaps the greatest known within the historical period, but now unfortunately extinct, gave on assay 6 dwts. 1 grain silver and 5 grains gold per ton.

Gold has also been obtained near Cape Terawhiti, Wellington.

[a] Bell, N.Z. Mines Record, Jan., 1908, p. 242; Maclaren. Geol. Mag., Dec., III, 1906, p. 514.



Junction of Clutha and Kawarau Rivers, Cromwell.

The Clutha, below Roxburgh.

GOLD-DREDGING RIVERS, NEW ZEALAND.

About 1862 some 42 ounces of alluvial gold were obtained here; unpayable gold-quartz veins in Triassic slates and sandstones are also known.[a]

AUSTRALIA.

The auriferous vein-deposits of Australia clearly fall into two distinct divisions, that are well separated, both geologically and geographically. The older includes the goldfields of Archæan and pre-Cambrian age, in the west and north-west. These are associated with the basement metamorphic schists of the continent. The younger division lies along the great Eastern Cordillera of Australia, and stretches northward from Tasmania through Victoria, New South Wales, and Queensland, and is continued by way of the Torres Strait islands into the highlands of central and north-western New Guinea. The deposits of this class are apparently initially dependent on great granodioritic intrusions that have taken place along the axial line of earth folding. The gold-quartz veins may occur either in the igneous rock itself or in the sedimentary strata overlying or adjacent. While the general age of the granitic or granodioritic intrusion (petrologically it finds its closest analogue in the granodiorites of the Californian Sierra Nevada) is not definitely fixed, there are many reasons for assigning the intrusion to the later stages of the Permo-Carboniferous.[b] All adjacent strata of greater age may therefore carry auriferous veins. The general habitus of the gold deposits in the north is the granitoid rock; while in the south gold-quartz veins are more often found in the sedimentary rocks through which the granodioritic rocks are intrusive. Important exceptions to both rules occur and are of especial value as forming evidences of a general genetic connection between the gold deposits of the north and south respectively. The uplift in the north having been greater, or possibly the overlying beds having been thinner, denudation has proceeded to relatively greater depths there than in the south, where the auriferous mineralisation, while not so obviously connected, *e.g.*, in Bendigo, Ballarat, and Beaconsfield (Tasmania), with igneous intrusions as in the northern fields of Queensland, is nevertheless to be referred to the same period of volcanic activity. With the information available at the present time there appears no valid reason for separating those goldfields

[a] McKay, loc. cit. sup., p. 5.

[b] Andrews, Proc. Linn. Soc. N.S.W., Ser. 3, VII, 1902, p. 167.

that are apparently dependent on basic rocks (*e.g.*, augite-andesites, as at Lucknow, Gympie, &c.) from the general series, since the more basic rocks are not widespread, and, when considered as a whole, may be regarded as either local segregations from the acidic magma or, more probably, as the normal basic members generally sequent on acidic eruptions. It has already been suggested that the actual auriferous deposition may possibly have been a function of the extrusion of these more basic members. The remarkable similarity of the Eastern Australasian chain of goldfields to those of the Californian type, extending along the Pacific slope from Lower California to Northern Alaska, may once more be pointed out. It is perhaps more than a coincidence that the greatest alluvial deposits of the modern world should have been derived from parent-veins in rocks so similar. In Australia, as in California, auriferous concentration has proceeded in the rivers during the whole of Tertiary time. In each country many of the older placers have been covered by basaltic flows.

The subjoined table shows the total gold yield, to 1907 inclusive, of Australia since the year 1851, when the placer deposits of New South Wales were first known :—

State.	Gold. Fine Ounces.	Value, Sterling.
Victoria	65,792,063	£279,498,833
Western Australia	18,363,787	78,004,406
Queensland	15,603,481	66,278,652
New South Wales	13,034,001	55,364,882
Tasmania	1,535,017	6,523,821
South Australia	626,329	2,757,562
Commonwealth	114,954,678	£488,428,144

QUEENSLAND.

The history of gold in Queensland opens with the ill-fated "rush" to Canoona in 1858, when 15,000 to 20,000 diggers were left starving on the banks of the Fitzroy river, near the site of the present town of Rockhampton. Disaster was averted only by the prompt action of the Governments of New South Wales and Victoria in sending steamers to the spot to take away the unfortunate adventurers. The irony of fate is illustrated by the facts that Canoona is only 12 miles from Mount Morgan, one of the greatest of the world's gold mines, and that there was, moreover, considerable alluvial gold in the neighbourhood that remained undiscovered by the early diggers. There is thus considerable analogy between this abortive rush and another, and even greater, that was taking place about the same time to Pike's Peak in Colorado, beside the then unknown Cripple Creek field, destined in later days to become so widely famed.

In 1862, alluvial gold was found near Peak Downs, Clermont, and this field remains to the present day the principal placer region of Queensland. The first reef worked in Queensland was the Hector on the Crocodile goldfield, near Rockhampton. The date of its discovery was 1865. In 1867, the Gympie, and in 1868, the Ravenswood fields were opened up. The present leading field, Charters Towers, remained unknown until 1872.

Yorke Peninsula.—Horn Island, one of the Prince of Wales group, lies in Torres Strait, and with others of the group (Possession, Prince of Wales, Hammond, and Thursday islands), carries slightly auriferous veins. Gold in payable quantities was first found in 1894. The auriferous veins lie in a decomposed granite made up largely of felspar and quartz, with a green decomposition product from a ferro-magnesian silicate.[a] The islands are a continuation of Yorke Peninsula, and the granites are probably therefore akin to those of the Queensland Cordillera that furnish the greater part of the gold yield of the State. The zone of oxidation in the veins extends only to 10 feet in depth. Pyrite and galena are common. The veins are rich but are very small, and contain refractory ore. On Possession Island, a few miles south-east of Horn Island, small networks of auriferous veins in a similar porphyritic granite have been mined.[b] These fields are intermittently worked.

The Hamilton and Coen veins form the most northerly of the Queensland mainland goldfields. They are situated on the western slope of the central chain of the Cape Yorke Peninsula. The veins lie along a broad zone developed along the contact line of metamorphic schists and quartzites with biotite-granites. Eurite dykes are common, and the characteristic tonalite (quartz-mica-diorite) of Charters Towers is also found.[c]

The Philp (Alice River) field, discovered in 1904, lies at the head of the Alice river, 140 miles due west of Cooktown, in a granite of the normal auriferous type. The value of the quartz crushed is about an ounce fine gold per ton. At Starcke goldfield, 50 miles north-west of Cooktown, alluvial gold has been worked since 1890. It is derived apparently from veins in quartzites. These veins are

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[a] Cameron, Rep. Geol. Surv. Queensland, No. 180, 1902, p. 18.

[b] Loc. cit., p. 22.

[c] Ball, Rep. Geol. Surv. Queensland, No. 163, 1901.

notable for the association of gold in shoots with stibnite.[a] Some of the veins on the Munburra section are associated with porphyry dykes.

The Palmer goldfield was discovered in 1873 and for a time produced large quantities of alluvial gold. By the end of 1877 it had yielded 819,697 fine ounces of alluvial gold worth £3,481,849, in addition to which huge quantities had been smuggled out of the country by the Chinese who had flocked to these alluvial fields. Soon after the discovery of the placers the veins were opened up and many thousands of tons of quartz were crushed for yields of 1½ to 2 ounces per ton. The total produce of the Palmer goldfield has been, to the end of 1907, some 1,323,735 ounces fine gold worth £5,622,866.

The country of the Palmer veins is sedimentary rock, viz., shales, sandstone, and limestones, probably of Carboniferous or of even greater age. It is to be correlated with that of the Hodgkinson field, 60 miles to the south-east. The sedimentary rocks are traversed by dykes of dolerite and diorite. Both the Hodgkinson and the Palmer fields lie close to great areas of the Permo-Carboniferous granitoid masses.[b]

The Hodgkinson field is situated some 60 miles west of Cairns. Of late years its gold yield has been surpassed by the value of wolfram and molybdenite obtained. Stratified rocks of the Gympie (Carboniferous) series, composed of nearly vertical shales, sandstones, grits, and conglomerates, are traversed by two great barren quartz "buck reefs," 3 to 40 feet in width. The material of the "buck reefs" often resembles a granular quartzite, but it may, on the other hand, be finely laminated and jasperoid. The buck reefs occasionally form sheer upstanding walls 100 feet high, and may be traced by the eye across country for many miles. Two groups of auriferous veins may be made out, the first striking with, but underlying at right angles to the strata; the second cuts across the strata and underlies always to the east. Free gold occurs in laminated quartz, and is associated with variable quantities of galena and pyrites. Near Thornborough, the Southern Cross reef carries 3 ounces gold per ton in a matrix of quartz and scheelite. The yield of the Hodgkinson field to the end of 1907 had been 227,703 fine ounces gold, worth approximately £967,000.

Croydon.—The Croydon field is situated some 100 miles south-east of the head of the Gulf of Carpentaria.[c] It is, with the

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[a] Cameron, Rep. Geol. Surv. Queensland, No. 209, 1907, p. 6.

[b] Jack, "Geology of Queensland," Brisbane, 1892, p. 122; Id., Rep. Geol. Surv. Queensland, No. 144, 1899.

[c] Rands, Rep. Geol. Surv. Queensland, No. 118, 1896; Dunstan, loc. cit. No. 202, 1905; Id., loc. cit., No. 212, 1907.

exception of the comparatively unimportant Cloncurry goldfield, the most westerly of the Queensland goldfields, which are, as has already been stated, almost entirely grouped along the flanks of the eastern coastal range, and are in close genetic connection with the granitoid core of that uplift. The goldfield was proclaimed in 1886 and has since been famous for its exceedingly rich shoots of gold. The country of the reefs is a granitoid rock, and, to a lesser extent, an allied felsite. The former rock, owing to the greater rapidity with which it has weathered, is now almost completely concealed beneath thin conglomerates and sandstones of the Desert Sandstone (Upper Cretaceous) Formation, and beneath laterites and detrital rocks of comparatively recent age. The felsites, on the other hand, form the hilly country to the north-east of Croydon. There is no evidence available as to the age of the granites and felsites, but it may be shown from petrological data that they are probably to be grouped with the Permo-Carboniferous intrusions of the Cordilleran uplift. The granite is greatly altered even at depths of 1,300 feet from the surface. It is made up of a pink or grey felspar with clear quartz and contains a little dark-greenish product arising from the alteration of hornblende or mica. In most specimens, however, the ferro-magnesian silicate is in very small quantities, and in such cases the rock presents a decidedly aplitic appearance. The associated minerals are remarkable. Graphite, occurring apparently in broad zones in the granite, is abundant, as also is calcite, siderite, and fluorspar. As might be expected from the influence of igneous intrusions on the carbonaceous Permo-Carboniferous rocks, the Queensland auriferous veins in general carry a good deal of graphite, *e.g.*, at Hamilton, Coen, Croydon, Cloncurry, Gympie, Normanby, Yorkey, Stanthorpe, &c. In some places indeed the actual transition from coal to graphite under the influence of the igneous intrusion may be made out, as at Mount Bopple and Cape Upstart.[a] Graphite also occurs under similar conditions in New South Wales. The granite country is impregnated to a small extent with pyrite, chalcopyrite, galena, and arsenopyrite. Both coarse and fine-grained granites occur. The former have generally been supposed to be intrusive into the latter, but for this assumption there is no clear evidence. The felsites are as a rule fine-grained rocks, but occasionally contain free quartz in large grains. They also contain graphite. They are possibly somewhat younger than the granites since felsitic dykes have been noted in the latter, and since the granite appears to underlie the felsite. A chain of intrusive basic (dolerite) dykes

[a] Dunstan, Rep. Geol. Surv. Queensland, No. 203, 1906, p. 12.

occurs along the zone of reefs, but has no connection whatever with ore-deposition, since the intrusion is obviously subsequent to vein-filling,[a] and indeed cuts the veins. Later faults are abundant and have disturbed the reefs greatly. Veins occur both in the granites and in the felsites. In the former they lie in "formations," or zones of disturbed and altered country characterised by the presence of abundant graphite. The value of the Croydon bullion is very low, being a little over £2 per ounce. The reefs in the felsites are of comparative unimportance. Their bullion is, however, of much higher grade, being worth perhaps £3. 4s. per ounce.

The principal reefs are the Golden Gate, True Blue, Highland Mary, &c. These are dispersed along a narrow zone running north-west and south-east for more than four miles. The pay-ore occurs in rich well-defined "shoots." The gangue is quartz, which is, in the case of the Golden Gate reef, of three kinds, and has been formed at two distinct periods. These varieties of quartz are locally called "gold stone," "poor stone," and "buck." The "buck" is barren and occasionally carries pyrite, while the "poor stone" also has pyrite and differs from the "gold stone" only in the absence of galena and gold, the galena in rich stone being invariably finely divided and always accompanying the gold. An excess of galena indicates rich gold-quartz.

The Golden Gate reef is very flat, dipping east-north-east at 18°. It has been worked to a depth of 1,600 feet (Golden Gate Consols Shaft).

Since its discovery in 1886 the Croydon field has yielded to the end of 1907 a total weight of 704,828 ounces fine gold.

Etheridge.—The Etheridge goldfield is situated on the same granite *massif* as the Croydon field, but is about 100 miles further east-south-east. The oldest rocks of the district are sharply folded slates, schists, sandstones, and quartzites. These are intruded by diorites that have generally been forced along the bedding planes. The folded sedimentaries are intruded over large areas by granitic dykes and stocks that in some cases occur in so great an abundance as almost to obliterate the characters of the original sedimentaries; more especially is this the case when the granite apophyses occur in well-bedded rocks. Euritic dykes, intrusive into the granite, are found in some parts of the field.[b] Sedimentary strata were deposited on the metamorphic and igneous rocks during older and younger Cretaceous times, the later deposits being the wide-spread Desert Sandstone.

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[a] Dunstan, ibid., 1905, p. 11.

[b] Cameron, Rep. Geol. Surv. Queensland, No. 151, 1900, p. 2.

The reefs of the Etheridge lie near the border of the main granitic mass, partly indeed in the slates and schists and partly in the granite. They are small and refractory, but are of high tenor, carrying large quantities of pyrite and galena, with occasional blende and chalcopyrite. In general the highly pyritous veins have been richer immediately below water-level than in the oxidised zone above. Those veins lying within the sedimentary rocks at some distance from the granite contain but little sulphide mineral. The progress of the field has been greatly hampered by the high cost of transport and of supplies, and even more by the local difficulties of ore-treatment and by the scarcity of water. The principal reefs are the St. George, Cumberland, Durham, and Queenslander. Owing to the exceedingly refractory nature of the ore, the veins being often solid pyrite and galena below water-level, no great depth has been reached by these mines. The total yield of the Etheridge fields to the end of 1907 was 494,937 fine ounces.

Cloncurry.—The Cloncurry goldfield in the north-east of the State is the only auriferous area not situated on the line of the eastern Cordilleran uplift. It is, nevertheless, in the neighbourhood of a small granitic outcrop. The veins are of little importance, and lie in sandstones and shales. They are highly pyritous. The oxidised products at the outcrops of the copper lodes of the district occasionally contain free gold. Gold has also been found here associated with native bismuth.[a] A considerable amount of alluvial gold associated with native bismuth was formerly obtained, one such nugget weighing 28 pounds troy.

Charters Towers.—The Charters Towers goldfield has for many years been the leading field in Queensland. It lies about 1,000 feet above sea-level and some 80 miles from its coastal port of Townsville. It is probably the most productive of those of the world's goldfields, whose veins lie entirely in acid plutonic rocks, its yield being a little more than a million sterling per annum. Its general geological features are nevertheless much less known than those of many a poorer and less accessible field. This ignorance arises mainly from the fact that a close geological survey of the area can be attempted only with the aid of the microscope in the field itself. Charters Towers rocks have a fairly wide range in the acidic plutonic group—from a granite with little ferro-magnesian content to a tonalite (quartz-mica-diorite). The relations of these rocks in the field have yet to be worked out in detail. They have, however, been indicated in an excellent map based on macroscopic characters, and published in 1898 by Messrs. Jack, Rands, and

[a] Jack, "Geology of Queensland," Brisbane, 1892, p. 21.

Maitland, of the Queensland Geological Survey. The map is, however, unaccompanied by any written description, and so loses much of its value. Some little space will, therefore, be given in this place to a description of the petrological characters of these rocks, from specimens collected on the field. The grey granites show numerous quartzes crowded with fluid-inclusions. Felspars are, as a rule, somewhat kaolinized, but are orthoclase, microcline, and some twinned plagioclase felspar. The ferro-magnesian silicate is normally a grass-green hornblende. Epidote and apatite are accessory minerals. The tonalites, on the other hand, contain little interstitial quartz with enclosures of hornblende, magnetite, and

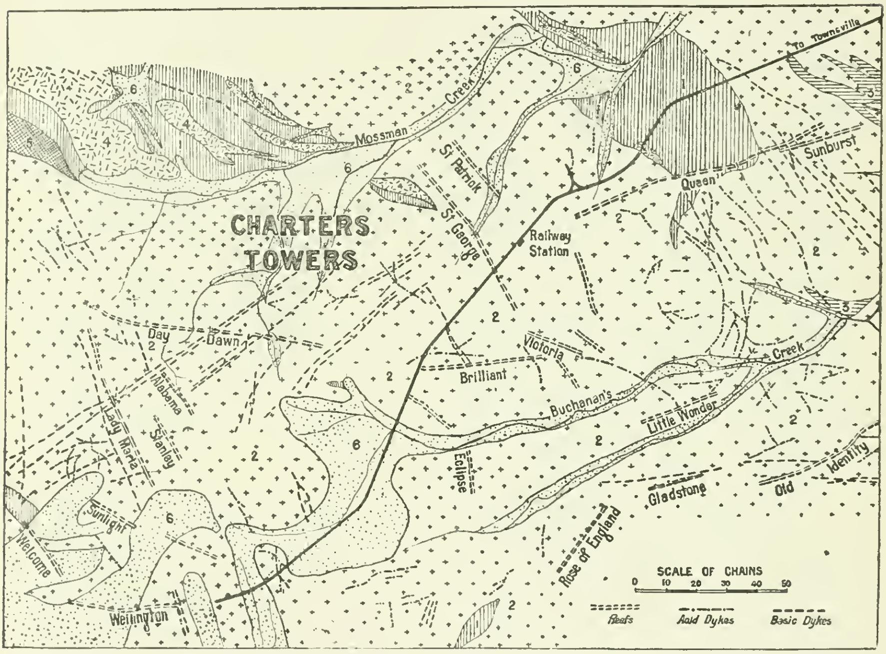

Fig. 103. Geological Sketch Map of Charters Towers Goldfield (*Jack*, *Rands*, and *Maitland*).
1. Slates, quartzites, and limestones of undetermined age. 2. Granite and tonalite with coarse porphyry. 3. Quartz-schists. 4. Diorite (basic). 5. Serpentine (?). 6. Recent superficial deposits.

zoisite. Their felspars are nearly all striped, but all are much saussuritized. The majority show idiomorphic outlines, and many are well and strongly zoned with a saussurite core. So far as it may be made out, the extinction angle of the felspar is 20° to 25°, and hence is fairly close to that of andesine. A little clear orthoclase occurs moulded on the plagioclase. Brown and green ragged boitite-mica is abundant, and generally contains "eyes" of epidote. Hornblende occurs in small grains, but is not abundant. Epidote is present both as

Charters Towers, Queensland.

a rock-forming mineral and in the saussurite product. Zoisite occurs in the interstitial quartz. Chlorite, obviously resulting from the decomposition of the hornblende, is present in some quantity. The rock may, therefore, be regarded as a typical tonalite. The author is indebted to the courtesy of Mr. W. A. MacLeod, of Charters Towers, for the following partial analysis of this rock :—[a]

SiO_2	67·00
Al_2O_3 & Fe_2O_3	21·80
Na_2O	5·22
K_2O	1·86
CaO	4·16
MgO	·53
Loss on ignition	·90
	101·47

A third type of rock represented in the writer's collection is a light-grey rock showing very little ferro-magnesian silicate. Under the microscope the ground mass of the rock shows as a fine-granular aggregate of quartz and clear felspars. The section contains numerous rounded but almost idiomorphic quartzes. Other phenocrysts are orthoclase in small quantity and plagioclase completely saussuritized. Epidote is very abundant. On the whole, the rock may be most conveniently described as a quartz-porphyry. The petrology of this field certainly promises to throw considerable light on the problems of auriferous deposition, and further work on it is greatly to be desired.

A short distance to the north-east and also to the north-west of the main auriferous area the granitoid rocks, as at Ravenswood, a neighbouring field to be described later, are associated with highly indurated slates and quartzites of undetermined age, but through which the granites and tonalites appear to be intrusive. The auriferous country generally is intersected by numerous dioritic dykes that are apparently older than the vein fissures, for the latter fault the former. Many of the richest deposits were in former days found at the intersection of the veins with the dioritic dykes, especially when brecciated fragments of the dyke were scattered through the veinstone. This type of enriched matrix appears to have furnished the largest pay-shoot yet discovered on the Charters Towers field, viz., one that passed from the upper levels of the Day Dawn and Day Dawn Block and Wyndham mines into the lower levels of the Mills United mine.[b] The country included within the lode under these circumstances showed values equal to that of the true vein-quartz.

[a] MacLeod, *in litt.*

[b] Paull, Trans. Aust. Inst. M.E., III, 1895, p. 244.

The average width of the main reefs of the field—the Brilliant and the Day Dawn—may be taken as 3 feet. Its gangue, as already stated, is quartz and decomposed granitoid country. The Brilliant section of the reef channel has been the most productive. It was, in 1908, being worked below 2,700 feet (Brilliant Extended Company). It has generally been supposed that the Brilliant and Day Dawn sections were portions of a single continuous lode, but it is now certain that the Day Dawn is a separate lode and lies to the east of the Brilliant. The lode-channel consists rather of a chain of ore-bodies than a continuous vein. The ore-bodies are seldom more than 6 feet in width. The richer pay-shoots carry from 1 to 2 ounces per ton, but the average value of the ore is very much less, and is probably below 15 dwts. per ton. The gangue contains about 7 per cent. of sulphides (pyrite, galena, blende, pyrrhotite, and a little arsenical pyrites). Free gold is rarely seen in depth. Higher values in the sulphide zone are generally indicated by galena. The oxidised zone reached a depth of between 200 and 300 feet.

The total yield of the Charters Towers district (which, besides Charters Towers itself, includes the long-abandoned Cape River goldfield) from the discovery of gold to the end of 1907 was 5,647,938 ounces fine gold worth nearly £25,000,000 sterling. In recent years, and indeed until the rise of the Kalgoorlie field in Western Australia, the Charters Towers field held the premier position among Australian goldfields.

Ravenswood.—The Ravenswood gold-quartz veins, discovered in 1868, furnished the first of the important goldfields of Queensland, yielding both rich placer gold and rich vein-quartz in the oxidised zone. Their yield to end of 1907 has been 693,206 fine ounces gold worth nearly £2,950,000. The auriferous veins are contained within basic granitite (biotite-granite) and hornblende-granite containing subordinate orthoclase. With them are associated quartz-porpyhries, quartz-felsites, and granophyres. Numerous felsite dykes traverse the granite. These granites are probably younger than a series of grauwackes and slaty shales that are developed in the neighbourhood. The veins carry a quartz-filling, and the gold, below the oxidised zone (here 70 feet in depth), is always associated with galena, arsenopyrite, chalcopyrite, bismuthinite, and blende. The reefs are small, from 8 inches to 2 feet in width, but are of high tenor. The ore is refractory. On all the reefs in this field the pyrites-zone when first struck in sinking was much richer than the "brownstone" above, indicating therefore, a general secondary downward enrichment.[a] The Donnybrook

[a] Maclaren, Rep. Geol. Surv. Queens., No. 152, 1900; Cameron, ib., No. 183, 1903.

veins, a few miles south-east of Ravenswood, lie in the metamorphosed rocks very close to the granite boundary and dip with the strata. These veins are small and erratic, and, when in the metamorphosed sedimentary rocks, contain, as on the Etheridge goldfield, more free-milling gold and less sulphide-ore than those in the adjacent granite.

Minor Central Fields.—Of minor importance is the Normanby goldfield, lying 40 miles south of Bowen in soft decomposed granite, that in places passes almost to a hornblende gneiss. According to Jack[a] the veins are in a porphyry-rock made up of quartz, a little black mica, and tourmaline crystals, well impregnated with pyrite. Of similar character is the rock of the Eungella gold occurrences, lying a little further south. The reefs of the Mount Nebo goldfield next to the south occur partly in diorite and partly in grey and black shales and sandstones of the Gympie Series (Carboniferous). The igneous rocks appear to be partly interbedded and partly intrusive.

Mount Morgan.—The Mount Morgan has been one of the most productive of modern gold mines. It is an isolated mine lying 26 miles south-west of Rockhampton on the Fitzroy river and just within the Tropic of Capricorn. It was discovered in 1886 and carried extraordinarily rich outcrop-stone. The name is somewhat of a misnomer since the so-called mount was originally only 500 feet above stream-level and 1,225 feet above sea-level.

Granite rock is extensively developed in the district, the auriferous area lying between two large outcrops of the characteristic granite of the Australian Cordillera. Hornblende is the predominant mineral, but the rock varies greatly in character, often ranging from a normal granite to syenite, and even to an aplitic rock or to a quartz-felspar-porphyry. The auriferous deposits themselves lie within Gympie (Carboniferous) rocks. These are quartzites, conglomerates, grauwackes, shales, slates, serpentines, and limestones. All are more or less altered and metamorphosed. No traces of granite fragments are found in these sedimentary beds and the assumption therefore is that the age of the granite intrusion is at least more recent than Lower Permo-Carboniferous. The metamorphism of the Permo-Carboniferous beds further points to the same conclusion. Vertical basic dykes, apparently of dolerites, are intrusive through the Gympie Series in the neighbourhood of the ore-deposits. These are older than the "Desert Sandstone" that occurs in the neighbourhood, and are probably later than and have no genetic connection with the ore-deposition.

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[a] "Geology of Queensland," p. 30.

The basic dykes are generally holocrystalline, with plagioclase, augite, and olivine, but vary widely in texture and character. Four principal dykes occur in the ore-body. These are the two parallel doleritic north and south dykes, each about 20 feet wide and separated by a distance of some 500 feet; the north and south andesite dyke, about 18 feet in width; and the east and west dolerite dyke. The whole of the copper-gold ores of Mount Morgan lie to the west of the andesite dyke, though gold values are obtained on both sides of it. In addition to the foregoing

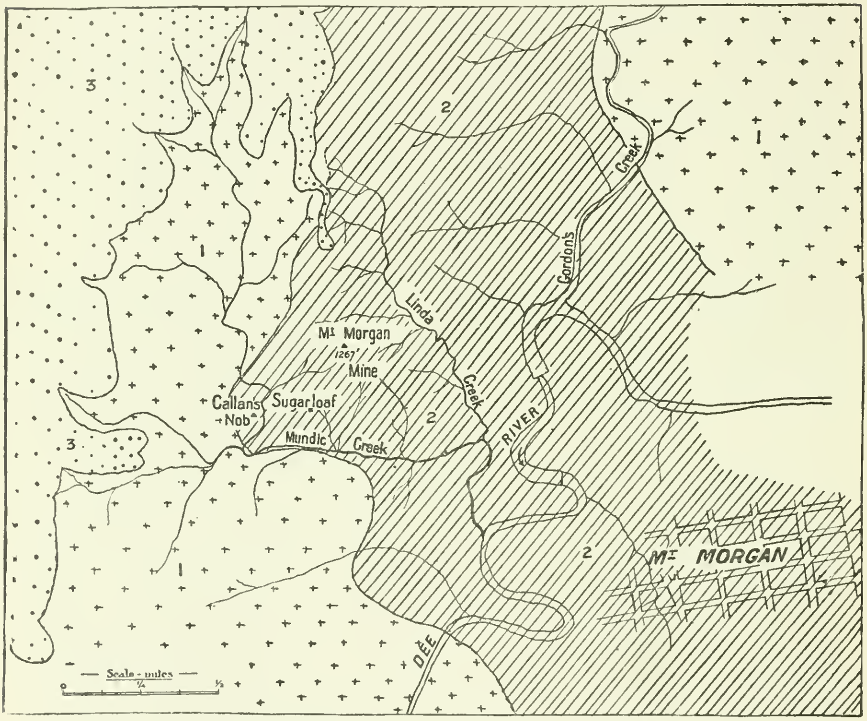

Fig. 104. Geological Sketch Map of the Vicinity of Mount Morgan (*Jack*).
1. Granite, granodiorite, and syenite. 2. Gympie (Carboniferous) quartzites, slates, schists and limestones. 3. Desert sandstones (Upper Cretaceous).

the ore-body is intersected by numerous small dykes, striking in all directions, and ranging up to 5 feet in thickness.[a] The Desert Sandstone (Upper Cretaceous) shows in the neighbourhood only as the remnants of a former wide-spread tableland. Its basement beds are auriferous,[b] with gold obviously derived from the neighbouring Mount Morgan lodes. Thus a superior

[a] Wilson, Queensland Govt. Min. Jour., Sept. 15, 1908.
[b] Jack, Rep. Geol. Surv. Queens., No. 132, 1898, p. 20.

limit to the age of Mount Morgan auriferous deposits is furnished. Mount Morgan is by far the most productive mine, both in gold and in copper, in Queensland. The total value of both metals produced in 1907 being £1,000,124, of which £619,208 was due to gold and £385,705 was the value of copper. The copper ore is obtained from the 750-foot level, but occurs for some 500 feet above that level, the oxidised zone persisting for 250 feet below the original summit of the hill.

The Mount Morgan field has, since its discovery in 1886, produced in fine ounces (of which all but a few hundred ounces per annum must be credited to the Mount Morgan mine itself) as follows :—

Year.	Fine Ounces.	Year.	Fine Ounces.
1886	47,957	1897	170,368
1887	82,338	1898	167,933
1888	113,704	1899	177,422
1889	314,356	1900	199,262
1890	213,372	1901	157,099
1891	141,685	1902	146,906
1892	121,514	1903	120,758
1893	118,291	1904	133,195
1894	116,295	1905	128,975
1895	127,793	1906	131,939
1896	147,853	1907	145,774
	Total..	.. Fine ozs.	3,119,589
	,, ...	.. Crude ozs.	3,230,569
		Value about	£13.251,750

During 1906 the copper production of the mine was 2,567 tons, and during 1907, 4,713 tons. The copper yield will probably increase in future years. To the end of 1907 the mine had paid in dividends some £7,062,020.

The ore of Mount Morgan varies greatly in character. Siliceous hæmatite, a bluish-grey quartz, a rock simulating pumiceous sinter, and a certain quantity of kaolinic matter, all have been found at the outcrop. As the sulphide zone is reached, pyrite, and still further in depth, chalcopyrite together with pyrite, is met with. The original surface of the mountain was lateritic in appearance, and carried spheroids of limonite, that in cavities became quite stalactitic. In places the surface rock was stained black with manganese oxides. The large quantity of kaolinic matter found at the surface was derived partly from the felspars in the grauwackes and partly from the decomposition of the basic dykes that traverse the mountain. The cellular siliceous ore covered on the surface about 2½ acres in extent. It was everywhere at least

60 feet in depth, and reached a maximum depth from the surface of 160 feet. Nevertheless, nodules of unweathered and unaltered siliceous rock full of pyrite were encountered at the surface. The depth of the oxidation zone from the surface varied between considerable limits—from 180 to 300 feet. Free and visible gold was encountered in considerable quantities at the outcrop, but is unknown in depth. This secondary surface ore often yielded several hundreds of ounces per ton, and some blocks of the limonite indeed reached tenors of 800 ounces per ton.[a] The outcrop gold was exceptionally high in grade, thousands of ounces running 997 and 998 fine. The siliceous and kaolinic ores beneath the outcrop, but still within the oxidised zone, contained as much as 43 per cent. silver. In depth the ore carries from 2½ to 3½ per cent. copper and from 1½ to 8 dwts. gold per ton. Stains of copper were at times noticeable in the outcrop ore. There may thus in Mount Morgan be made out four fairly distinct zones in the vertical distribution of the gold content, viz. : (*a*) a rich surface zone with free gold ; (*b*) a poor oxidised zone of cellular quartz ; (*c*) an enriched sulphide (pyrite) zone ; and (*d*) a leaner pyrite-chalcopyrite zone.

Various hypotheses have from time to time been held as to the origin of this remarkable deposit. Dr. R. L. Jack, in various reports made when little information was available as to character of the ore at the lower levels, advanced a geyser theory of origin. This view he has largely modified as a result of the examination of deeper workings, and in his last report on the subject says :[b] " Consequently a period of time has elapsed since the formation of the surface ores, long enough to render it almost inconceivable that any deposit of a 'thermal spring in the open air' could have remained undenuded." The short examination of the Mount Morgan deposit, made by the present writer in 1901, brought him to the conclusion that the occurrence was to be best explained by the operation of siliceous and auriferous pyritous solutions on, with minor metasomatic replacement in, a sandstone or grauwacke, the impregnation and replacement taking place mainly in a thoroughly shattered zone. The cellular surface rocks then visible were apparently merely the weathering products of an impregnated, by no means clean, sandstone, or, much more probably, a grauwacke. The cavities were certainly such as would have been left by the removal of pyrite and by the decomposition of felspar. Thus also were formed the abundant iron oxides and the kaolin that were found at the surface. The free gold also was readily explainable, on the assumption of

[a] Dunn, loc. cit. inf., p. 350.

[b] Jack, Rep. Geol. Surv. Queens., No. 132, 1898, p. 20.

Mount Morgan, Queensland.

Open-cut, Grasstree Level, Mount Morgan.

liberation from the auriferous pyrite and chalcopyrite. It is worthy of note that comparatively little trace was shown in the outcrop ores of the great copper content now known to exist in depth. By virtue of its siliceous impregnation and of its consequently superior powers of resistance to denudation, the ore-mass was differentiated from the adjacent country, and when discovered stood forth as a hill. The period of impregnation was connected with the acid rocks rather than with the dolerites. This theory of origin, it will be obvious, is essentially that suggested 10 years before for the deposit by Rickard and by Wilkinson.[a]

A recent geological report on Mount Morgan is that by Dunn.[b] This, though published only in 1905, was, however, written many years before, when the geological structure of the Mount was but imperfectly understood. While it has apparently not been modified in view of later developments, the development of the enriched surface zone and its relations to the sulphide bodies are nevertheless clearly set forth, although, at the same time, the impoverishment of the lower portion of the oxidised zone and the enrichment of the upper zone is held to be due to the action of sea water.[c]

Southern Fields.—The Lower Permo-Carboniferous gold-fields of Queensland include the Gympie, Mount Shamrock, Calliope, Crocodile (in part), Yatton, Hodgkinson, Palmer, Nebo (Mount Britton), and others of minor importance.[d] With these the present author would, for reasons that have already been advanced, also include the famous Mount Morgan mine. All, or nearly all, are intruded by dioritic dykes.

Gympie.—The Gympie area, which has given its name to the formation, may be taken as the typical goldfield. Its veins lie in sedimentary rocks—grauwackes, altered sandstones, grey and dark-coloured carbonaceous shales, grits, conglomerates, limestones, and breccias. Amygdaloidal dolerites, tuffs, and andesites (the Gympie "greenstone") are found interbedded with the above, while through them are intruded much altered diorite and augite-andesite. From the present point of view, the important beds are the four so-called "slates," since it is only in or near them that the gold-veins are productive. The three upper beds are dark fine-grained shales and argillaceous sandstones containing graphite and calcite. The lowest bed is a fine-grained grauwacke. The upper three are 100 to 130 feet apart, while the lowest is 400 feet

[a] Rickard T. A., Trans. Amer. Inst. M.E., XX, 1891, p. 133; Wilkinson, C. S., Rec. Geol. Surv. N.S.W., II, 1891, p. 86.

[b] Proc. Roy. Soc. Vict., XVII, 1905, p. 341.

[c] Loc. cit., p. 354.

[d] Jack, "Geology of Queensland," 1892, p. 76 *et seq.*

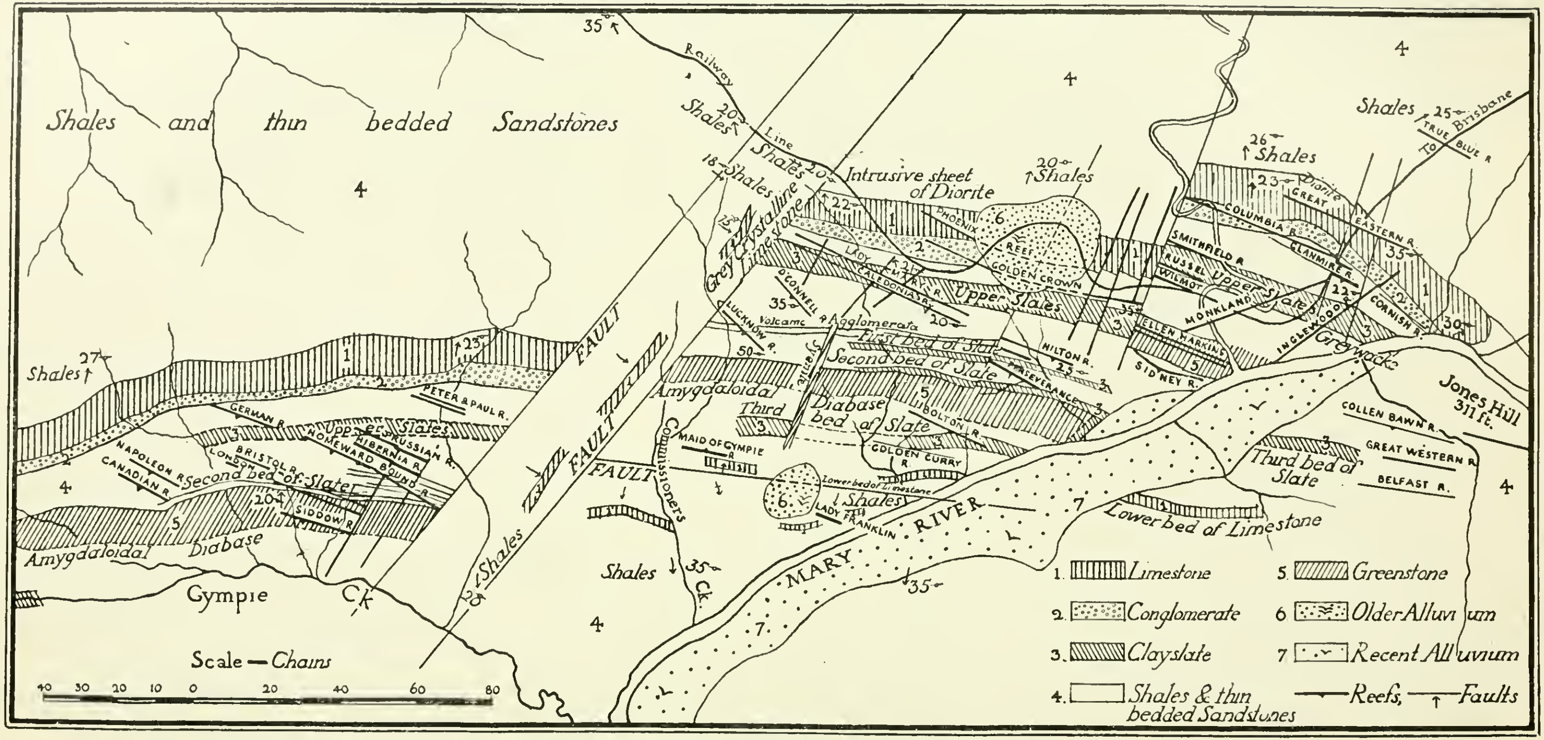

FIG. 105. GEOLOGICAL SKETCH PLAN OF GYMPIE GOLDFIELD, QUEENSLAND (*Rands*).

below the third. Shales in the immediate vicinity are fossiliferous, containing *Fenestella, Spirifera, Productus cora, Pleurotomaria carinata*, and *Orthoceras striatum*. The total thickness of the series is more than 2,000 feet.

The auriferous reefs strike north and south with the country, but dip east at right angles to the strata, thus crossing all the beds of the series. It is, however, only where they intersect the above-mentioned " slate " beds that they are auriferous. So well recognised is the connection between the deposition of gold and the intersection of quartz-veins that it governs the course of mining operations on the field, and instead of following down the veins by vertical or underlie shafts, as would ordinarily be the case, a vertical shaft is

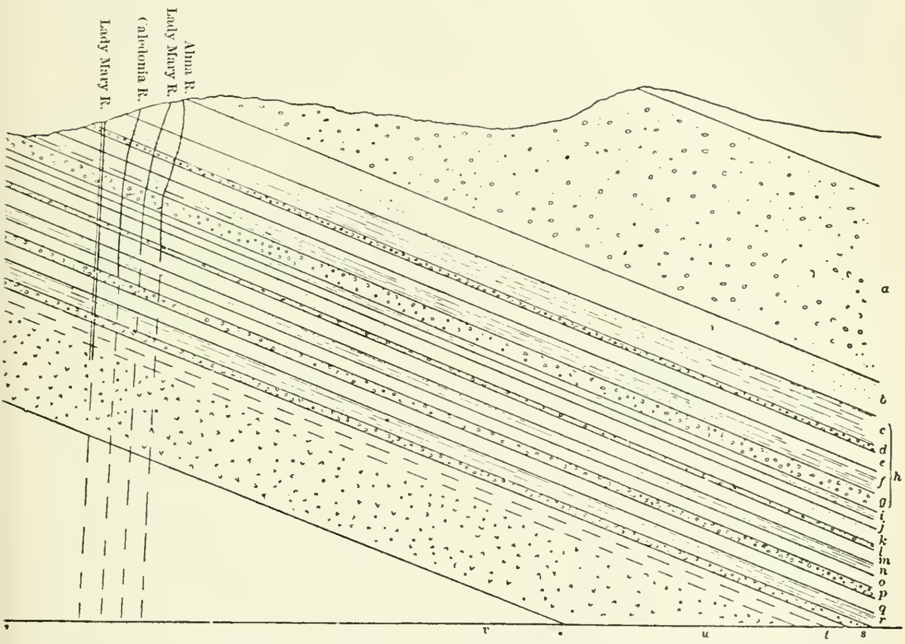

FIG. 106. PART OF SECTION ACROSS GYMPIE GOLDFIELD (*Rands*).

a, d, g, l, p, s. Conglomerates. *b, e, k, o.* Sandstones. *c, f, i.* Shales. *h.* Phœnix or Upper Shales. *n.* " First Bed of Slate." *r.* " Second Bed of Slate." *j.* Angular grit (volcanic ash). *m.* Green crystalline rocks. *q.* Altered grey-wacke. *t.* Diabase-porphyry. *u.* Hard, crystalline greenstone. *v.* Green and purple chloritic rock.

sunk through the vein or through the carbonaceous bed and a cross-cut driven west or east respectively to the calculated horizon of intersection of vein and " slate." The veins are often intersected by strike faults dipping with the country. When these contain abundant graphite, they are known as " plumbago floors," and are a source of much local enrichment.[a]

[a] Rands, Rep. Geol. Surv. Queens., No. 52, 1889; Id., loc. cit., No. 75, 1891; Id., loc. cit., No. 100, 1894; Id., loc. cit., No. 166, 1901.

Dr. Jack[a] has recorded a notable fact from the deep workings of the Scottish Gympie mine, where a mass of auriferous quartz-veins traversing an "intrusive andesite" has been discovered. In the andesite were also "floors" of graphite and small masses of slate. The andesite occupies a horizon between the top and bottom of the Gympie slates. Occasionally where the andesites have come into contact with the above-mentioned "plumbago floors," they suffer the same alteration to white rock that is observed in basaltic or doleritic dykes intrusive through coal seams.

Calcite occurs as a secondary matrix in the Gympie veins. The associates of the gold are pyrite, marcasite, mispickel, galena, sphalerite, chalcopyrite, tetrahedrite, stibnite, native arsenic, and tellurides of gold and silver—forming an entirely characteristic andesitic assemblage. The sulphides are, however, rarely auriferous. The tellurides noted are hessite and altaite, and occur very sparingly embedded in a calcite matrix.[b]

The Gympie field to the end of 1907 has produced 2,374,353 ounces fine gold worth £10,086,041. In 1906 the yield was 108,053 ounces gold worth £458,675, from 215,680 tons quartz. Dividends paid amounted to £177,554; more than half the above yield was produced by two mines, the Scottish Gympie and the No. 2 South Great Eastern. In 1907 both yield and dividends decreased considerably.

Minor Southern Fields.—Minor goldfields in Southern Queensland are Eidsvold, north-west of Gympie, lying in granite and diorite not greatly differing from those of the Charters Towers field. The reefs are quartzose, and carry pyrite, galena, and arsenopyrite. At Peak Downs an auriferous conglomerate is associated with *Glossopteris* flora, and is therefore of Permo-Carboniferous or later age. The auriferous portion of the conglomerate is said to contain 5 to 6 dwts. per ton. At Kilkivan the gold is associated with antimony, and at Mount Biggenden with bismuth. The last-named deposit is remarkable. It is an irregular mass of magnetite bounded on the north by slate and on the south by limestone.[c]

Dredging, hitherto quite unsuccessful in Queensland, is still being carried on at Cania, an old placer field. The famous "deep leads" of the southern colonies are unknown in Queensland, whose yield of alluvial gold amounts to only about 12,000 crude ounces annually, by far the greater part of which (7,343 ounces in 1906) is produced from the Clermont field.

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[a] Queensland Govt. Mining Journal, Jan. 14, 1905.

[b] Dunstan, Rec. No. 2, Geol. Surv. Queensland, No. 196.

[c] Rands, Rep. Geol. Surv. Queensland, No. 60, 1890.

The total gold yield of Queensland is shown in the subjoined table :—

Year.	Fine Ounces.	Year.	Fine Ounces.	Year.	Fine Ounces.
To end of 1877	1,819,104	1888	397,972	1899	668,227
1878	270,554	1889	634,605	1900	676,027
1879	243,475	1890	513,819	1901	598,382
1880	222,441	1891	477,976	1902	640,463
1881	225,431	1892	509,541	1903	668,546
1882	185,009	1893	510,342	1904	639,151
1883	173,460	1894	548,595	1905	592,620
1884	250,127	1895	506,285	1906	544,636
1885	250,137	1896	502,146	1907	465,882
1886	279,488	1897	600,949		
1887	348,890	1898	647,487	Total..	15,611,767

Total value of gold won to end of 1907 .. .. £66,314,528

NEW SOUTH WALES.

The majority of the auriferous areas of New South Wales are closely connected with the granitic masses of Permo-Carboniferous age, that form the core, not only of the chief mountain chain of New South Wales, but also, as we have already seen, of that of Queensland. The gold-veins may exist in the granite, or in its felsite or porphyrite apophyses (as in North Queensland), or even in dioritic rocks, or they may occur (as in Victoria) in adjacent Devonian or Silurian rocks.

The earliest recorded discovery of gold in Australia was made at the Fish river, Bathurst, New South Wales, in 1823, by a surveyor named O'Brien. There is, however, room for doubt, in this case, whether the particles recorded as gold by that observer were really so, or were mica or pyrite. In 1839, Count Strzelecki, of whose mineralogical knowledge there is no question, found auriferous pyrite in the Vale of Clwydd. Two years later native gold was recognized by the Rev. W. B. Clarke in granites and quartziferous slates occurring west of Hartley. Owing, however, to the fears entertained by the authorities of the unsettling effect of gold-seeking on the progress of the colony, both these geologists were induced for a time to keep secret their discoveries.

It was not until 1851 that E. H. Hargraves, who had then just returned from the great Californian diggings, demonstrated the existence of gold in payable quantities in the neighbourhood of Bathurst. Within a fortnight of the public announcement, made in May of 1851, more than 1,000 men were at work in the vicinity of Hargraves' find. The discovery had the natural effect of encouraging wide-spread prospecting, and by the end of that year the great alluvial goldfields, not only of New South Wales, but also of Victoria, were fairly well known.

Gold is widely distributed in New South Wales, occurring in reefs and lodes intersecting the Silurian, Devonian, and Carboniferous rocks; it has also been successfully worked in the ancient Permo-Carboniferous conglomerates of Tallawang, near Mudgee, where nuggets weighing as much as 5 ounces were obtained. Auriferous alluvial deep leads of Cretaceous age are recorded from Mount Brown, in the far north-west, while those of Tertiary and recent ages are widely known and have long been worked. They formed, indeed, the earliest source of the gold won in the state. The majority of the goldfields of New South Wales occur along a broad, not very well-defined belt in the high land in the eastern portion of the state, but rich fields nevertheless occur as far west as Cobar and Wyalong, and a minor occurrence is known in the far north-west of the state at Tibbooburra, where the gold lies in veins that traverse the eroded Palæozoic rocks where these are intruded by basic or other dykes. Veins also occur within the igneous rocks themselves.[a]

Pittman divides the alluvial gold deposits of New South Wales into :—

(*a*) Recent and Pleistocene alluvials.

(*b*) Beach sands along the sea-coast.

(*c*) Tertiary alluvial leads.

(*d*) Cretaceous alluvial leads.

(*e*) Permo-Carboniferous conglomerates.

The marine beach sands are best developed near the mouth of the Richmond river in the north of the state, where black sands, made up largely of zircon, ilmenite, garnet, and quartz, contain fine grains of gold, platinum, and cassiterite. They are, as on the coast of north-west America and of the south-western part of New Zealand, reinforced in bulk and in value after storms. They have been worked intermittently since 1870. Raised beaches containing black-sand seams with gold have also been worked. The gold, both the younger and older deposits, is, of course, in a state of extremely fine division. In the raised beach deposit the sand is so far cemented as to require rough crushing. McAuley's lead is the only one that has up to the present proved payable. Pittman notes that although the beach sands have been tested

[a] Pittman, "Mineral Res. New South Wales," Geol. Surv. N.S.W., 1901, p. 6, from whence many of the following details have been derived.

along some hundreds of miles of coast line, it is only in the immediate neighbourhood of basalt that they have been of economic value.

The Tertiary alluvial leads are the remnants of ancient auriferous river-gravels that have, from a variety of causes, been preserved to the present day. They represent mainly Pliocene gravels and, as might be expected, show considerable deviation in their course from the direction of existing valley systems. In many cases the Pliocene gravels owe their preservation to having been buried beneath a considerable thickness of basaltic lava that, by covering up the valleys with their contained gravels, reduced to a great extent the then existing incqualities in the surface. Such buried auriferous gravels, as well as those formed by depression of the valley bottoms below base-level, are termed *deep leads*. Some of these were extremely rich. It is recorded that from an area of 40 by 40 feet in the North Lachlan goldfield near Forbes, no less than 1,900 ounces gold were obtained. Gold occurs in Tertiary leads (as also in the Recent and Pleistocene deposits) at the Rocky River goldfield near Uralla, and also at Gulgong, from whence in five years (1871-1875) £1,850,000 were obtained.

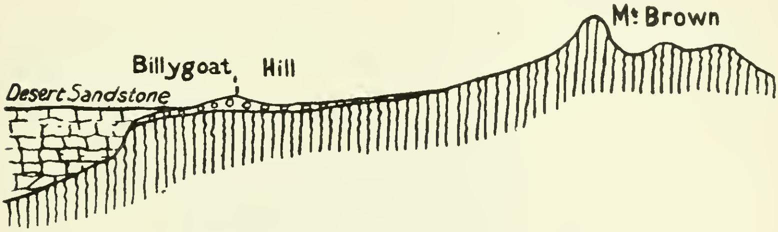


FIG. 107. AURIFEROUS LEAD OVERLAIN BY DESERT SANDSTONE, MOUNT BROWN (*Pittman*).

Often at Gulgong the average gold content of the "wash-dirt" was an ounce per load. The leads in the neighbourhood of Gulgong are numerous. For these an average width of 300 feet of gravel with a depth of 1 to 1½ feet of pay-dirt may be taken. They have for the most part been abandoned on account of the great difficulties of working due to inflow of water, difficulties that became insuperable when accompanied by increasing poverty of the gravels. Similar auriferous alluvial leads occur at Adelong, Albury, Braidwood, Grenfell, Gundagai, Rockley, Temora, Tumberumba, &c. Some of the famous Victorian deep leads, as those of the Chiltern Valley, near Corowa, are believed to pass into Southern New South Wales.

Cretaceous alluvial leads or buried channels occur in the north-western corner of the state at Mount Brown, south of Milparinka.

They dip, as will be seen from the accompanying section, beneath the Upper Cretaceous Desert Sandstone. Very rich gold was obtained from the lead, including one nugget of 25 ounces in weight. Similar Cretaceous leads occur at Tibbooburra, 25 miles further north, where granite and Silurian slates are almost hidden beneath the Desert Sandstone. Here also the auriferous leads dip beneath the Desert Sandstone. The gravels have yielded nuggets weighing 15 to 20 ounces. Another occurrence of much the same age and nature occurs at the Peak between Milparinka and Wilcannia.

The largest nugget ever found in New South Wales weighed 1,286 ounces 8 dwts., and was found in recent gravels at Burrandong near Orange.[a] Perhaps the most interesting occurrence of gold in the State from a geological point of view is that at Tallawang, about five miles to the north of Gulgong, where conglomerates, undoubtedly to be relegated to a position at the base of the Upper Coal measures, and therefore Permo-Carboniferous in age, were, in 1875, successfully worked for gold. The occurrence is of no great extent. Nuggets up to 5 ounces in weight were taken from it, and yields of from 1 to 15 dwts. per ton. On referring to Wilkinson's original note[b] there appears to be no doubt of the placer origin of the gold. These conglomerates are, however, not definitely Carboniferous, as stated by him, but rather Permo-Carboniferous, since they are associated with the *Glossopteris* flora of the Eastern Australian Coal Measures. The conglomerate has been worked principally at Clough's Gully. Several hundred tons of the cement were crushed, but the deposit was found to be very irregular in tenor. The gold was coarse, remarkably scaly, and *water-worn*. This is the only known occurrence of payable alluvial gold in these measures, though traces of gold had formerly been found in the same series by the Rev. W. B. Clarke. In the Gulgong field the original source of the alluvial gold has obviously been the veins developed, as the field evidence shows, by the intrusion of diorites or granitic intrusions through the Upper Silurian rocks. There is thus apparently fixed a superior limit to the age of the New South Wales gold-veins. The so-called Carboniferous occurrence at the Peak Downs in Queensland is also Permo-Carboniferous, for the cement beds there worked, as first described by Daintree, are associated with the typical *Glossopteris* flora.

[a] For a complete bibliography of New South Wales gold occurrences to 1900, *v.* Dun, Rec. Geol. Surv. N.S.W., VI, 1900, p. 187.

[b] Wilkinson, C. S., Ann. Rep. Dep. Mines, N.S.W., 1876, p. 173.

The Kiandra Deep Leads are described by Andrews.[a] They were discovered in 1859, but only the richer shallow alluvials were then worked. The township of Kiandra lies about 4,600 feet above sea-level, and is subject in winter to heavy snowfalls, a

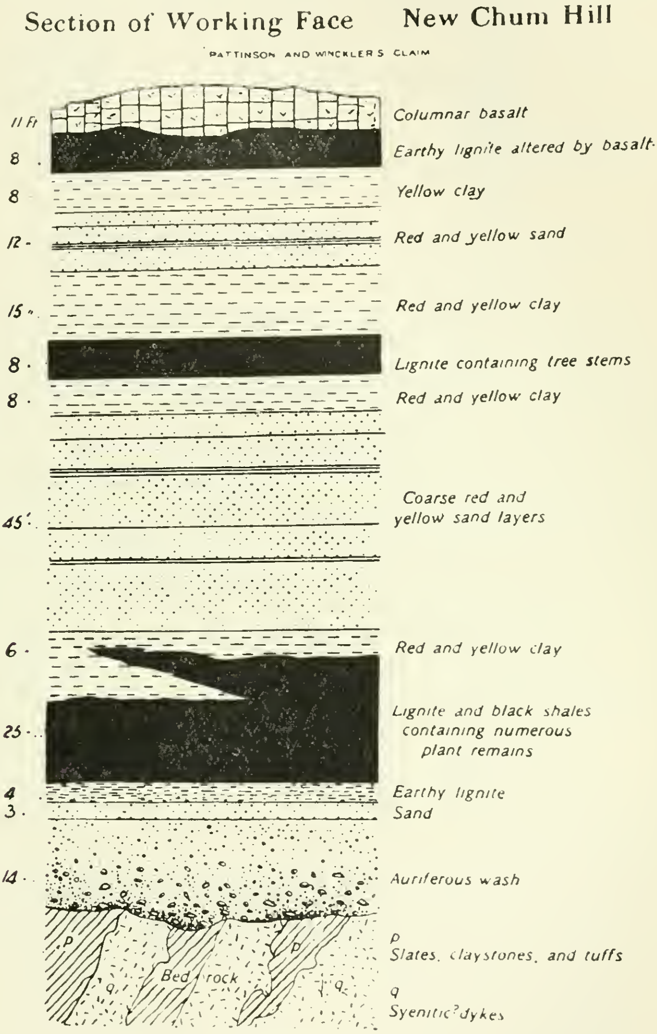


FIG. 108. VERTICAL SECTION THROUGH DEEP LEAD, KIANDRA (*Andrews.*)

feature unique in Australia. Two well-defined leads occur. Both are capped by basalt. The auriferous wash is not confined to a narrow gutter, but is distributed over an uneven bed, varying from 50 to 100 yards in width.

[a] N.S.W. Geol. Surv., Min. Resources, No. 10, 1901.

Dredging both for gold and for tin has been practised in New South Wales for some years. To the end of 1906 this method of gold recovery had produced the following quantities of gold:—[a]

Year.	Crude Ounces.	Value.
1900	8,882	£33,660
1901	23,585	89,628
1902	25,473	97,891
1903	27,237	104,303
1904	32,345	123,656
1905	35,388	136,090
1906	36,649	141,101
Total ..	189,559	£726,329

The chief dredging area is the Araluen division, furnishing more than one-third of the total for 1906. The average yield over a quantity of 3,425,000 cubic yards in this division was 1·96 grains per cubic yard. In the Stuart Town Division (on the Macquarrie river) 1,002,900 yards were treated for an average return of 6·47d. per cubic yard, the total value of the gold obtained being £27,044. The Sofala district on the Turon river, a tributary of the Macquarrie, yielded £12,430. Other areas of lesser importance are being dredged on various rivers in the state, generally with profit. For the whole state in 1906, 22 bucket-dredges recovered 27,643 ounces gold from 5,992,980 cubic yards material, or 4·33 grains per cubic yard. Seven centrifugal pump dredges treated 1,026,550 cubic yards for a return of 8,345 ounces or 7 32d. per cubic yard.

Turning now to the primary occurrences, the auriferous veins of New South Wales occur in Silurian and Carboniferous rocks, or are associated with granodioritic outbursts of probable Permo-Carboniferous age. The gangue is generally quartz ; but calcite, barytes, and fluorite are occasionally met with. Enormous masses of vein-gold have been found and, of these, that taken in 1872 from Beyer and Holtermann's claim at Hill End is probably the largest mass of solid vein-gold recorded. It weighed 630 pounds and was valued at £12,000.

Hillgrove.—There are several gold-occurrences on the eastern escarpment of the pastoral upland New England country, in the north-east of New South Wales. The chief of these is at Hillgrove, on Baker's Creek, about 20 miles west of Armidale.

Its mines are situated on the eastern edge of the main plateau, where it is intersected by deep steep-sided (32° slope) ravines, 1,400 to 1,500 feet deep. The oldest rocks on the

[a] Rep. Mines Dep., N.S.W., 1906, p. 24.

field are altered slates, schists, and quartzites, often much contorted.[a] The slates pass insensibly into a knotted schist. The sedimentary rocks carry the auriferous lodes. The eruptive rocks are basic granites, or rather, granitites approaching very closely in character to quartz-mica-diorites,[b] and are divided into four groups in point of apparent age. The first two and the older are unimportant in extent and in economic relations, but the third is largely developed, and to it is to be ascribed the genesis of the antimony and gold lodes. The last granitic intrusion is a fine-grained rock that has sent out into the slates numerous felsite

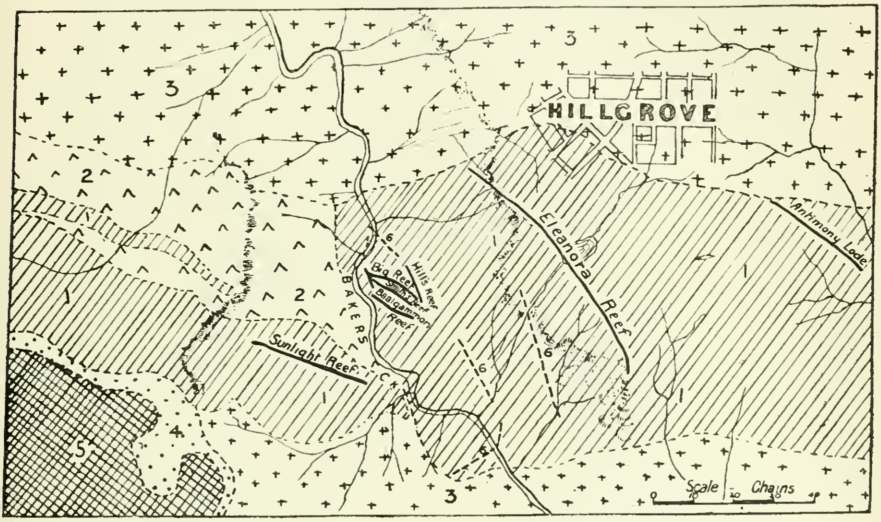


Fig. 109. Geological Sketch Map of Hillgrove Goldfield (*Andrews*).
1. Carboniferous slates, quartzites, and schists. 2. Fine-grained granite.
3. Coarse-grained granite (Carboniferous ?). 4. Tertiary gravel.
5. Tertiary basalt, overlying gravels. 6. Felspar-porphyry and felsite dykes.

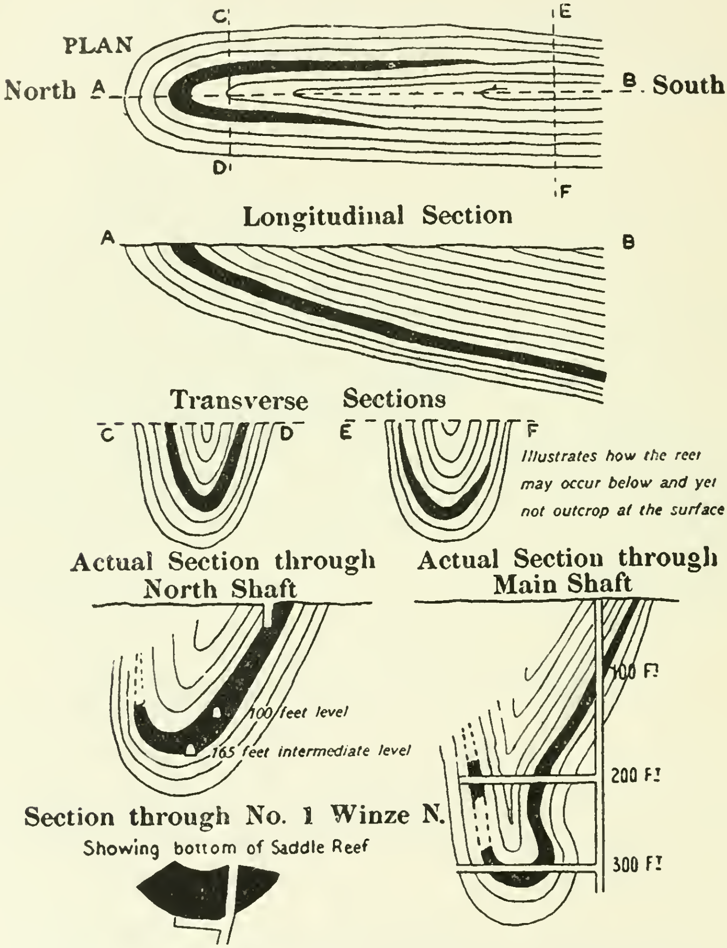
dykes. The main or third granite mass is traversed by some of the lodes that are continued into it from the slates, but the last and finest granite cuts off these lodes and is therefore younger in age. The granitic *massif* developed at Hillgrove forms also the core of the New England ranges. It is Carboniferous or Permo-Carboniferous in age. The whole district was covered by the great Tertiary basaltic lava flows of the New England region, that filled up the older valleys. The present minor valley system is, therefore, Pliocene and Post-Pliocene.

The slates of Hillgrove have been subjected to great strain and are notorious among miners throughout Australia for their

[a] Andrews, Min. Res. No. 8, Geol. Surv. N.S.W., 1900, p. 14.
[b] Loc. cit., p. 23.

"kicking" propensities, huge masses of rock flaking off the walls of the workings with explosive violence. In this respect the explosions are comparable only to the great "air-blasts" of the hornblende-schist of the Champion Reef on the Kolar field in Southern India.

The lodes of the district were originally worked in 1877-8 for their antimony content alone. A considerable amount of this



FIGS. 110–116. PLAN AND SECTIONS OF THE MOUNT BOPPY SYNCLINE (*Jaquet*).

metal is still produced. The presence of gold in the veins was not suspected until 1881, but for various reasons, it was not until six years later that the richer gold-lodes of Hillgrove were opened up. The Big and Little Reefs, among the earliest auriferous lodes discovered, yielded exceedingly rich outcrop-ore.

The veins or reefs of Hillgrove carry a well-defined quartz-filling that may, however, be prolonged by zones of barren, crushed, and brecciated country, containing but little quartz. Slickensides and flucans are abundant. Scheelite, associated with stibnite, is found in sufficiently large quantites to be of economic value. The matrix of the gold is generally quartz, but stibnite is nearly always present in great quantity. In depth, arsenical pyrites is also found. The reefs average from 12 to 18 inches in thickness, and may reach, as in the case of the Big Reef, a thickness of 4 feet. The Eleanora reef is the largest in the district, averaging 6 feet in width. It accompanies an intrusive dyke, on both sides of which it forms quartz. The amount of gold recovered on treatment of the ore is about 9 dwts. gold per ton, but the presence of stibnite is prejudicial to amalgamation and considerable quantities are left behind in the tailings.

Mount Boppy.—The Mount Boppy goldfield is situated on the western plains of central New South Wales, 25 miles from the Cobar copper field. Its chief producer is the Mount Boppy mine, from 1905 to 1908 also the principal gold-producing mine in the state. The lode was first worked for copper, and gold in quantity was discovered only about 1899. The rocks are Silurian slates and schists. The reefs lie, according to Jaquet,[a] at the base of an inclined synclinal fold, analogous in most respects to the "saddle reefs" of Bendigo. The synclinal axis pitches southward at high angles. The eastern leg is much more strongly developed than the western, and forms the main lode. The oxidised ore is composed essentially of quartz with iron oxide, and the unoxidised of quartz with pyrite, arsenopyrite, galena, and blende. The gold is present always in a state of extremely fine division.

The following table shows the quantity and value of gold obtained from this mine :—

Year.	Tons of Quartz Crushed.	Total Ounces of Fine Gold.	Value, Sterling.		
			£	s.	d.
1901	12,440	6,092·00	18,780	19	10
1902	10,697	7,815·00	24,211	2	11
1903	29,312	18,800·92	79,723	16	9
1904	35,378	21,799·80	91,460	3	4
1905	51,878	27,884·61	116,433	19	11
1906	72,976	30,087·48	126,229	4	1
1907	76,339	31,601·71	133,121	4	7
	289,020	144,081·52	£589,960	11	5

[a] Rec. Geol. Surv. N.S.W., VIII, 1905, p. 180.

To the 16th April, 1908, there had been paid in dividends £262,282. 13s., or a little less than half the value of the total gold product. The average tenor of the ore treated had been almost exactly 10 dwts. fine gold per ton.

Cobar.—The Mount Drysdale mine, 25 miles north of Cobar, also works quartz reefs in Silurian rocks (slates, sandstones, conglomerates, and breccias). The pay-ore hitherto mined occurred in a shoot 40 feet long and from 6 inches to 5 feet in width.

The Cobar district, though primarily a copper district, nevertheless contributes a considerable quantity of gold to the total produce of New South Wales. The mines were opened up in 1876, but it was not until 1893-4 that steps were taken to ascertain definitely the amount of gold in the copper ingots. Of this amount, no account had previously been taken, and the contained gold had up to that time been a perquisite of the London buyers of Cobar copper. The sulphides of the Cobar mine are pyrrhotite, pyrite, and chalcopyrite, with only 16 per cent. silica. They carry from 2½ to 3 dwts. gold per ton. The country is Devonian or Silurian slate and sandstone.[a]

Hill End.—The Hill End goldfield, some 30 miles north of Bathurst, is situated near the Turon river, the scene of vigorous and highly profitable gold-washing in the earlier days of the colony. The rocks of the goldfield are dark fissile slates, flinty altered claystones, and interbedded volcanic tuffs. From fossil evidence the series is regarded as Upper Silurian in age. The strata have been thrown into anticlinal folds and are intruded by quartz-porphyry dykes and sills. The reefs are lenticular and lie either in the black slate, or at the contact of slate with the igneous sills, or with the tuffs. They are bedded with the country. The richest veins have hitherto been found on the eastern side of the anticline. On this side also were the Hawkins Hill veins, from whence the already mentioned huge gold-quartz nugget was taken by Beyer and Holtermann. The richest gold has been obtained at contacts of slate and sill. Enrichment generally takes place when the quartz, which ordinarily forms the gangue, has been almost entirely replaced by a white mica (sericite). The gold hitherto obtained occurred in shoots in the veins. On this field, in marked contradistinction to many others, it was generally found that shoots were developed at corresponding places in all the parallel veins. The shoots were worked to depths of 400 to 700 feet.[b] A cross-reef

[a] Carne, Min. Res. No. 6, Rec. Geol. Surv., N.S.W., 1899, p. 106.

[b] Pittman, loc. cit., p. 32.

faulting the above-described veins carried in depth rich arsenical pyrites with free gold.[a]

Hargraves.—The Hargraves goldfield lies nearly 20 miles to the north of Hill End and at an elevation of 3,000 to 4,000 feet above sea-level. Its rocks, like those of Hill End, are Upper Silurian (or possibly somewhat younger) slates and tuffs intruded by granitic dykes and sills. The reefs at Hargraves are saddle-shaped; are developed in the folds of the beds; lie conformably with the strata; and occur in a series along an anticlinal axis, one beneath another at successive depths. They thus resemble in every respect the saddle reefs of Bendigo. The Hargraves auriferous belt extends for 1½ miles in length and ¼-mile in width. The most important line is that along Big Nugget Hill. It was on this field that a large mass of golden quartz weighing 106 pounds was found in 1851

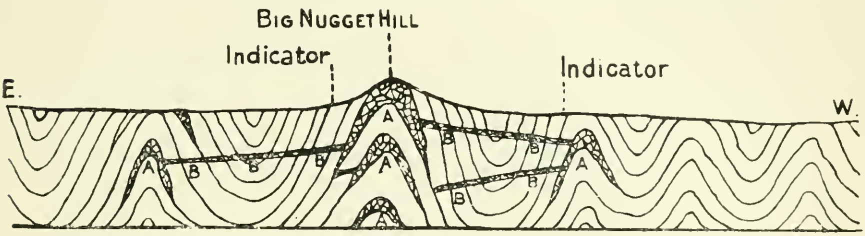


Fig. 117. Section through Big Nugget Hill, Hargraves (*Pittman*).
A.A.A. Saddle Reefs. *B.B.* Flat Reefs.

by an aboriginal shepherd. This discovery led to the opening up of an exceedingly rich alluvial field, that was not exhausted until the early 'seventies. Auriferous reefs of another kind, locally termed "flat reefs," occur at Hargraves. While these flat reefs have been found to be unpayable throughout the whole of their extension, they nevertheless contain extremely rich shoots, especially where they intersect a narrow band of dark-greenish slate interbedded with the country and locally termed the "Indicator." The indicator generally carries an exceedingly thin quartz-vein. The gold "makes" only in the flat reefs, but is always restricted to within a few inches of the plane of intersection. The general plan of operations pursued, in prospecting for "pockets" in the flat reefs, has therefore been to trench along the outcrop of the "indicator."

Lucknow.—The Lucknow mines are 6 miles from Orange in central New South Wales. Alluvial leads (Pleistocene and Pliocene) were worked in the vicinity as early as 1863. The veins, whose degradation had furnished the gold, were soon afterwards discovered.

[a] Watt, Rec. Geol. Surv. N.S.W., VI, 1899, p. 83.

They were of great richness at and near the outcrop, pay-ore occurring in rich bonanzas or ore-shoots. For the 8-year period, 1892 to 1899, the two principal mines of Lucknow (Wentworth Proprietary and Aladdin's Lamp) had produced nearly £800,000 gold. The present production is, however, unimportant, and is indeed largely obtained from the battery tailings left after the

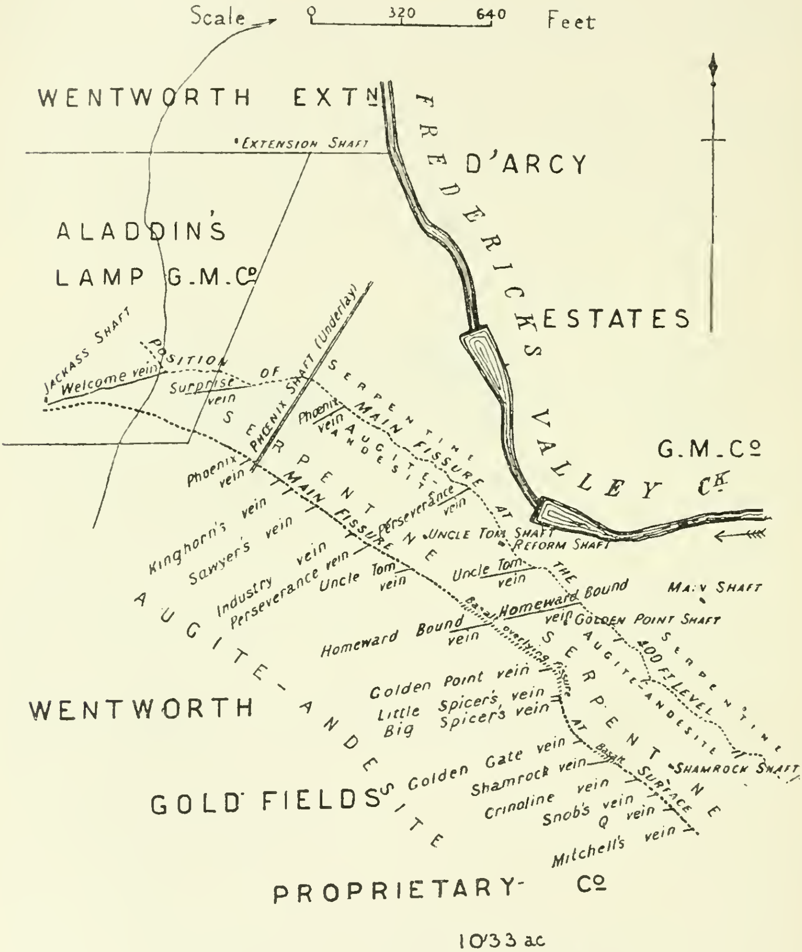


FIG. 118. PLAN OF LUCKNOW GOLDFIELD (*Pittman*).

treatment of rich ore. The Lucknow ore-bodies are somewhat remarkable. They are invariably found as shoots, pipes, or bunches of ore at or near the junction of a number of east and west veins with a north-west and south-east main fissure, which is often vertical, but generally dips north-east at 60°. The hanging-wall of the " main fissure " is a mottled dark-green and white serpentine, the foot-wall greenish-grey augite-andesite.[a] Occasionally, augite-andesite forms both walls of the "main fissure," but when this is the case no ore-bodies are developed. Three hundred feet or less to the north-east of the main fissure the augite-andesite again appears. The serpentine is therefore merely a band with a maximum width of 300 feet. It is believed to have originated from the decomposition of the augite-andesite.[b] Nephrite or jade has also been found, but only as a narrow band a foot or so in width, lying between the ore-body and the serpentine hanging-wall. The east and west veins in the footwall andesite are never known to cross the main fissure, although no less than 17 of them have been worked. They are generally vertical or dip at a high angle, and vary in width from a few inches up to 6 feet or more. They have a banded structure, enclose fragments of country (augite-andesite), and carry a gangue of quartz which on approach to the main fissure and to the serpentine is replaced by calcite, the matrix in particular of the rich ore-shoots. In the lower levels, at least, the quartz gangue is never payable. The gold in the calcite is either free or occurs in mispickel. Ore-bodies unconnected with the east and west veins have never been found.

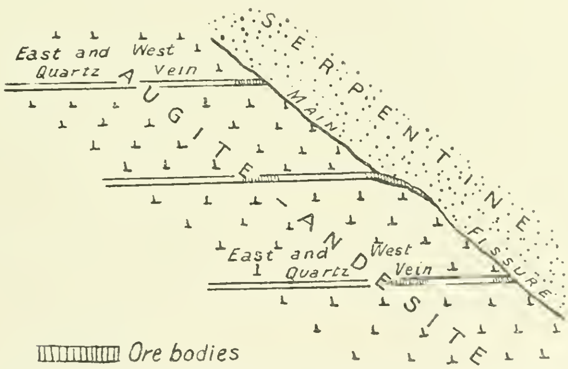


FIG. 119. PLAN SHOWING DETAILS OF OCCURRENCE OF ORE-BODIES AT LUCKNOW (*Pittman*).

The ore-bodies are developed as follows :—

(*a*) Shoots or pipes along the junction of the quartz-veins with the main fissure.

(*b*) As bunches extending horizontally along the main fissure for a length of from 20 to 50 feet, but always starting from the toe, or plane of contact, of a quartz-vein with the main fissure.

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[a] Pittman, Rec. Geol. Surv., N.S.W., VII, 1900, p. 3.

[b] Loc. cit., p. 4.

(*c*) As "droppers" from the footwall of the main fissure.

(*d*) As shoots in the east and west veins (but only near their junction with the main fissure) where calcite replaces the quartz for a short distance.

The gold was free in the upper zones, but in depth it lies in auriferous mispickel that is associated with metallic antimony and often with stibnite. In the lowest levels pyrrhotite replaces the mispickel, and the replacement is accompanied by a corresponding falling off in the tenor of the quartz. The mispickel occurs in characteristic stellate crystals that may contain 50 to 500 ounces gold per ton. The bullion is worth £3. 10s. per ounce.

Lyndhurst.—The Lyndhurst goldfield is in the Bathurst district, 8 miles west by south of Carcoar. The country is a sedimentary series of probable Lower Silurian age, and consists of bluish-grey claystones alternating with beds of a highly altered siliceous and pyritous rock that when thin forms, or when thick contains, the ore-bodies. The sedimentary rocks have been intruded by hornblendic granite, and by dykes and sills of diorite that are apparently off-shoots from the granite *massif*.[a] Another series of dykes—in this case of augite-andesite—is also found within the auriferous area. Small lenticular masses of bluish-grey limestone are often associated with the Lyndhurst ore-bodies. The thickness of the claystones and of the intercalated ore-bodies varies from that of a sheet of paper up to 20 feet. In the three principal mines the productive ore-bodies have been found only in association with dykes of diorite and augite-andesite, and these intrusions appear therefore to have had some genetic connection with ore-deposition. The ore-bodies are, as has already been seen, confined to hard intercalated beds. These were originally tuffs, but have subsequently been largely altered by siliceous sulphide impregnations. The tuffs are regarded by Pittman[b] as representing original submarine tuffs and flows, much broken and disturbed by steam injections while still in the plastic state. The normal process of replacement of calcareous tuffs by silica and pyrite is, however, quite competent to produce the appearance of friction or of deposition-brecciation. The Lyndhurst occurrences in this respect show considerable analogies with those of Newman Hill, Rico, Colorado. The bedded auriferous deposits cover about 500 acres. Three ore-beds averaging 10 to 11 feet in thickness, and separated by two claystone beds of 15 feet and 3 feet respectively in thickness, are definitely known. The value of the ore varies from

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[a] Pittman, Rec. Geol. Surv. N.S.W., VII, 1900, p. 9.

[b] Loc. cit., p. 13.

3 dwts. to 2 ounces gold per ton. The sulphides present are mispickel, pyrrhotite, and pyrite.

Wyalong.—The Wyalong field, in central New South Wales, between the Lucknow and Murrumbidgee rivers and on the same parallel of latitude as Sydney, lies in the heart of a scrub-dotted plain intersected by low ridges. Gold was not discovered in this district until August, 1893, but from that month to the end of 1906 the mines had produced 237,870 tons ore for 351,284 ounces gold worth £1,365,360. It will thus be seen that the general grade of ore treated is comparatively high, averaging indeed 1½ ounces per ton. The ore sent to the smelters ranges from 3 to 20 ounces per ton.[a] The deepest mines on the field have reached depths of 1,100 and 1,300 feet from the surface. The field suffers from scarcity of water (the rainfall being only 20 inches per annum), and this difficulty is accentuated by the impossibility of water-conservation, owing to the general flatness of the country.

The auriferous veins of Wyalong[b] lie entirely within a rock locally termed granite, but which appears to be rather a tonalite (quartz-mica-diorite) than a granite. It has in mass a distinctly gneissose structure, that close to the vein fissures develops into well-marked schistosity. The hornblende and biotite have a roughly parallel arrangement, thus giving a banded appearance to the rock. The felspar, which is entirely oligoclase, preponderates largely. There is a little quartz, with a large amount of hornblende. The ultimate analysis of the rock is as follows:—[c]

Moisture at 100° C.	0·13
Combined water	0·73
Silica (SiO_2)	58·93
Ferric oxide (Fe_2O_3)	1·73
Ferrous oxide (FeO)	5·01
Manganese oxide (MnO)	Trace.
Alumina (Al_2O_3)	17·48
Lime (CaO)	7·08
Magnesia (MgO)	4·33
Potash (K_2O)	1·34
Soda (Na_2O)	2·91
Titanic oxide (TiO_2)	0·52
Vanadium pentoxide (V_2O_5)	Strong trace.
Phosphorus pentoxide (P_2O_5)	0·14
Sulphide trioxide	Absent.
	100·33

The rock is therefore a quartz-mica-diorite and may be compared with the tonalite of Charters Towers, the petrological features of which field are indeed closely paralleled at Wyalong.

[a] Ann. Rep. Dep. Mines., 1906, p. 13.
[b] Watt, Min. Res., No. 5, Geol. Surv., N.S.W., 1899, p. 15.
[c] Watt, loc. cit., p. 14.

The alteration due to crushing and to subsequent percolation of passing waters proceeds far into the vein-walls, which are occasionally silicified. The country of Wyalong has been weathered to great depths by meteoric waters, and in the early days of the field was worked to a depth of 150 feet by pick and shovel alone.

Sedimentary rocks (Upper Silurian ?) have a very small development in the neighbourhood of Wyalong. They are represented, but lie about 2 miles to the east of the auriferous area. They are schistose slates and quartzites, that are associated with possibly intrusive diorites, large areas of which have been metamorphosed to hornblende-schists. The quartz-mica-diorite of the field is considered by Watt to be younger than both the schistose diorite and the sedimentary rocks. The veins occur in zones of crushed granite that are often 8 to 10 feet wide, and more or less parallel in strike. They are contained within an area of 2½ square miles. Some 8 to 10 such zones are known. The veins within the crushed granite zones are on the whole small, running from a few inches to 1½ feet. They are lenticular and are often highly slickensided. Quartz is the ordinary vein filling. Reddish-brown opal is also present. It is, however, always restricted to the upper oxidised zone, and carries fairly large grains of free gold. In depth the gold is exceedingly fine, and is associated with pyrite, and smaller quantities of galena, mispickel, and blende. Even in the upper oxidised zone the gold is fine, especially in the "ironstone" or gossan. There has thus obviously been no appreciable actual secondary surface enrichment, the outcrop gold being apparently merely a residual deposit from the decomposition of pyrites. Owing to the general flatness of the land surface, the fineness of the gold, and the very small rainfall, no alluvial deposits have been formed at Wyalong.

Mitchell's Creek.—The Mitchell's Creek goldfield is in the Mudgee district, 9 miles from Wellington. The rock of the district is a Silurian slate that is intruded by numerous augite-andesite dykes.[a] The principal reef (Mitchell's) lies within an augite-andesite dyke. It varies in width from 3 inches to 5 feet, and in value from 5 to 13 dwts. per ton. Dick's reef is also in diorite (augite-andesite).

Yalwal.—The Yalwal field is on the eastern side of the Australian Corderilla, some 8 miles from Nowra, on the Shoalhaven river. Alluvial gold had long been worked in the vicinity, but the reef gold remained untouched until 1873. The veins have since been mined spasmodically, but often successfully. The ore-bodies

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[a] Macdonald, W. F., Trans. Inst. Min. Met., XV, 1906, p. 526.

occur as impregnations in indurated siliceous slates, quartzites, and conglomerates, associated with rhyolitic and basic lava flows, all of probable Devonian age. These are overlain unconformably by the Upper Marine Beds of the Permo-Carboniferous system. The Devonian rocks were intruded in Carboniferous times by granites and by quartz-felspar-porphyries.[a] No reefs with well-defined walls exist in the district, but veinlets of quartz traverse the quartzites and silicified slates. Rich deposits and seams of gold are found near these veinlets, while all the rocks, including the conglomerates, contain small quantities of gold (1 to 2 dwts. per ton). The country is sparsely impregnated with pyrite. The rock is in general much silicified. Below the water-level are huge masses of pyrite and arsenopyrite. The quartz is ordinarily chalcedonic.

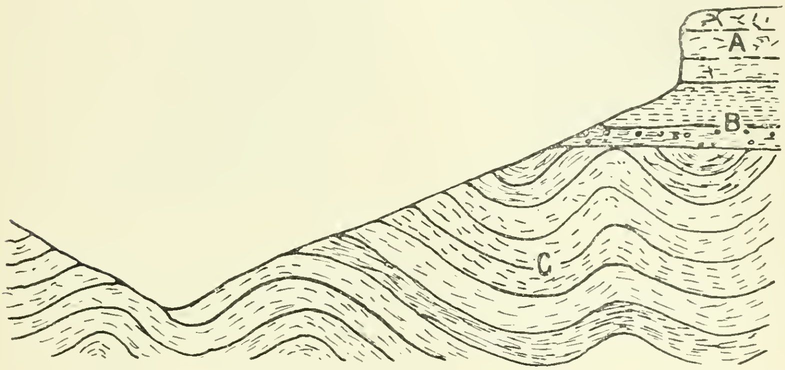


Fig. 120. Sketch Section of the Yalwal Goldfield (*Pittman*).
A. Nowra grits (Permo-Carboniferous). *B*. Shales and conglomerates (do.). *C*. Devonian quartzites, conglomerates, and silicified slates containing gold.

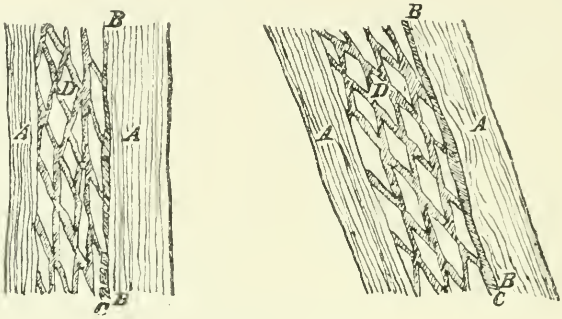
The gold is exceedingly fine. Free gold occurs only in the oxidised zones. It is clear that the gold was originally carried in the sulphides. Ore-deposition is associated by Andrews with the Carboniferous (?) granitic intrusions. Mining and milling costs are lower at Yalwal than elsewhere in the State, the total costs, as long ago as 1900, amounting to less than 8s. per ton. This low figure is due to cheap extraction from an open-cut that lies at a considerable elevation above the crushing mill.

In the rhyolitic lavas (Devonian ?) of Grassy Gully, five miles from Yalwal, gold has been found in chalcedonic quartz in a devitrified rhyolitic glass. The pay-ore is apparently an irregular cementation of the country, and always contains pyrite. The genesis of the ore-deposits appears to be similar to that observed at Yalwal.[b]

[a] Andrews, Min. Res., No. 9, N.S.W. Geol. Surv., 1901, p. 14.

[b] Jaquet, Rec. Geol. Surv. N.S.W., VII, 1900, p. 18.

Panbula.—At Panbula and Wolumba, in the extreme south-east corner of the State, gold occurs in a rhyolitic felsite that contains numerous spherulites. Free gold is found in and adjoining the thin fissures with which the felsite is seamed. The gold is exceedingly fine and the country is thoroughly impregnated with pyrite. A notable local enrichment is observed in the vicinity of a quartz-vein, locally known as the "Pilot Reef" or "Indicator." This reef has been traced for nearly a mile. It is often pyritous but is itself always barren.[a]



FIGS. 121 AND 122. PLAN AND SECTION OF REEF. PANBULA GOLDFIELD (*Power*).

A. Rhyolite country. *B.* Hanging-wall. *C.* Quartz-veins. *D.* Shattered zone, with fragments of rhyolite cemented by quartz.

From 1851 to 1907 inclusive the gold yield of New South Wales has been :—

Year.	Crude Ounces.	Value.
1851-1900	13,118,356	£48,422,001
1901	213,689	737,164
1902	190,316	684,970
1903	295,778	1,080,029
1904	324,996	1,146,109
1905	328,747	1,165,013
1906	302,556	1,078,866
1907	247,363*	1,050,730
	14,991,801	£55,364,882

* Fine ounces.

[a] Carne, Ann. Rep. Dept. Mines, N.S.W., 1896, p. 100.

VICTORIA.

The yield of gold from Victoria, the smallest of the States of Australia with the exception of Tasmania, has been more than half that of the Commonwealth. Its gold-mining history may be said to date from the "rush" to Buninyong, though gold had earlier in the year (1851) been discovered at Clunes and at Anderson's Creek. Discoveries rapidly followed from widely-separated points; from Pleasant Creek, Ararat, Avoca, Tarrangower, Bendigo, McIvor, Beechworth, &c., and a general "rush" to the southern Eldorado took place that has been paralleled in history only by the mad race to California of some three years earlier. In the decade from 1852 to 1861 the enormous amount of 25,369,436 ounces gold, worth more than £100,000,000 sterling, had been produced. The year of greatest production was 1856, when 3,053,744 ounces were obtained. Among the earlier returns are included some of the largest nuggets known; of these the weights of the chief are shown below:—

Name.	Locality.	Date of Discovery.	Weight. Ounces. Gold.	Approx. Value.
Welcome Stranger ..	Moliagul	5 Feb., 1869 ..	2,516	£9,553
Welcome	Bakery Hill. Ballarat..	15 June, 1858 ..	2,195	9,325
Blanche Barkly ..	Kingower	27 August, 1857	1,743	6,915
Canadian	Canadian Gully, Ballarat..	31 Jan., 1853 ..	1,319	5,532
Dunolly (2 nuggets) ..	Dunolly	1857.. ..	1,364	5,500
Sarah Sands	Canadian Gully..	18 Sept., 1854 ..	755	3,200

Since the first discovery of gold the total yield of Victoria to the end of 1906 has been 69,202,178 crude ounces (65,096,487 fine) worth £276,516,978.

Rocks of doubtful Archæan and Cambrian age form the basement series of the Victorian strata. Important auriferous quartz-veins are not developed in these, but lie for the most part in the overlying sharply-folded Ordovician slates and sandstones. These have been separated from the overlying Silurian mainly by aid of their contained graptolites. The Silurian rocks also contain auriferous quartz-veins. The numerous granite intrusions into the Palæozoic sediments are for the most part of a fairly basic type, as has been well shown by Hogg,[a] who calls attention to the relatively abundant occurrence in these rocks of plagioclase felspar; and many of his rocks obviously fall within the group of granodiorites,

[a] Proc. Roy. Soc. Vict., XIII, N.S., 1901, p. 214.

as outlined by Lindgren.[a] According to Howitt, quoted by Gregory,[b] the granitoid rocks of Victoria may be divided into a pre-Silurian granite and a Devonian, or at least, pre-Carboniferous granodiorite. Limburgite dykes of Tertiary age are numerous, but have exercised little or no effect on auriferous deposition.

The goldfields of the Ordovician rocks of Victoria are : Bendigo, Ballarat, Castlemaine, Maldon, Daylesford, Blackwood, Berringa, Steiglitz, Clunes, Creswick, Maryborough, Dunolly, Wedderburn, Inglewood, Avoca, Ararat, Stawell, and St. Arnaud on the west, with Chiltern, Rutherglen, Myrtleford, Harrietville, Dargo, Bulumwaal, Dart River, &c., on the east.

The Silurian quartz-veins lie in shales, sandstones, mudstones, and limestones, at Walhalla, Wood's Point, Foster, Tanjil, Yarra Basin, Reedy Creek, Rushworth, Heathcote, and Upper Goulburn Basin.[c]

In addition to the foregoing there are, in the Benambra and Bogong counties in the extreme north-east of the State, goldfields, or rather gold occurrences, in metamorphic rocks (schists and gneissic granite) of possible pre-Cambrian age. Veins may also occur in the intrusive granitoid rocks.

The principal producing districts of Victoria were for 1906 :—

	Ounces.
Bendigo	221,187
Ballarat	164,065
Beechworth	134,812
Castlemaine	99,386
Gippsland	97,180
Maryborough	80,267
Ararat and Stawell	24,899

The principal producing mines were :—

	Ounces.
Long Tunnel, Walhalla	25,294
Long Tunnel Extended, Walhalla	20,345
New Moon, Bendigo	15,493
South New Moon, Bendigo	13,330
New Argus, Bendigo	13,930
Virginia, Bendigo	12,872

[a] Amer. Jour. Sci., IV, IX, 1900, p. 269.

[b] Mem. Geol. Surv. Vict., No. 1, 1903, p. 42.

[c] Kitson, Victorian Year Book, 1905, p. 519.

Gippsland.—Gippsland, in the south-eastern region of Victoria, contains several mining districts, the most prominent of which are Walhalla (Long Tunnel); Jericho (New Loch Fyne, &c.); Bulumwaal or Boggy Creek; and Omeo. In the Walhalla district the reefs are in or are associated with granitoid dykes. The main auriferous belt commences south of Walhalla and runs north-north-west through Jericho, Matlock, Wood's Point, Enoch's Point, and Jamieson. At Bulumwaal, eight miles north of Bairnsdale, gold-quartz veins are found in the intrusive granitoid rock. The Ordovician series in the Gippsland area is partly overlain by Devonian or at least Upper Palæozoic strata which carry a few gold-quartz veins of importance, but which are nowhere else in Victoria known to be auriferous. The evidence for the Devonian age of these upper beds is, however, very slender. The Ordovician rocks are there intruded by massive diorite dykes that strike and dip with the country. Walhalla is situated at the bottom of a deep ravine. Its veins were discovered in 1863, and the famous Long Tunnel Company was registered in July of that year. The reefs were very rich at the surface. The Long Tunnel has been one of the richest quartz mines in Australia. The mine was long worked from a shaft sunk from a point 575 feet within the tunnel, and the lode has been followed for a depth of 4,100 feet on the dip. To the middle of 1908 it had crushed 648,385 tons for 765,246 ounces, and had paid in dividends £1,270,200. To the end of 1898 the reef (Cohen's) on which the Long Tunnel mine is worked had, in the various mines of Walhalla, yielded 2,000,000 ounces. The adjacent Long Tunnel Extended Company, formed in 1870, and working on the same reef, has produced gold to the value of £1,530,000, and has paid in dividends £770,880. To the 2,200 feet level the Cohen's reef was associated with a diorite dyke.

The Matlock field lies in the dividing range of south-eastern Victoria and contains one well-known mine, the New Loch Fyne, working on a great diorite dyke some 300 feet wide and intersected by numerous quartz-veins. The whole of the dyke is highly pyritous and yields milling ore. To the end of 1898, the New Loch Fyne had yielded 49,889 ounces from 50,247 tons quartz, and had paid £96,200 in dividends. A number of fields of minor importance are being worked in Gippsland.

Beechworth.—The Beechworth district includes the gold-fields of Rutherglen, Chiltern, Beechworth, Yackandandah, Bethanga, Wandilgong, Harrietville, Alexandra, Gaffney's Creek, Wood's Point, and Big River. This district lies between the Murray river and the dividing range, and for the most part east of the Ovens river. Its gold is mainly derived from the great deep "leads" buried beneath Upper Tertiary basaltic flows. The principal reefing divisions within the district are at Bright, Harrietville, and Gaffney's Creek. In the last, the gold-quartz veins occur as flat "floors" in diorite dykes that run for miles through the country, their strike nearly coinciding with that of the Ordovician rocks. The dykes attain a maximum width of some 200 feet.

While no clear evidence of the relation of the goldfields of Victoria to the quartz-mica-diorite (granodiorite) masses of post-Silurian age is available from the two leading goldfields of Ballarat and Bendigo, this evidence is amply furnished by some of the minor

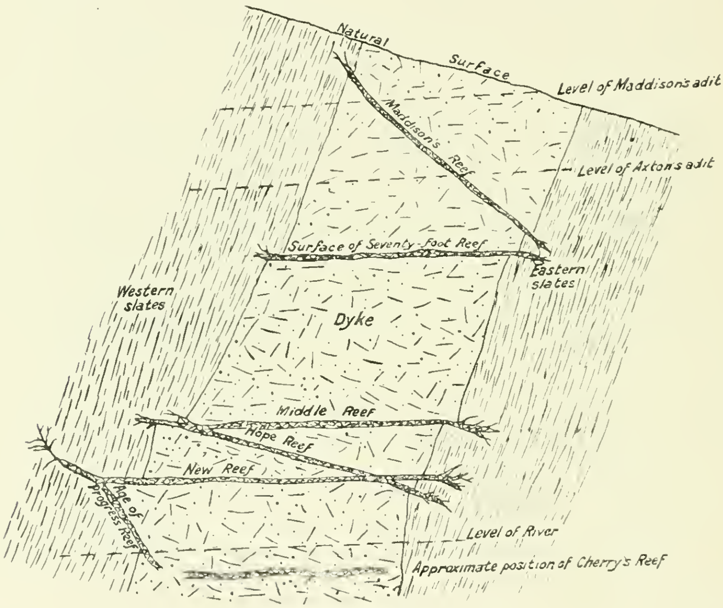


FIG. 123. AURIFEROUS QUARTZ "FLOORS" IN MORNING STAR DYKE, WOOD'S POINT (*Whitelaw*).
(Scale about 160 feet to the inch.)

fields. Of these, Wood's Point[a] is perhaps the best example. Here, Lower Ordovician rocks are intruded by various types of quartz-mica-diorites.[b] In the latter auriferous deposition has taken place, the gold occurring generally in quartz-floors in the dykes. The thickness of the floors varies directly with the width of the dykes, the wider dykes (over 50 feet) possessing the thicker floors (1 to 10 feet). Pyrite and galena ordinarily accompany the gold. In the principal dyke (the Morning Star) the richest gold is obtained near the contact of dyke and slate.

[a] Whitelaw, Mem. Geol. Surv. Vict., 1905, No. 3, p. 11.

[b] Gregory, loc. cit. sup., p. 32.

Ballarat.—Ballarat lies 70 miles west-north-west of Melbourne. Its rocks are thin-bedded unfossiliferous shales and sandstones, striking practically north and south and dipping generally to the west, though the dip is often reversed owing to faulting.[a] The nearest granitoid rocks exposed are some miles to the east of Ballarat, near Gong Gong Creek and Warrenheip. These are later

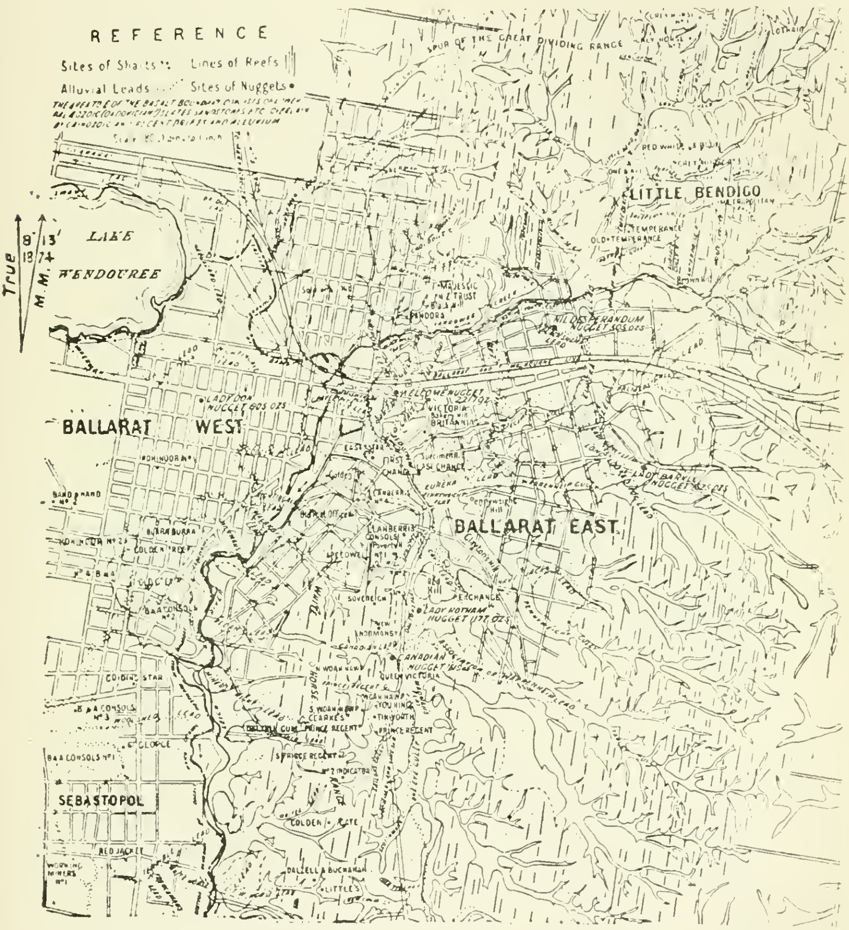


FIG. 124. SKETCH PLAN OF THE BALLARAT MINING FIELD (*Murray*).

in age than the Ordovician slates, and have metamorphosed them along the immediate contacts. Their metamorphic influence does not reach as far as Ballarat, though they may be nevertheless considered partly responsible for the great crumpling to which the sedimentary rocks of the region have been subjected. Sub-acid felsitic rocks

[a] Gregory, Mem. Geol. Surv. Vict., No. 4, 1907.

are intrusive through the Ballarat rocks, and are probably to be connected with the granitoid magma. The limburgite dykes that are intrusive at Ballarat belong to a Tertiary period of basic volcanic activity.

The quartz-mines of Ballarat occur in three distinct areas: Little Bendigo, Ballarat East, and Ballarat West. The first-named is situated to the north of the Ballarat East section. Its vein-channels strike approximately north and south. The principal is the Monte Cristo line—a band of alternating sandstone and slate, bounded by two parallel fault lines, and containing numerous transverse flat quartz-veins that pitch slightly to the south and dip east. A central band of slate is known as the Jarvis Indicator.[a]

The Ballarat West area is covered by basalt and its veins therefore do not outcrop. They were discovered by the alluvial miners who had followed the rich alluvial leads beneath the basalt. The veins have now been worked in depth to 2,300 feet. They are irregular lenticular masses with many lateral and vertical extensions.

Ballarat East furnished many of the great gold nuggets of the early 'fifties. Similar large nuggets of gold have been found in the underlying quartz-veins. One type of vein in Ballarat East is represented by almost horizontal veins that are auriferous only at or in the immediate vicinity of their contacts with certain bands of slate termed "indicators." Nuggets, are, however, occasionally found within the "indicator belt," but away from the indicator (55 feet away in the Woah Hawp mine).[b] The relation of the auriferous pockets to the indicators appears to have been realised first in 1871.

Considerable discussion has arisen as to the nature and origin of the "indicators." Rickard[c] gives the following excellent definition: "The indicator is essentially a very thin thread of black slate, which is remarkable on account of its extraordinary persistence, and also because the quartz seams which cross it are notably enriched. In places it is so impregnated with iron pyrites as to have the general appearance of a sulphide streak." The indicators have long been regarded as owing their black colour to carbonaceous material, which has further been cited as the reducing agent responsible for the precipitation of gold and sulphide. Bradford and Gregory,[d] however, regard the indicators as thin secondary seams developed along more or less vertical lines in the

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[a] Whitelaw, Rep. Dept. Mines Vict., 1901.

[b] Gregory, loc. cit., p. 12.

[c] Trans. Amer. Inst. M.E., XXX, 1900, p. 1009.

[d] Loc. cit., p. 13.

sedimentary rocks. The indicators as examined by Gregory are of three types: (*a*) thin seams of pyrites; (*b*) chloritic bands; (*c*) rutile bands (*e.g.*, the Pencil Mark). The views of Messrs. Bradford and Gregory as to the secondary origin of the indicators have not found general acceptance, and, despite their evidence, the view is still held that the indicators represent interstratified

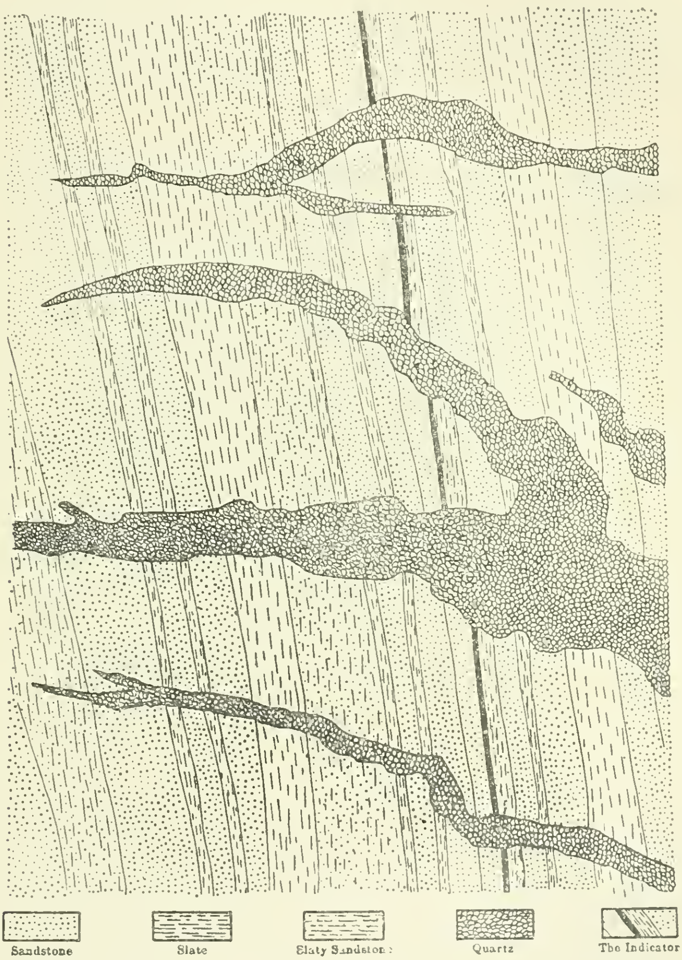

FIG. 125. VERTICAL SECTION OF THE "INDICATOR" IN THE NEW NORMANBY MINE, BALLARAT (*Rickard*).

sedimentary bands, the materials of which are partly replaced by pyrite, chlorite, and rutile, and that before, during, and after the formation of the quartz veins, the indicators were faulted and disturbed in common with the country. The various eccentricities displayed by the indicators are probably all to be explained on the latter assumption. Under the hypothesis of secondary origin, it is exceedingly difficult to account for the lack of fault-phenomena on the indicator walls. The typical indicator mines are grouped in the southern portion of the field. On them the earliest gold-mining was commenced in 1854.

To the east of the "Indicator" proper are similar dark bands that have exercised a like effect on auriferous solutions. They are the "Eastern Indicator," "Black Seam," and "Pencil Mark." To the west are the "Telegraph" and the "Western Indicator." Bradford[a] asserts that if rich gold is met with at any

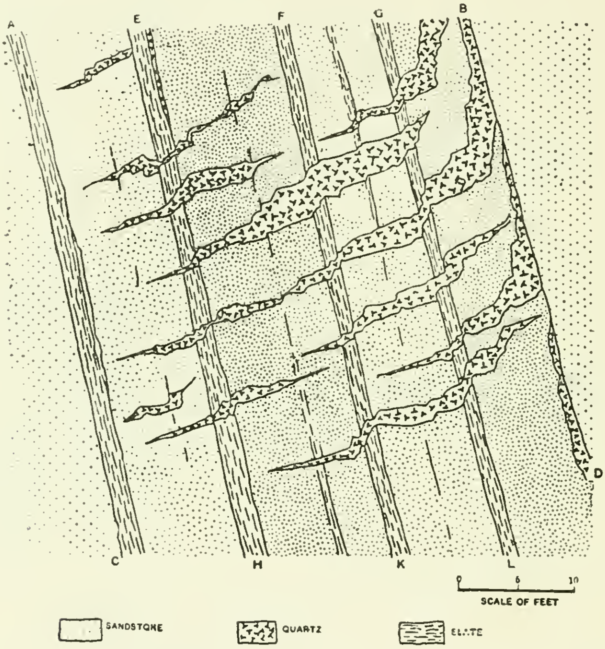

FIG. 126. VERTICAL SECTION OF THE METROPOLITAN LODE, BALLARAT (*Rickard*).

given level on one indicator there is then no likelihood of gold occurring at the same level in the eastern or western indicators. In the northern part of the field the mines are working quartz-lodes developed along fault planes. The greatest enrichment has taken place along a strike fault, indicated by a clay seam resulting from fault-crushing, and known as the "Leather Jacket."

The gangue of the Ballarat veins is ordinarily a white quartz, which is rarely laminated. Much of it may be of metasomatic origin. In the fault fissures the gangue is often a brecciated country rock with quartz and calcite and gold, galena, blende, arsenopyrite,

[a] Aust. Min. Stand., June 1, 1899, p. 20.

and pyrite. Another gangue material is a mixture of calcite, dolomite chlorite and sericite. The average fineness of the gold is about 974.[a]

As an instance of the extraordinary richness of the Ballarat alluvials it is stated that more than £40,000,000 gold was obtained from its older leads between the years 1851-1868.

Bendigo (Sandhurst).—The goldfield of Bendigo, 100 miles north-west of Melbourne, lies in a region of low hills. Placer gold was discovered in 1851, and was the only source of gold until 1854, when the gold-quartz veins were opened up. The greatest yield from Bendigo was in 1853, when 661,729 ounces worth £2,646,800

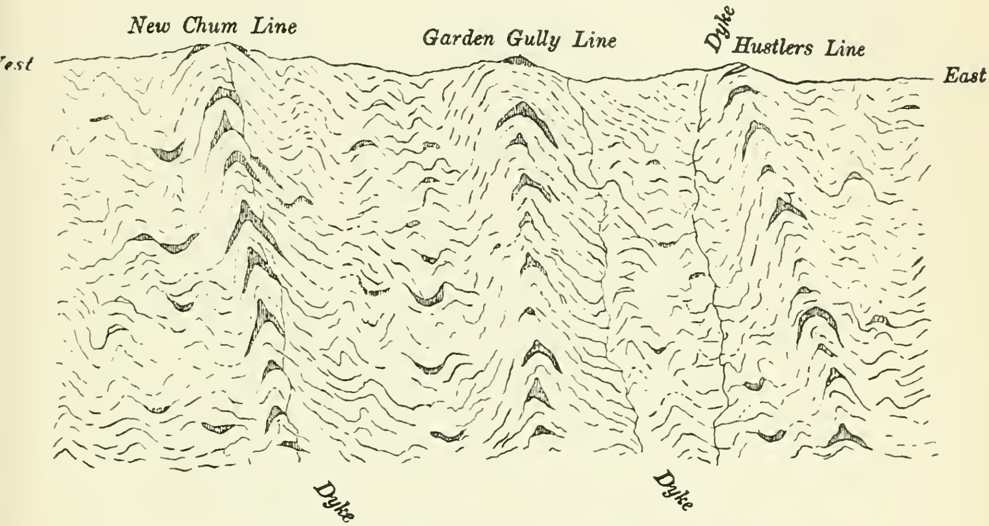

FIG. 127. IDEAL SECTION SHOWING MAIN LINES OF REEF, BENDIGO (*Rickard*).

were obtained, all, of course, from the placer deposits. Anticlinal axes in the Ordovician strata are here very prominent, and it is along these that the famous "saddle reefs" have been developed. Numerous bedded veins of quartz have been formed in the saddles, and also in the inverted saddles, though the latter are of little economic importance. The former follow the crests of the anticlines for long distances, and are thickest at the crests, pinching out in depth along the "legs" on either side. The general strike of the anticlines is north-north-west and south-south-east. The veins lie along and between beds of slate and sandstone. Eleven such parallel lines of saddle reefs have been distinguished. Of these, three have been worked on an extensive scale, viz., New Chum, Garden Gully, and Hustler's. The first has been traced

[a] Lidgey, Rep. Dep. Mines, Vict., 1894; Don., Trans. Amer. Inst. M.E., XXVII, 1897, p. 57.

for a distance of 14 miles, the second for 7 miles, and the third for 5 miles. The greatest depth to which the New Chum line had been worked was, at the end of 1907, some 4,343 feet. At this depth the incoming water was very hot, and it was found necessary to cease mining operations at the bottom of the winze that had attained this depth until the water and adjacent rock had cooled.[a] The anticlines undulate considerably in longitudinal direction, so that their pitch is sometimes to the north and sometimes to the south, often indeed as steeply as 20°. The anticlinal axial planes are not

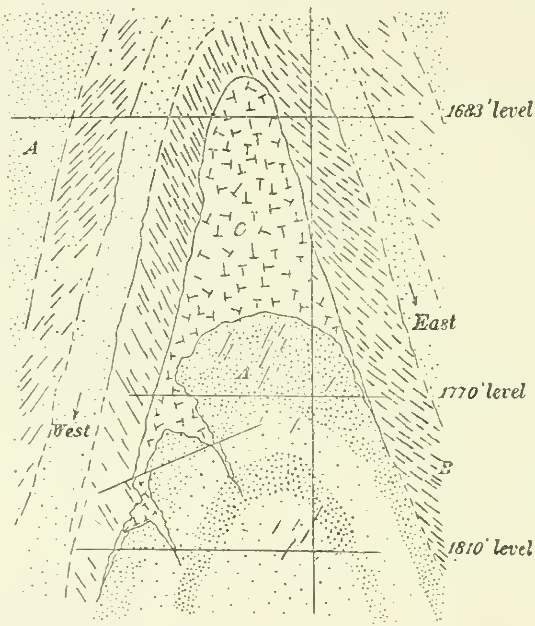

Fig. 128. True Saddle Reef, New Chum Consolidated Mine. Bendigo (*Rickard*).
A. "Centre-country" of sandstone. *B*. Slate. *C*. Quartz.

truly vertical, but dip slightly to the east. The saddle reefs underlie each other at varying distances up to 300 feet or more. Structures simulating saddle reefs have been found, and are generally due to cross-fissuring. In working the saddles, prospecting for lower saddles is effected by sinking shafts designed to strike a "leg" of an underlying saddle, from whence stopes are carried up to the crest of the anticline. The inverted saddles are both poorer and smaller than the true saddles. The "legs" generally thin away to a single thread, but sometimes branch off, forming a number

[a] Min. Jour., Feb. 29, 1908.

of threads. Occasionally the crest of the anticline is continued upwards along a fault line induced by tension along the anticlinal axial plane. The gangue is ordinarily white banded quartz containing occasional horses of country. The distribution of the gold is irregular. The largest and richest body of ore yet uncovered was found at a depth of 600 to 700 feet on the Garden Gully line. The gold is generally finely divided, but is sometimes clearly visible. Pyrite, blende, and galena generally accompany the fine gold. Fissure veins and other normal vein types are also found at Bendigo as well as saddle reefs, and in many cases have proved profitable.

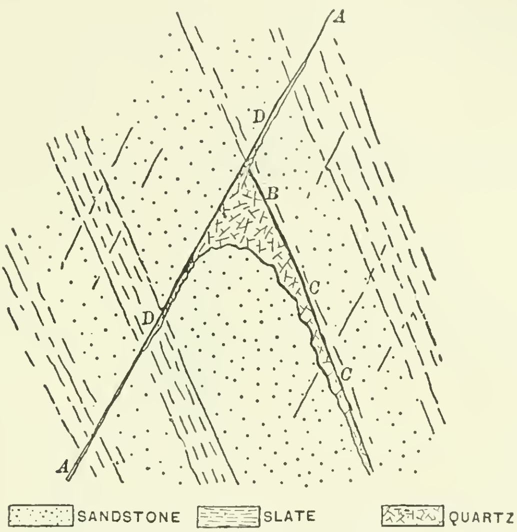

Fig. 129. False Saddle Reef, Bendigo (*Rickard*).

The most productive have been the networks of veins that are locally known as "makes of spurs" or "spur formations." Monchiquite[a] dykes traverse the country.

Lindgren[b] describes the occurrence of albite in the veins of Bendigo. It occurs both intergrown with the quartz and also as well-developed prismatic crystals, projecting from the walls of the vughs in the quartz. Later crystals of calcite sit on the quartz and albite, and pyrite on all three. Similar occurrences of albite are found in the Mother Lode region and in the Alaska-Treadwell mines, and also at the Morro Velho mine of the St. John del Rey Company, Minas Geraes, Brazil.

[a] "Limburgite" of Howitt, Rep. Dep. Mines, Victoria, 1893.

[b] Econ. Geol., I, 1906, p. 163.

The nearest exposed acidic igneous rocks are the granodiorites that lie some 7 miles to the south of Bendigo.[a]

Maryborough.—Maryborough, south-west of Bendigo, is a typical Victorian alluvial camp. Its reefs are also important, and

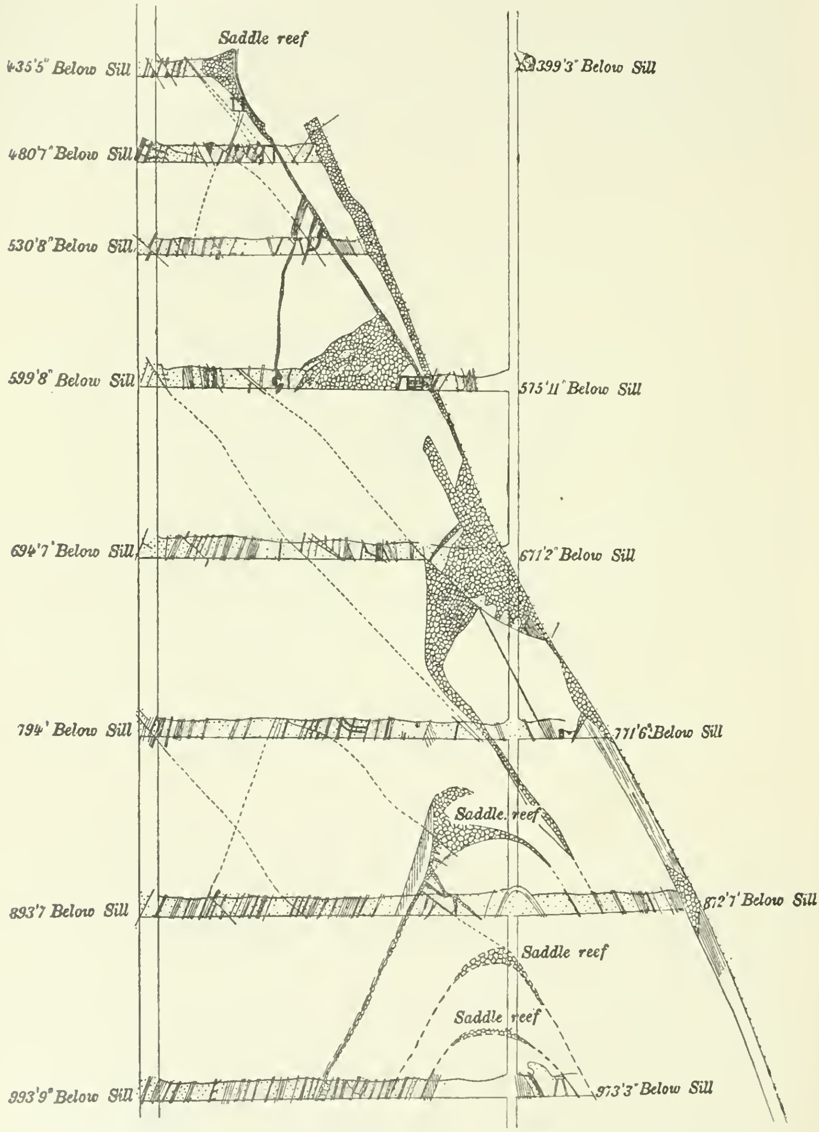

FIG. 130. CROSS-SECTION THROUGH PORTION OF LAZARUS MINE ON THE NEW CHUM LINE OF REEF, BENDIGO (*Dunn*).

[a] For detailed descriptions of Bendigo the following may be consulted: Rickard, Trans. Amer. Inst. M.E., XX, p. 463; XXI, p. 686; XXII, p. 289; Don., Ib. XXVII, 1898, p. 566; Dunn, Rep. Dept. Mines, Victoria, 1893.

in the early days of the field gave enormous returns from short outcrop shoots.

Tarnagulla, the scene of the Poseidon rush of 1906 and of its nuggets, carried the famous Poverty reef, 25½ feet of which along the strike yielded a ton of gold. The reef was here some 20 feet thick for a depth of 60 feet, and often reached tenors of 50 ounces per ton. The Poverty reef is believed to have yielded gold of a total value of at least £1,340,000. It was in these and in the neighbouring Kingower, Moliagul, and Dunolly diggings that the largest Victorian nuggets were found.

Avoca, St. Arnaud, and Amherst in the Maryborough division are placer camps of minor importance. In the Castlemaine division, south of Bendigo, the principal field is Maldon (Tarrangower). The rocks are Ordovician schists and quartzites intruded by granitic and basic intrusions, the latter (limburgite) having no appreciable effect on the primary ore-deposition. The granitic intrusions, on the other hand, are of importance, since auriferous reefs occur on each wall of a granite dyke. The granite is mainly felspar and quartz with subordinate mica. The principal mine is the South German. Its reef is some 10 feet in width and is highly pyritous, containing pyrite, arsenopyrite, chalcopyrite, and stibnite. The gold is very fine. Maldonite, or bismuth-gold, has been found here.

The Castlemaine field is described by Baragwanath.[a] It lies 22 miles south of Bendigo. The discovery of gold was made in 1851, the outcrop stone proving very rich. The rocks of the district are Lower Ordovician, the horizon being determined by the numerous graptolite remains.[b] The rocks vary in thickness from fine-grained shales to grits. They are intruded by granodiorite and are metamorphosed for a distance of some 70 feet from the contact. For a further distance of 440 yards from the granite, intrusive veinlets or apophyses intersect the strata in various directions. The most noticeable feature in the Ordovician strata is the rapid succession of meridional anticlinal and synclinal folds across the field. The quartz occurrences, as on many Victorian Ordovician fields, are to be grouped as follows :—

(*a*) Fissure reefs, occupying and completely filling well-defined fissures.

(*b*) Saddle reefs, as at Bendigo.

(*c*) Fault reefs, irregularly deposited along fault planes.

(*d*) "Spurs," deposited in irregular crevices in the strata.

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[a] Mem. Geol. Surv. Victoria, No. 2, 1903.

[b] Hall, Geol. Mag., VI, 1899, p. 438.

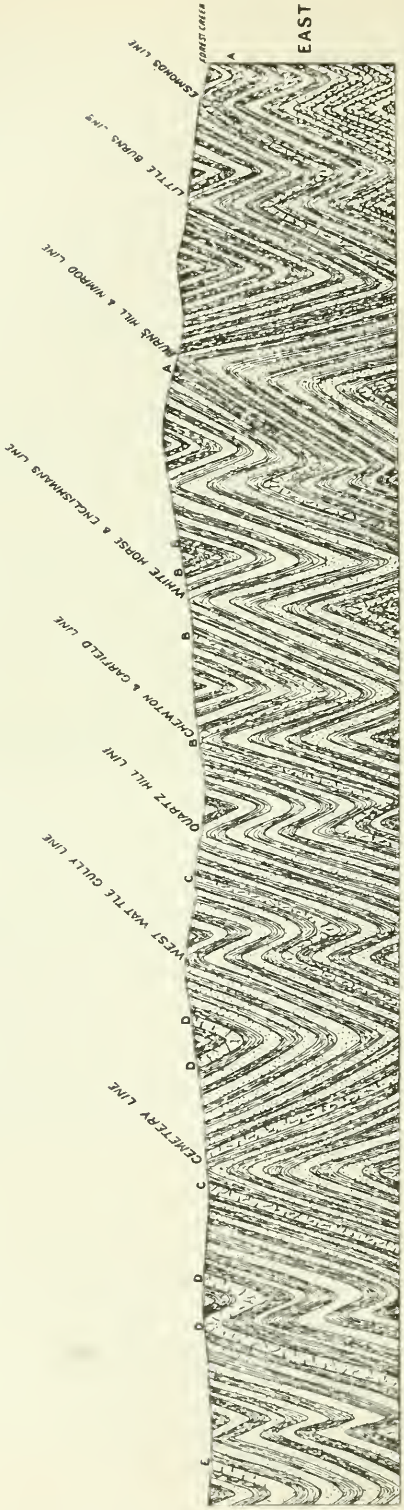
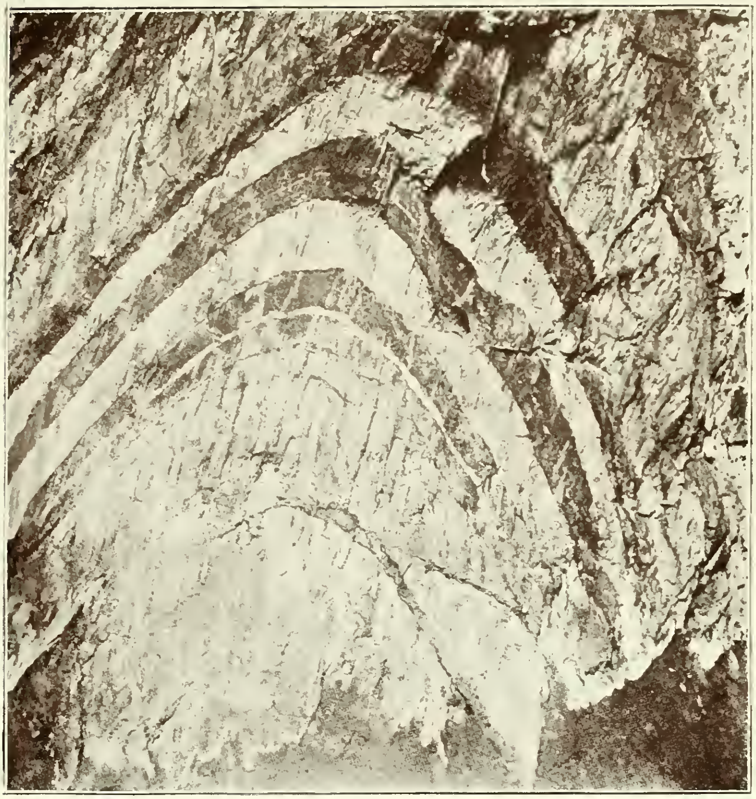


Fig. 131. Section of Eastern Portion of Castlemaine Goldfield, Victoria (*Baragwanath*).



Anticlinal Fold, Nimrod Line, Castlemaine.
(Geological Survey of Victoria.)

Arltunga Goldfield, MacDonnell Ranges, Central Australia.

Although the limburgite dykes are Tertiary and the majority of the quartz reefs are much older there are, nevertheless, important instances of payable quartz having been deposited since the basic Tertiary intrusions. Yields as high as 30 ounces per ton were obtained in quartz-veins in a dyke of this nature.[a] Where the dykes intersect auriferous veins they do not, however, appear to cause any perceptible enrichment.

Though gold generally occurs in quartz at Castlemaine it may also be found in clean slate and in sandstone, usually occurring as shots or "nuggets," the latter weighing as much as 3 or 4 ounces. Associated with the gold are small quantities of pyrite, arsenopyrite, blende, and galena.

Ararat.—The Ararat division lies towards the western desert region of the State and on the western end of the main Victorian dividing range. The Ordovician rocks are folded meridionally as elsewhere in Victoria and are intruded by granitic rocks, some of which contain gold-quartz veins that were worked at a profit until the veins passed in depth (200 feet) into undecomposed granite.

The principal field in the Ararat division is Stawell, where are situated some of the deepest workings in Victoria. The Magdala-cum-Moonlight and Oriental mines are the most prominent. Their general geological characters resemble those of the eastern fields.

Alluvial.—The alluvial deposits of Victoria are divided, without, of course, any very sharp divisional line, into the shallow deposits in the course of the present water-channels, and the so-called "deep leads" that form the beds of ancient rivers, and that have since been covered by accumulations of drift or by volcanic lava-flows.

The gold of the shallow placer deposits of Victoria was nearly all exhausted within the first 20 years of gold-digging. Nevertheless, from time to time, small areas that have escaped the shovel and pan of the older generation of diggers are brought to light. The chief of these in recent years has been the Poseidon, aptly named, though certainly so by chance.[b] It is situated near Tarnagulla, a famous camp in the 'fifties. A small "rush" to this field took place towards the end of 1906, and numerous nuggets were unearthed. The largest was found on December 18th, 1906, and weighed 953 ounces gross (703 ounces fine) and was sold for £2,878. 16s. 6d. Other nuggets of 675, 502, and 387 ounces

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[a] Baragwanath, loc. cit., p. 14.

[b] Poseidon was the grandfather of Argo, the leader of the expedition to Colchis in search of the Golden Fleece.

respectively have since been found, and within a distance of 84 feet no less than 3,000 ounces gold, all in large nuggets, were obtained. All lay in the soil and clay and within a foot of the surface.

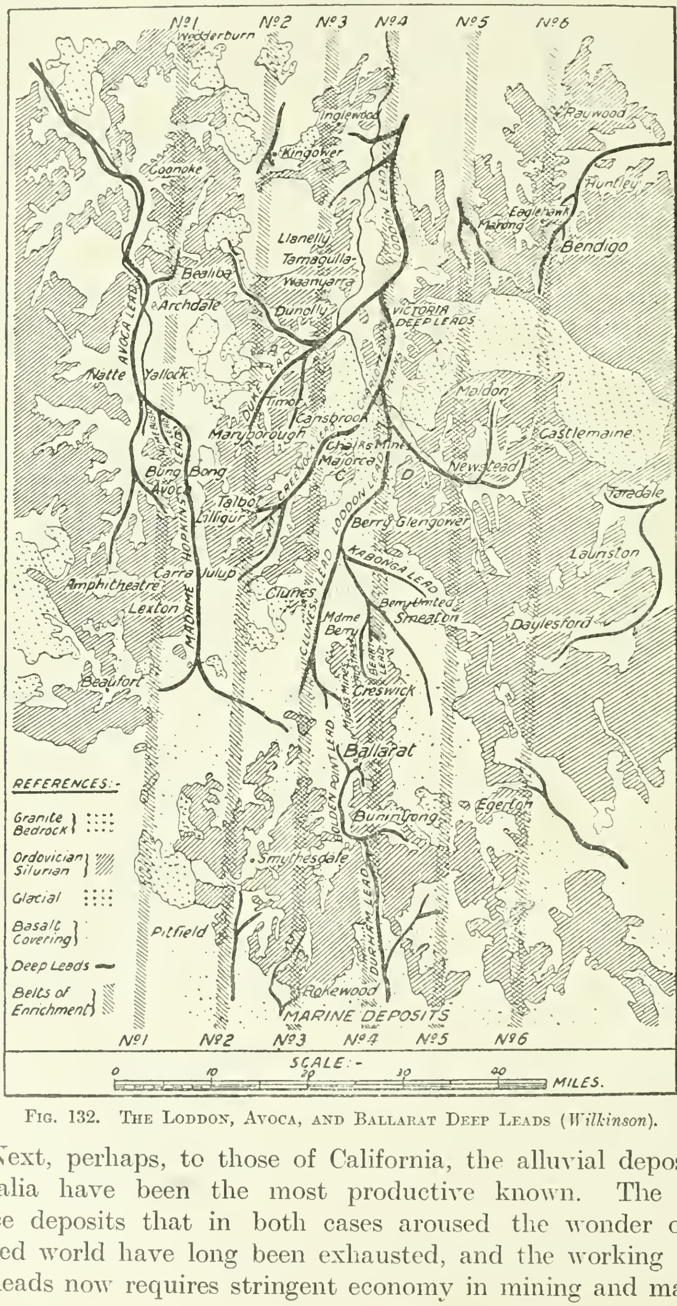

FIG. 132. THE LODDON, AVOCA, AND BALLARAT DEEP LEADS (*Wilkinson*).

Next, perhaps, to those of California, the alluvial deposits of Australia have been the most productive known. The richer surface deposits that in both cases aroused the wonder of the civilised world have long been exhausted, and the working of the deep leads now requires stringent economy in mining and management, for it is necessary in most cases to follow the buried channels beneath great depths of later alluvium, or of alluvium and basaltic lava-flows.[a]

The oldest rocks forming the bedrock of the gravels are Ordovician and Silurian shales and sandstones, in places intruded by granodiorite and granite. The Victorian area has for long been a land surface in which deep valleys existed at least as early as Middle Pliocene times and possibly earlier still. In later times, owing to the regional depression and the lessening of the grade of the rivers due to tilting accompanying secular movements, the older gravels were covered by silts and clays. Many of the Tertiary valleys were filled and their direction hidden by great basaltic lava-flows that range in thickness up to 400 feet. It appears that there were two widely-separated periods of basaltic eruption, and the basaltic flows that fill many of the buried valleys of Gippsland are believed to be older than those of Western Victoria. There also appear to have been three or four periods of temporary cessation of volcanic activity, when sedimentation was resumed, since there are, between the flows, bands of alluvium of varying thickness.

The auriferous zones within the Ordovician rocks of Victoria are disposed meridionally, and "deep leads" directly derived from the denudation of these zones are naturally richer than those whose channels ran along the broader intermediate barren zones. Within the zones themselves there are also areas of special enrichment that have formed by their denudation the most notable placer fields of the State. Where tributary "leads" cross the belts of enrichment they also are notably more productive. Wilkinson, to whom we owe the most recent and one of the best descriptions of these interesting deposits, concludes[b] that it is only where the fine gold transported from a distance has been supplemented by the local gold derived from gold-quartz veins lying in areas or belts of enrichment, that the deep leads may be profitably worked. Very often the enrichment due to local gold-quartz veins is, in leads of low gradient, confined to within a few hundred feet downstream from the vein. Several of the deep leads have been traced for a distance of 50 to 60 miles. The auriferous gravel or "wash" as a rule consists of sand with water-worn quartz pebbles of an average diameter of perhaps 3 inches, but which may nevertheless reach 3 feet in diameter. The thickness of the wash varies considerably with the character of the bedrock and with the original grade of the old river channel. Its average thickness is 3 feet, but it may reach 12 feet.

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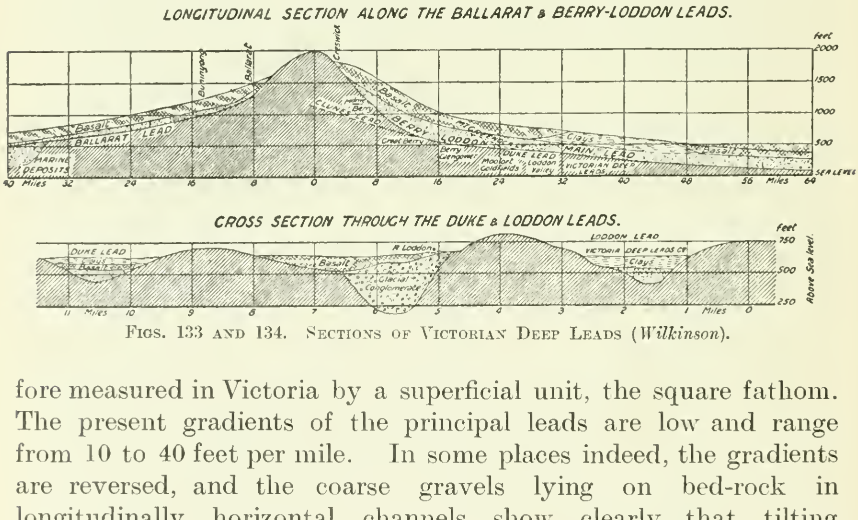
[a] Lindgren, Mining Mag., II, 1905, p. 33.

[b] Wilkinson, H. L., Trans. Inst. Min. and Met., 1907, p. 9.

From various causes, of which a normal decrease in the velocity of many streams below their junction with other streams is the principal, the richness of deep-lead gravels is generally greater below the junction of the old streams than in either of the tributary channels. The Ordovician slates are noticeably more effective in retaining gold than the sandstones of the same series, since the latter wear smooth and the former to natural riffles.

The principal deep-lead systems of Victoria are the Stawell, Avoca, Loddon, Campaspe, Goulburn, Ovens, and Murray, all in old channels in which the streams flowed north towards the site of the present valley of the Murray, and probably to a then existing similar river system, or possibly to an inland sea. The Pitfield, Ballarat, and Dargo leads are the chief of those lying in the old channels possessing a southward course. Most of the gold lies either on bed-rock or in some 2 or 3 feet of gravel above bed-rock. This portion alone is worth working. The amount extracted is there-



FIGS. 133 AND 134. SECTIONS OF VICTORIAN DEEP LEADS (*Wilkinson*).

fore measured in Victoria by a superficial unit, the square fathom. The present gradients of the principal leads are low and range from 10 to 40 feet per mile. In some places indeed, the gradients are reversed, and the coarse gravels lying on bed-rock in longitudinally horizontal channels show clearly that tilting has occurred since the deposition of these gravels. By far the richest and most extensive ancient placer channel is the great Loddon Lead system with its various tributaries, of which the Madam Berry Lead, near Creswick, has been the richest. In the Madam Berry mine, on that lead, an area of wash 5,800 feet long and 450 feet wide yielded more than £1,500,000. The extraordinary local richness of this lead is due to the enriching effect of a series of quartz-reefs, each in itself perhaps unpayable, over which the old stream has flowed. Except in Gippsland and near Daylesford the leads are rarely sufficiently elevated to be worked level free. The most important deep lead in the north-eastern portion of the State is the Chiltern-Rutherglen, which has been worked from beneath the Chiltern Hills for 25 miles towards the Murray River. It is probably continued beneath that river into New South Wales.

According to Wilkinson,[a] the factors determining the quantity of alluvial gold in the wash are :—

(1) The disposition of the auriferous zones of Victoria.

(2) The position of the belts of enrichment on the various auriferous zones.

(3) The longitudinal gradient of the lead bed.

(4) The cross profile of the lead channel.

(5) The variations in width of wash and consequent variations in value.

(6) The junction of two leads.

(7) The capacity of the bed-rocks for arresting and retaining particles of gold.

The deep leads are worked by sinking shafts to bed-rock in the deepest part of the channel, and driving levels within the bed-rock from the bottom of the shafts. From the levels the overlying gravels are reached by a series of rises or raises.

Numerous dredging companies have been formed to work the shallower placers. Some of these, especially in the neighbourhood of Beechworth, have been very successful. The largest (the Eldorado, Beechworth) obtained in 1907 gold to the amount of 3,492 ounces, together with 39 tons tin-ore.

The total quantity of gravel treated in Victoria in 1906 by bucket-dredging, pump-sluicing, and jet-elevating, was 17,307,277 cubic yards, which yielded 85,271 ounces gold, or an average yield of 2·36 grains per cubic yard. Of the value recovered £45,629 was paid in dividends.

During the present century gold to the following amount and value has been obtained from Victoria :—

Year.	Crude Ounces.	Value.
1901	789.562	£3.102.753
1902	777,738	3,062,028
1903	822,424	3,259,482
1904	821,017	3,252,045
1905	810,050	3,173,744
1906	834,775	3,280,478
1907	695,576*	2,981,855

* Fine ounces, returns of crude ounces not being available.

[a] Loc. cit., p. 7.

The total yield of Victoria from 1851 to 1907 inclusive has been 65,792,063 fine ounces worth £279,498,833.

TASMANIA.

The geology of the older rocks of Tasmania presents no essential difference from that of similar strata in Victoria, save that the Archæan and pre-Cambrian rocks are developed in Tasmania to a relatively much greater extent than on the mainland. These fundamental rocks are highly crystalline quartzites and hornblende-mica-schists, that form an extensive belt down the west coast of the island. They contain no auriferous deposits of importance. The auriferous rocks, *par excellence*, of Tasmania are, as in Victoria, the Ordovician sedimentary rocks. Through these strata is intrusive the granitic core of the Australian Cordillera,[a] which is certainly younger than Silurian, and is possibly, though the evidence on this point is not conclusive, younger even than Permo-Carboniferous. At the Lisle and Golconda fields auriferous veins traverse the granite. The further evidence available goes to show that the period of auriferous ore-deposition was certainly not subsequent to the Permo-Carboniferous, and that there is therefore no possible genetic connection between the ore-deposits and the great Mesozoic diabase eruptions of Tasmania. According to Waller[b] the auriferous copper-schists of Mount Lyell are undoubtedly due to the intrusion of the granite into Lower Silurian rocks. It will thus be apparent that the general relations of Tasmanian auriferous occurrences resemble very closely those of the already-described goldfields of the Eastern Cordilleras of Australia.

The principal goldfields of Tasmania are Beaconsfield, Lefroy, Mathinna, and Mount Lyell. The first three are closely related geologically and lie in the not greatly altered Lower Silurian or Ordovician sedimentary rocks of the north-east of the island.

The first payable gold was found in Tasmania in 1852, at the Nook, near Fingal, where the first gold-quartz mine was also opened up some seven years later. The entire production of gold prior to 1867 was only 843 ounces, while that from 1866 to 1907 has been about

[a] Twelvetrees, Trans. Aust. Inst. M.E., V, 1898, p. 105; Montgomery, Ib. III, 1895, p. 204.

[b] Rep. Aust. Ass. Adv. Sci., 1904, X, p. 629.

1,700,000 crude ounces, worth £6,538,252. The more recent returns are as follows :—

Year.	Fine Ounces.	Value, Sterling.
1901	69,491	£295,176
1902	70,996	301,573
1903	59,891	254,403
1904	65,921	280,015
1905	73,541	312,380
1906	60,023	254,963
1907	65,354	277,607

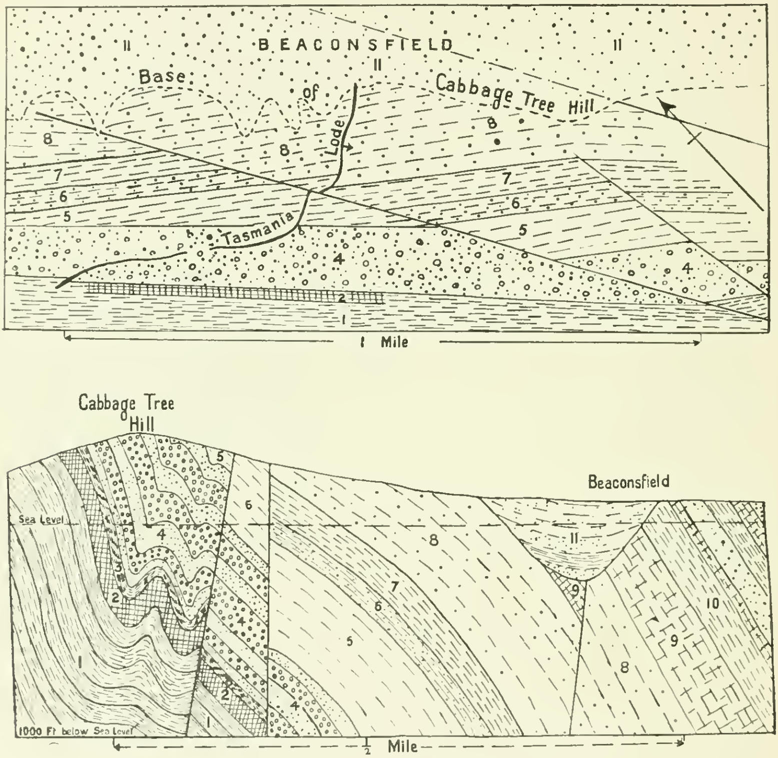
Beaconsfield.—The Beaconsfield goldfield contains a single mine—the Tasmania—which is situated on the west side of the Tamar river, and about three miles from deep water. The reef was found in 1877 as a gossan, from 1½ to 4 feet in width, outcropping at the crest of a long ridge (Cabbage Tree Hill) that overlooks the low-lying ground of the West Arm branch of the Tamar river.

The Lower Silurian sedimentary series in which the reef occurs is made up of sandstones, grits, conglomerates, shales, and limestones, conformably bedded, striking north-west and south-east and dipping north-east at 65°. The lower slopes of the ancient ridge on which the vein outcrops, are now hidden by the alluvial deposits of the West Arm, a drowned Tertiary valley. The old deep gravels of this valley carried rich alluvial gold where they were deposited immediately below the Tasmania vein-outcrop.

The Tasmania reef strikes about north-east and south-west, almost indeed at right angles to the strike of the strata, and underlies to the south-east at 1 in 2½ to 1 in 3. It obviously fills a fault-fissure, since the beds are vertically displaced on either side of the course of the vein. Fossils of a species of *Orthis* were obtained in the workings, indicating the general Lower Silurian age of the country. The reef is from 2 to 25 feet in width and averages perhaps from 6 to 8 feet. At the present time its tenor ranges from 9 dwts. to 63 ounces per ton. The average tenor, as deduced from the ore crushed, has been 25 dwts. per ton. "Horses" are of frequent occurrence in the lode. The oxidised zone descended to a depth of 400 feet. In the lower levels the gold is associated with pyrite, chalcopyrite, and blende. Siderite is common. Shoots in this mine are not particularly well marked, and, despite the former belief to the contrary, the varying nature of the country walls has apparently not exercised a great deal of effect on local vein enrichment.[a] The Tasmania pumping plant is probably the most powerful employed at any gold mine ; its use is necessitated by

[a] Montgomery, Rep. Parl. Papers, Tasmania, XXIV, 1891.

the fact that the mine, owing to the dip and nature of the strata and the disposition of the watercourses, drains the country over a wide area. At times the pumps have had to deal with quantities of 8,100,000 gallons of water per day. In June, 1906, the subsidence of a limestone cave, 1¼ miles from the workings, led to the flooding of the lower levels. The Tasmania shafts had attained in 1908 a depth of 1,250 feet. The reef above the 715-foot level had then been completely blocked out.



FIGS. 135 AND 136. PLAN AND SECTION OF COUNTRY IN THE NEIGHBOURHOOD OF THE TASMANIA LODE, BEACONSFIELD (*Montgomery*).

1. Blue slate. 2. Black shining slate. 3. Soft slate. 4. Light and dark grits and conglomerates. 5. Black sandstone. 6. White sandstone. 7. Dark blue sandstone. 8. Light sandstones. 9. Limestone. 10. Slate.

The Tasmania reef is almost anomalous among gold-quartz veins, inasmuch as it shows no dependence, direct or indirect, on intrusive igneous rocks. The nearest known igneous rocks are the peculiar white binary quartz-felspar granite and the biotite-granite of Anderson's Creek, some three miles west of the mines. Both granites are decidedly aplitic in appearance.[a]

[a] Twelvetrees, Rep. Aust. Assoc. Adv. Sci., X, 1904, p. 211.

To the end of 1907 the Tasmania mine had produced 695,158 ounces gold from 686,735 tons quartz, and had distributed to its shareholders to the end of the year 1905, £772,672 in dividends. Since that date the profits made on working have been absorbed by large capital expenditure.

Lefroy.—The Lefroy district is seven miles east of the Tamar, and 28 miles north of Launceston. Its country is slate and sandstone of probable Lower Silurian age. The strata have been greatly folded and dip irregularly. In the vicinity of the veins, however, the dip is only from 15° to 30°.[a] The general strike of the strata, as at Beaconsfield, on the other side of the Tamar, is north-west and south-east. Unlike Beaconsfield, where there is no visible occurrence of igneous rock in the immediate vicinity of the mine, Lefroy shows granite in the south-west of the field.

Slow subsidence of north-eastern Tasmania in Tertiary times has filled with alluvial deposits the old valleys at Lefroy, as at Beaconsfield. A little alluvial gold has from time to time been found in the deep leads so formed.

The auriferous veins lie in a long lenticular area of soft country, that strikes north-west with the Lower Silurian strata. The auriferous lodes strike east and west and, as is general in a schistose or slaty country, are disposed *en echelon*. The lodes occupy fault-fissures in the country, and movements appear to have taken place in the fissure subsequent to the first deposition of auriferous quartz, brecciating the walls and the already deposited quartz. The lode-channels are often 50 to 100 feet wide, with intervening, and sometimes brecciated "horses." The gangue is quartz, and the gold is associated with pyrite, chalcopyrite, arsenopyrite, and stibnite, the last being considered a particularly favourable indicator for gold, especially in the mines closest to the granite. The gold is distributed in more or less regular shoots. The rich shoots of the Lefroy field have invariably pinched out at 350 to 400 feet, and although gold has been obtained at greater depths of 800 and 1,100 feet, the quartz has been low grade. The general course of the payable reefs is N. 75° E., with an underlay south from 3° to 46°.[b]

Mathinna.—Mathinna[c] lies some 40 miles east of Launceston and 1,000 feet above sea-level. The auriferous series is clay, slate, graphitic slate, quartzite, sandstone, and argillaceous sandstone. The main-fissure lines in the Golden Gate zone strike nearly

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[a] Montgomery, Rep. Govt. Geol. Tas., 1897, p. 111.

[b] Jolly, Trans. Aust. Inst. M.E., IV, 1897, p. 132; Sandeman, Trans. N. Eng. Inst. M.E., XLIX, 1900, p. 28.

[c] Twelvetrees, Rep. Mines Dep., Tasmania, 1906, p. 1.

north and south. Twelvetrees notes that in the New Golden Gate mine, a reef is auriferous when its course is a little east of north, but barren when to the west of north. An anticlinal axis runs north-north-west and south-south-east through the field, and is believed to bear an important relation to the lode fissures, which suggest to a certain degree saddle-reef development, though the legs certainly do not dip exactly with the country on both sides of the crest. The vein-matrix is quartz, with pyrite and arsenopyrite. A connection is traced by Twelvetrees with the granites that are exposed 10 miles to the north-east of Mathinna, where the reefs in the granite carry gold: "The few observations that I have been able to make in various parts of the State (Tasmania) would tend to support the supposition that the origin of our gold-quartz is mainly granitic, and that the formation of the reef is essentially associated with tectonic disturbance of the stratified rocks." The values on the Mathinna field are mainly in the sulphides, samples of which from the 1,600-foot level of the New Golden Gate have yielded as much as 80 ounces of gold per ton. The sulphides are pyrite, arsenopyrite, galena, chalcopyrite, and blende. Galena and blende are locally considered the most favourable indicators. Blende is, however, absent from the lower levels. Secondary outcrop enrichment of the normal type has taken place on this field, much of the outcrop stone yielding from 3 to 11 ounces per ton. The deepest shaft at Mathinna in 1908 had reached 1,900 feet. At this depth quartz assaying 24 dwts. per ton was met with. The gold in the upper levels was always of greater fineness than that from depth; for example, the alluvial gold was 953·5 fine; from the surface to the 360-foot level, the vein-gold was 955 to 900·5 fine; and at the 1,100 and 1,200 foot levels only 925·5 to 850 fine.

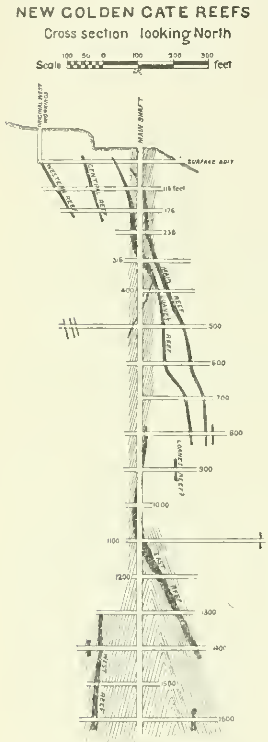

Fig. 137. Section through New Golden Gate Mine, Mathinna (*Twelvetrees*).

The auriferous quartz-veins of Mathinna do not occur, as do true saddle reefs, in the crests and troughs of the folds. They are confined, as at Lefroy, to broad zones of fissured country. The Golden Gate zone is 600 to 1,000 feet wide. The New Golden Gate mine, Mathinna, to the end of 1906 had produced 222,755 ounces gold from 267,140 tons quartz worth £847,075, and had paid in dividends £355,200 on a share capital of £9,600. The main shaft is sunk to a depth of 1,620 feet.

Mount Lyell.—Mount Lyell is one of the famous copper mines of the world. The district was discovered to be payably auriferous in 1883, when a rich quartz outcrop was found, from which a hundredweight of stone yielded to the discoverer £831 gold. This was, however, not the outcrop of the Mount Lyell mine

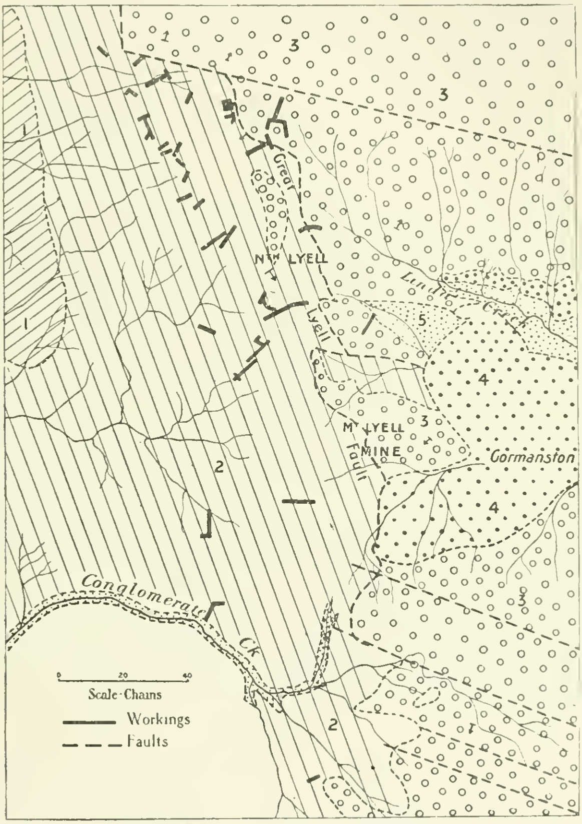

Fig. 138. Sketch Map of Geology of Mount Lyell (*Gregory*).
1. Queen River porphyry. 2. Mount Lyell schists. 3. Devonian conglomerates. 4. Glacial deposits. 5. Alluvium.

itself, since that mine was not discovered until 1886, and then the alluvial shoadings alone were worked. In 1893, the present Mount Lyell Company was formed, the smelters commencing work in 1896.

The rocks of Mount Lyell are considered by Gregory[a] to be margarodite-schists and chlorite-schists derived from porphyrite

[a] Trans. Aust. Inst. M.E., 1905, X, p. 67.

or porphyrite-tuffs ; these are associated with schistose quartz-porphyries and schistose volcanic tuffs, of pre-Silurian (?) age. Diabase-porphyrites and diabase dykes are intrusive into the series. The series is apparently associated with undoubted Silurian sandstones and limestones and with conglomerates of probable Devonian age. The rocks of the field are greatly faulted. The ore-deposits comprise mineralised bands of schist (fahlbands) and lens-shaped masses of very pure sulphide ores. The minerals are chiefly pyrite and fahlore, with chalcopyrite and bornite. The first two indicate high grade, but are erratic in distribution. A range of assays yielded the following averages :—

	(1)	(2)
Copper	1·54 ..	6·96 per cent.
Silver	·36 ..	·19 ozs. per ton.
Gold	·008 ..	·019 ,, ,,

The masses of sulphide ore furnish the bulk of the ore-deposit. The footwall side of the great ore-body is the richer in copper, silver, and gold. Bornite and fahlore enrichments occur within the body, and assay Cu 3·65 per cent., Ag 2·07 ounces, Au 0·02 ounces per ton.[a] Some secondary outcrop enrichment has taken place. This is a relative and not an actual enrichment, as is evident from the poverty of the "Ironstone Blow" in copper and silver. The average tenor of the ore being treated in 1907 was 2·18 per cent. copper, 1·65 ounces silver, and 94 dwts. gold per ton. About 400,000 tons ore are being treated annually for some 20,000 ounces gold. From August, 1903, to March, 1907, about 1,500,000 tons ore were mined for some 30,000 tons copper, 2,711,516 ounces silver, and 82,481 ounces gold.

Placer gold has never been of importance in Tasmania. The largest nuggets recorded were found on the Whyte river in 1883 and weighed 243 and 143 ounces respectively.

SOUTH AUSTRALIA.

The goldfields of South Australia proper are small and unimportant. They are, with one exception (Tarcoola), contained within the Cambrian and pre-Cambrian rocks of the mountain range that traverses Kangaroo Island, then swings to the north through Cape Jervis and passes through Mount Lofty to the east of Adelaide. Further north the range is prolonged to the north-east towards the famous Broken Hill silver fields, but the older rocks are here exposed only as discontinuous outcrops. Both Cambrian and pre-Cambrian strata are extensively intruded by igneous rocks. The fields near

[a] Gregory, loc. cit., p. 125.

Adelaide have in the past furnished considerable quantities of alluvial gold, but have not otherwise been of importance. For the most part they may be dismissed with the mere indication of their position. They occur on Kangaroo Island, and at Jupiter Creek, Hahndorf, Echunga, Gumeracha, Barossa, and Mount Pleasant, all from 17 to 35 miles north or north-west of Adelaide.

The Echunga field was one of the earliest known in South Australia, having been discovered in 1851, consequent on the great stimulus given to prospecting by the discovery of the rich placers of New South Wales and Victoria earlier in that year. The gold of Echunga was mainly alluvial and lay in Older Pliocene gravels on the slopes and tops of the hills, as also was the case at the Barossa and at other fields further south. Several gold veins have been worked in the neighbourhood, but have not proved profitable. At the Balhannah mine, 14 miles east-south-east of Adelaide, small nuggets of gold occur with native bismuth in a quartz-vein. The country of the vein is kaolinised slate and argillaceous sandstone of Cambrian age.

Of the numerous small fields lying toward the New South Wales frontier at Broken Hill, the Teetulpa, Wadnaminga, King's Bluff (Olary), Nillinghoo, and Mannahill are the principal. These are all well served by the Pietersburg—Broken Hill railway. They nearly all depend on placer gold, and their gold-quartz veins are but little worked. The placers of the Teetulpa field, 15 miles east of Waukaringa, were first worked in 1886. The "wash" was rich, but was very limited in extent. The largest nugget found weighed 29 ounces 15 dwts. The gravels are of Pliocene age. The total amount of placer gold obtained from this field is unknown, but it is believed that gold to the value of £300,000 was obtained.[a] The Wadnaminga field, opened two years after Teetulpa, lies in a region of Cambrian mica-slate, sandstone, clay-slate, and crystalline dolomitic limestone. The slates and flags contain large scattered boulders of granite and quartzite. The veins of Wadnaminga are small, but carry rich pockets of gold-quartz.

The outlying goldfield of Tarcoola (Long. 134° 30′ E.; Lat. 30° 31′ S.) is some 360 miles north-west of Adelaide, and 170 miles from the nearest railway station at Coward Springs. The field lies in a sand-waste, barren beyond description. It is difficult of access and its mines are consequently expensive to work. The country is an interstratified quartzite, sandstone, and siliceous slate overlying a generally mica-less granitic rock that is associated with diorite, felspar-porphyry, and hornblende granite. The sedimentary members form a low ridge about 200 feet in height. The reefs

[a] Brown, "Handbook of Mining, South Australia," 1901, p. 7.

traverse both the sedimentary rocks and the underlying granite. Diorite dykes are found and have probably exerted some influence on ore-deposition. The gold is finely divided and occurs in shoots.[a] The first alluvial gold was found in 1893, and in 1899 a "rush" of minor importance took place, the richness of the vein-outcrops furnishing the inducement. At the first crushing of the principal mine (Tarcoola Blocks) 384 tons quartz yielded at the rate of 3½ ounces per ton. From May 16th, 1901, to June 30th, 1907, this mine had crushed 26,719 tons ore for a yield of 36,086 ounces crude gold worth £112,355.

The gold returns of South Australia and of the Northern Territory have not always been separated. Their total combined yield to 1903 inclusive has been £2,573,357.

Of South Australia alone the following figures are probably as correct an approximation to the truth as is now possible :—

Year.	Ounces.	Value, Sterling.
1859–1900	....	£556,631
1901	4,918	16,613
1902	7,245	24,878
1903	8,650	23,650
1904	17,897	76,025
1905	10,983	45,853
1906	13,961	58,453

Northern Territory.—The Northern Territory has long been administered by South Australia, but was in 1908 being taken over by the Federal Government. Its principal goldfields lie along a belt that stretches for some 200 miles south-east of Port Darwin along an exposure of pre-Cambrian rocks. The principal area is that of Pine Creek, 145 miles from Port Darwin, with which it is connected by railway.

The basement rocks of the region are pre-Cambrian schists, phyllites, and quartzites. These are overlain by Cambrian limestones, containing *Olenellus*, *Agnostus*, and *Macrodiscus*. The limestones are succeeded by Ordovician (?) and Permo-Carboniferous strata. The pre-Cambrian rocks are extensively intruded, *e.g.*, at Pine Creek, by a coarse-grained granite. Diorite and gabbro dykes are also found traversing the pre-Cambrian members.[b]

The affinities of these goldfields are clearly with those of the "Auriferous Series" of Western Australia. The lodes of the Pine

[a] Brown, Rec. Mines Dept., S.A., 1902.

[b] Brown and Basedow, Rep. Govt. Geol. S.A., "Northern Territory," 1905, p. 14.

Creek district are rich but small. Those lying within the phyllites and schists are often lenticular. The mines are largely in the hands of Chinese. English companies have spent a considerable amount of capital on the gold mines of the territory, but with unfortunate results. The outcrops of the veins of the Pine Creek region have at times shown considerable enrichments. At the Extended Union mine, Union district, 30 miles north of Pine Creek, gold occurred near the surface in numerous curved laminated plates 1½ inches wide and ½-inch thick. The country of the vein is crystalline dolomite disposed in scattered masses in phyllite.[a]

The Arltunga goldfield lies in the heart of the central desert of Australia. It is therefore difficult of access, and naturally presents insuperable obstacles to cheap and efficient working. The mines are in the White Range, 70 miles north-east of Alice Springs Telegraph Station. The country is quartzite and quartzose sandstone with occasional dykes of granite and diorite. The veins occur in the quartzite. The outcrop stone is ferruginous and highly cellular, indicating abundance of pyrite in depth. Gold was discovered in 1897, and to June 30th, 1907, there had been treated 8,780 tons quartz for 10,886 ounces gold worth £40,524, or an average tenor of £4. 12s. per ton.

The earliest discovery of gold in the Northern Territory appears to have been made by a telegraph operator in 1870, but no influx of miners took place until two years later. From 1881 to 1890 the total yield was 478,840 ounces gold worth £1,639,908. The present yield is about 20,000 ounces annually.

WESTERN AUSTRALIA.

The State of Western Australia was until the last twenty years generally believed to be devoid of mineral wealth, a belief that arose rather from the inaccessibility of its interior desert country than from any actual knowledge of the geology of the State, for even at the present day there are, towards the South Australian border, wide tracts of untraversed country. The first important gold-discovery was made at Kimberley in 1882. It was followed, five years later, by that of Yilgarn, 200 miles east of Perth. The sensational finds at Coolgardie, in 1892, with which the history of gold in Western Australia may properly be said to commence, paved the way for numerous similar discoveries to the north, east, and south.

[a] Basedow, *in verb.*

The gold mines of central Western Australia are situated on a desert tableland about 1,200 to 1,400 feet above sea-level. The chief town and gold-mining centre, Kalgoorlie, is some 300 miles east of Perth. The auriferous rocks are disposed in long narrow bands, with a general meridional or north-north-westerly strike. But little is known of the boundaries of the belts, especially in their northern extensions, for natural and climatic conditions militate greatly against geological work, and the important results that have already been obtained by the Geological Survey of Western Australia are almost entirely the work of recent years, and represent an amount of labour and actual hardship inconceivable to workers in less torrid climes.

Of the areas so far examined, that of the Pilbara goldfield appears to throw the greatest light on the age and relations of the auriferous series. Gneissoid granites are believed to represent the fundamental rocks of the country. On this floor are laid the great series of rocks to which the general designation, "greenstone schists" has fitly been applied, the much-abused term, "greenstone," being here, as by Williams and others in the Lake Superior region, employed merely as a comprehensive field term. The schists of the Pilbara district have not as yet been examined microscopically, but they are undoubtedly in part identical with those of the Mount Magnet, Kalgoorlie, and other fields to the south. So far as they have been differentiated, they have been found to consist in the main of amphibolites and hornblendic schists, certainly derivative from igneous rocks. Near the younger granitic rocks the hornblende-schists are occasionally so far reconstituted as to form massive diorites.

Mica-schists, talc-schists, chloritic schists, and siderite-schists also occur in the Pilbara area, but the most remarkable rock here, as in the other auriferous areas, is the banded hæmatite-magnetite-quartz rock, identical with that noted in the Indian, Rhodesian, and Eastern Transvaal belts. Here, also, it forms narrow bands or beds 30 to 60 feet wide, running for long distances parallel to the foliation and direction of the main belts, and furnishing the saw-toothed and serrated ridges that occupy such a prominent position in a greenstone-schist landscape.

On the Kalgoorlie goldfield, where the rocks have been most closely examined, in addition to the prevailing amphibolites and hornblende-schists that carry the auriferous lodes, there also occurs a series of sedimentary rocks ranging from soft shales and sandstones to slates and quartzites. The first are often highly graphitic, containing numerous nodules and crystals of iron pyrites.

Everywhere the auriferous series is intruded by numerous, often parallel, diabasic and doleritic dykes. These are generally vertical, and, as will be seen later, they have exercised a notable effect in the formation of the younger gold deposits. In addition to the basic intrusions, there are found a great number of acidic dykes, which may be regarded as apophyses from the younger granites. These range from granites through aplites to rock, which may, in hand specimens, almost be termed vein-quartz. They appear, however, to have had no effect on auriferous deposition, and are themselves barren.

In the Pilbara district the steeply-inclined schists are overlain by a fairly horizontal series of sandstones, grits, conglomerates, and thin limestones, associated with amygdaloidal diabase and felsitic volcanic rocks, as their basal members.[a] To this series the term "Nullagine beds" has been given. The presence of the amygdaloidal diabase is noteworthy, and may afford a clue to the age of the basic intrusive dykes of the auriferous series. Again overlying the Nullagine beds, and with apparent unconformity, is the extensive deposit of limestones, which forms characteristic *mesas*, and has from the place of its greatest development, been termed the "Oakover beds." All these, in their general characters, correspond very closely with the Cuddapahs and associated Karnuls of India.

Three main forms of auriferous deposits may be distinguished in Western Australia: (*a*) "Lode formations." (*b*) Banded-hæmatite-magnetite-quartz rock. (*c*) Normal quartz veins. The first form furnishes the most important matrix of gold in the State, and is especially well developed at Kalgoorlie, Kanowna, and Peak Hill. "Lode formations" are merely zones of rock impregnated with fine gold and with tellurides of gold. They merge insensibly into barren solid rock on either side, and are probably belts of sheared and fissured rocks, through which mineral solutions, liquid or gaseous, have had free passage. They have naturally no well-defined walls, and their limits are determined solely by their assay values. The normal change produced in the hornblendic schists in these zones seems to be the development of chloritic schists.

According to Lindgren,[b] the general alteration of the country has been by metasomatic processes from an amphibole-chlorite-zoisite-albite rock to a quartz-sericite-albite-carbonate rock. He

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[a] Maitland, Bull. West Aust. Geol. Surv. No. 15.

[b] Econ. Geol., I, 1906, p. 539.

concludes that all the evidence presented by the Kalgoorlie vein-minerals points to a genesis of the veins at considerable depth.

The laminated hæmatite-quartz rocks enclose a class of ore-bodies of quite subordinate economic importance. They are developed only on the northern goldfields to any extent, notably on the Lennonville and Boogardie fields, and also on the fields to the north of Lake Austin. The quartzites themselves are, moreover, not innately auriferous, and it is only where they are crossed by basic dykes, faults, or cross-veins that they carry gold, and then for only a few feet on either side of the intersection. Since the quartzites generally range from 30 to 60 feet in width, and since the intersections are always at right angles, the shoots thus formed are extremely narrow.[a]

Quartz veins are responsible for the gold on the majority of Western Australian fields, and may fairly clearly be divided into two classes, viz., blue and white. As a general rule, the former prevails on the northern goldfields and the latter on the southern. No clear distinction as to their age has yet been made, but the white veins appear to be the younger since they cut through and mineralise many of the laminated quartzites.[b] Quartz veins nearly always occupy shearing planes parallel to the plane of foliation, and within a given zone the country may be so thoroughly traversed by them as to form a stockwork. The more massive veins are characterised by the assumption of the lenticular habit.

To these main forms of gold matrices must be added the auriferous conglomerates of the Nullagine district. These furnish a very close parallel in mode of formation to the famous "banket reefs" of the Witwatersrand. They have been described by Maitland as forming the Mosquito Creek Beds towards or at the base of the Nullagine series. They occur in lenticular masses, and contain gold both in thin white quartz veins parallel to the bedding planes, and also as grains interspersed through the matrix of the conglomerate. The veins are much richer than the conglomerates, the former averaging 2·82 ounces, the latter only 0·62 ounce per ton. Not the least characteristic feature of the southern goldfields of Western Australia, and especially of Kalgoorlie, is the occurrence of tellurides of gold and silver.

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[a] Maitland, Ann. Rep. West Aust. Geol. Surv., 1903, p. 10.

[b] Ib., 1902, p. 16.

The following table shows the gold-yield of Western Australia from 1886 to the end of 1907 :—

Year.	Crude Ounces.	Value, Sterling.
1886	302	£1,148
1887	4,873	18,517
1888	3,493	13,273
1889	15,493	58,872
1890	22,806	86,664
1891	30,311	115,182
1892	59,548	226,284
1893	110,891	421,385
1894	207,131	787,099
1895	231,513	879,748
1896	281,265	1,068,808
1897	674,993	2,564,977
1898	1,050,184	3,990,698
1899	1,643,877	6,246,733
	Fine Ounces.	
1900	1,414,311	6,007,610
1901	1,703,417	7,235,653
1902	1,871,037	7,947,662
1903	2,064,801	8,770,719
1904	1,983,230	8,424,226
1905	1,955,316	8,305,654
1906	1,794,547	7,622,749
1907	1,697,552	7,202,411
Total to end of 1907 ..	18,363,786	£77,996,071

Kimberley.—The Kimberley field is the most northerly gold-field of Western Australia. It lies on the South Australian border, and about the 18th parallel of south latitude. It was discovered in 1882 by Mr. E. T. Hardman, then Government Geologist of Western Australia, and was proclaimed in 1886. The rocks of the district are Archæan crystalline schists overlain by Cambrian, Devonian, and Carboniferous rocks. The reefs lie in the schists, and in the associated granitoid gneisses.[a] Greenstone-schists form the country of the most important auriferous reefs. The schists are vertical, or nearly so, and seem to be arranged in a series of folds, the trend of which has been modified by the faulting which has taken place subsequent to the formation of the schists. Observations seem to indicate the occurrence of a double foliation in the district.[b] The placer deposits were thin ; the reefs are irregular, small, and unpayable. This field was the scene of the disastrous Kimberley

[a] Hardman, Rep. Geol. Surv. W.A., 1885, p. 22.

[b] Maitland, Bull. Geol. Surv. W.A., No. 15 ; Id., Annual Mines Report, 1903, p. 8.

"rush" of the 'eighties. The period of greatest production was in 1887, when some 4,873 ounces were obtained. The field is now almost deserted, and its output is only a few hundred ounces annually. The total production of the Kimberley field to the end of 1906 has been 13,911·4 fine ounces from quartz, and 1,771·49 ounces fine gold from placer deposits.

Pilbara.—The oldest rocks occurring in the Pilbara area are granites and gneisses. These form the platform on which the newer formations were laid down, and everywhere underlie the deposits of the great plains extending from Port Hedland to Doolena Gorge on the Shaw River. To the gneissoid rocks succeed greenstone-schists and allied rocks, occupying an extensive area of country and appearing to be almost everywhere genetically connected with the occurrence of gold. These schists are associated with laminated, and sometimes hæmatite-bearing, quartzites. The rocks of the greenstone-schist series have as yet not been closely studied microscopically, but some of the members seem to owe their origin to the metamorphism of eruptive rocks. There are, however, associated with them, rocks of undoubted sedimentary origin.

Next in age to the greenstone-schists come the sandstones, grits, conglomerates, thin limestones, and associated volcanic rocks that are so well exposed in many parts of the district. These are grouped together as the Nullagine Beds. This formation, the actual base of which can rarely be seen, forms an important feature in the geology of Pilbara. On the strength of the lithological and structural similarity to those of the Leopold Range in Kimberley, the Nullagine Beds are assumed to be of the same age, viz., Cambrian. Above the Nullagine Beds come the sandstones, limestones, cherts, &c., that form the table-topped hills in the vicinity of the Oakover river. These do not, so far as has yet been observed, occupy any very extensive area of country, nor are they very thick. They are known as the Oakover Beds. Basic igneous rocks are intrusive into the schists, gneisses, and granites, and often form very conspicuous features in the landscape, owing principally to their black weathered summits standing out in bold relief. Wherever good sections can be seen of these dykes, they are generally vertical. They do not attain any very great width, and have nowhere been seen to pierce the Nullagine Beds.

The general direction of the auriferous belts almost everywhere coincides with the strike of the greenstone-schists, which, with few exceptions, form the country of the auriferous reefs. The width of a belt naturally varies, and in the three most northerly zones the exact width cannot be defined. The prevailing dip is that of the enclosing schists, which is generally to the southward.

Quartz reefs occur in great abundance throughout the schistose rocks, and, to a more limited extent, in the area occupied by the granitic rocks. The quartz reefs are of two distinct types, viz., white quartz reefs, and laminated quartz and jasper veins, the latter approaching very closely in character the hæmatite-bearing quartzose rocks to which allusion has already been made. It is indeed from one of these beds of laminated quartz rocks at the Coongan river that the chief camp of Marble Bar derives its name. The laminated rocks range from almost pure quartz, through banded jaspers, with crystals of magnetite, to bands appearing to the eye to be virtually pure hæmatite. Quartz reefs of what may be termed the massive type occur plentifully in both the schist and the granite areas, but it is only in the former that the laminated and iron-bearing quartz rocks have been found. The reefs nearly always occur along the planes of foliation of the schists. They cannot be said to be of great length, and as a rule are thin, though they may occasionally swell out into large lenticular masses. Shoots occur in the veins.[a]

The principal mining camps of the Pilbara field are Marble Bar and Nullagine. The greater part of the goldfield lies north of the 22nd parallel of south latitude, and east of the 119th meridian. The goldfield was proclaimed in 1895 and to the end of 1906 had produced from 23,725 tons ore, 42,626 ounces fine gold, in addition to 308 ounces from specimen stone and 4,007 ounces from the alluvial. The output of the field has recently diminished, but the completion of the projected railway from Port Hedland to Marble Bar, will, it is believed, assist the field materially.

West Pilbara.—The West Pilbara field lies between the Pilbara field, and the north-western coast in the neighbourhood of Cossack. At the Mallina Diggings the gold is associated in the veins with stibnite. Their present yield is small. The greater part of the gold produced to the end of 1906 has come from the Pilgrim's Rest leases at Station Peak, which have produced 9,151 ounces, out of the total of 12,752 ounces vein gold for the field ; to this is to be added 3,255 ounces placer gold. The veins at Station Peak are in schists intruded by diabase or diorite dykes.

Ashburton.—The Ashburton field lies along the basin of the Ashburton river, which reaches the sea at Onslow on the north-west coast. Little is known geologically of the country, and nearly all of the gold recovered (7,265 ounces) has been from placer deposits, and has probably either been derived from veins in clay-slates or from conglomerates similar to those of the Nullagine series.[b]

[a] Maitland, Bull. W.A. Geol. Surv., No. 15.
[b] Woodward, Ann. Gen. Rep. Dept. Mines, 1890, p. 21.

Gascoyne.—The Gascoyne Goldfield is of no present importance, having produced to the end of 1906 only 268 ounces alluvial and 218 ounces vein gold, the latter derived from Archæan rocks.

Peak Hill.—The mines of the Peak Hill Goldfield are situated between 24° and 26° S. lat. and 117° and 120° E. long. Its chief mining camp is Peak Hill. The country is banded hæmatite-magnetite-quartz rock, micaceous schist, and banded or granular quartzite Intrusive rocks are apparently absent. Great veins or dykes of quartz cross the schistose rocks. These are slightly auriferous and cut through the productive gold-quartz veins.[a] Depressions in the surface of the schists are filled by an iron-stained well-cemented conglomerate of recent age, in which gold occurs both free in grains, scales, and nuggets, and also in fragments of the original quartz matrix.

Gold is found in the schists in interlacing quartz veinlets disposed along bands of weathered country, and is also disseminated through the adjacent country. Most of the alluvial gold is obtained by dry-blowing. The total output of vein gold obtained from vein-quartz to the end of 1906 was 204,518 ounces fine, of which the Peak Hill mine alone produced 196,289 ounces fine gold. No records have been kept of the amount of alluvial gold obtained.

Murchison.—The geology of the Murchison field is now fairly well known. The auriferous rocks are metamorphic schist, slate, quartzite, and ferruginous sandstone, with which are associated granite and quartz-diorite. Numerous veins occur in the quartz-diorites. The ridges of the country are generally formed by the banded ferruginous quartzites, at the intersections with which the quartz reefs are always enriched. Dykes of granite and quartz-diorite (approaching tonalite) are numerous. The gangue matrix is quartz, and below the water level the veins contain galena and pyrite. The gold occurs in shoots, often at the intersection with certain beds.[b]

The auriferous rocks of the northern part of the field are massive and foliated greenstone-schists, including diorites, pyroxenites, and amphibolites. These occur in belts, some of which are of great extent, one being at least 60 miles long by 10 to 15 miles broad. The auriferous reefs occur almost entirely within the greenstone-schist belts, few of importance traversing the granite. The granitoid rocks vary from the biotite-granite of Mount Magnet to a granodiorite, the general characters of which are well described by Gibson.[c] The granodiorites are found near Cue and Nannine. The hæmatite-

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[a] Maitland. Bull. Geol. Surv. W.A., No. 4, 1900, p. 40.

[b] Woodward, Rep. Dep. Mines, W.A., 1893, pp. 9-11.

[c] Bull. No. 14, Geol. Surv. W.A., 1904, p. 14.

quartzite bands in the schist series run northward with the schist belts for great distances. The principal centres of the Murchison field are Mount Magnet, Day Dawn, Cue, and Nannine.

The Day Dawn area contains the Great Fingall mine, one of the most celebrated of Western Australian mines. Its veins lie entirely within the greenstone-schists, the foliation of which is, however, apparent only in weathered specimens. The large shoot in the Great Fingall had, to 1906, produced 804,854 tons stone of an average value of less than an ounce gold per ton, or in all 749,446 ounces. The shoot occurs at a turn in the reef and has been followed down for more than 1,300 feet. The zone of greatest enrichment in the shoot was determined by the junction of a flat lode on the footwall.[a] To May, 1908, the Great Fingall mine had paid £1,612,500 in dividends.

The Cue veins lie at the contact of granodiorite with the greenstone schists. Some of the veins radiate out into the granitic rock; the others lie in the granodiorite contact zone, and run parallel with the contact.

At Mount Magnet and Boogardie the main auriferous series is formed by a belt of more or less highly altered greenstones, which extend in a general northerly direction from West Mount Magnet through Moyagee as far north as Lake Austin and the town of Cue. The belt attains a maximum width of about 15 miles, and includes diorite and pyroxenite, together with hornblende- and chloritic schists that may merely represent crushed and sheared varieties of the former. The greenstones are intersected by numerous faults, and are also traversed by belts of laminated quartzites that are often highly ferruginous, and that are raised as ridges above the surrounding country.

The greenstones are bounded on either side by beds of granite, from which small tongues of aplite emanate. In many portions of the district dykes of granite intersect the greenstone. The foliation of the greenstone seems to have taken place prior to the intrusion by the granite. The laminated hæmatite-magnetite-quartz rocks of Boogardie are traversed by numerous faults, the mapping of which is of considerable importance from a mining point of view, inasmuch as it is along the intersection of these faults with the laminated quartzites that the rich shoots of gold for which the district is famous occur. Wherever seen, the faults cross the strike of the quartzites at right angles, and as the latter are generally only from 30 to 60 feet in width, it necessarily follows that the width of the ore-shoots is also small, more particularly as they never continue into the country on either wall. The fault-fissures are

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[a] Woodward, Rep. Dept. Mines, W.A., 1906, p. 150.

invariably filled with brecciated quartzite, re-cemented by chalcedonic quartz and traversed by small angular quartz veins. The fissures vary from 3 to 6 feet in width.

Quartz reefs occur plentifully in both the granite and the greenstone, though, as a rule, it is only those close to the greenstone which have proved to be auriferous to any extent. The shoots in these reefs are short, but frequently rich. It is interesting to note that the quartz reefs often form the continuation of the faults by which the laminated quartzites are intersected.

The total yield for the Murchison field to the end of 1906 is as follows :—

	Fine Ounces.	
	Alluvial.	Vein.
Cue	575	212,280
Nannine..	6,452	202,946
Day Dawn	975	846,718
Mount Magnet	1,150	249,627
Total	9,152	1,151,571

Yalgoo.—The Yalgoo field lies in foliated greenstone schists. Its veins, and particularly the Emerald Reef, were very rich at the surface, but have not been profitable in depth. Only about 4,000 ounces fine gold are produced annually. The schists are traversed by numerous diorite dykes, which, as well as the reefs, strike east and west with the foliation of the schists.[a] To the end of 1906 the field had produced 59,962 ounces gold.

East Murchison.—The principal mining centres of the East Murchison field are Lawlers, Lake Darlot, Mount Sir Samuel, Lake Way, and Black Range. The country is the usual Archæan schist, associated with granites and gneisses, and intruded by basic rocks. The Lake Darlot field was formerly one of the chief alluvial fields of the State, but its placers are now exhausted. At Lawlers the reefs occur along the zone of contact between the gneissic granite and the greenstone schists. Numerous acidic (granitic and felsitic) veins break through the greenstone-schist, and with these are associated the gold-quartz reefs.

The principal mine is the East Murchison United. Its quartz veins are intersected by felsitic dykes. The auriferous belt in general has a width of 12 to 16 miles, and is continuous between Lawlers and Mount Sir Samuel, disappearing at Abbots, a little to

[a] Woodward, Rep. Dept. Mines, 1895, pp. 21-22.

the north of Mount Sir Samuel. It has thus a total length of some 50 to 60 miles. The ore deposits are of the following types :—

(*a*) Reefs at contact of greenstones and granite.
(*b*) Normal quartz reefs (fissure veins).
(*c*) Lode-formations.

Reefs of the second class are found both in the granites and in the greenstones, but it is only in the latter that they are auriferous. As a rule, the reefs of Lawlers are large and low grade.[a]

Mount Sir Samuel is 32 miles north of Lawlers. Its rocks are hard, unweathered, greenstone schists intersected by numerous granitic dykes.

The Black Range district in the west of the East Murchison field is characterised in its schist-belts by the banded or laminated hæmatite-quartzites which here appear to occupy lines of faulting since they disturb the older auriferous veins. The returns from the two divisions of the East Murchison fields to the end of 1906 are :—

	Fine Ounces.	
	Alluvial.	Vein.
Lawlers	4.441	576,663
Black Range	886	63,518

Mount Margaret.—In the Mount Margaret goldfield, the principal areas are Laverton (Mount Margaret), Mount Morgan, and Mount Malcolm. Leonora is the principal mining camp of the Mount Malcolm district, and contains one well-known mine, the Sons of Gwalia. This mine has produced since mining operations commenced 445,591 ounces from 716,549 tons ore. Its vein is in an impregnated zone or " lode-formation " containing numerous lenticles of quartz. The workable width of the lode is determined entirely by assay. The gold occurs in pay-shoots.

The country of the Leonora belt must be regarded as a single area of basic rock, which has been more or less crushed, foliated, and completely converted into schists, the latter structure being on the whole the most usual ; to such schistose zones the auriferous reefs are almost entirely confined. The greenstone on the eastern side of the belt is highly metamorphosed, the great development of the banded and hæmatite-bearing quartz-rock forming one of the most notable scenic features of the district. Along the summit of the ridge, extending from Mount George to Leonora, and thence to Lake Raeside, outcrops of this quartz are found in the form of bands or lenses, from 200 yards to more than half-a-mile in length, and from

[a] Gibson, Ann. Rep. Mines Dept. W.A., 1906, p. 154.

1 foot to 100 feet in thickness, and projecting several feet above the surface in the form of perpendicular walls. The best veins on the Leonora field occur near the contact of the granite and the schists. Veins carrying gold are known to pass from the schist into the granite.

The Mount Morgan district, like the Mount Malcolm, possesses one mine of outstanding importance, viz., the Westralia Mount Morgans. Its outcrop-ore was exceedingly rich, 3,000 tons yielding at the rate of 4½ ounces gold per ton. The ore occurs in lenses in the schists, the lenses having an average width of 100 feet, and overlapping each other. The gold is found in shoots within the lenses. To a depth of 150 feet, the oxidised ore yielded 2 ounces per ton, but in the sulphide zone the average value of the ore crushed has been 11 dwts. To the end of 1906 239,461 fine ounces gold had been obtained from 386,221 tons ore.

The Laverton (Mount Margaret) district contains several valuable mines; the most prominent are the Ida H. (Laverton) with a yield of 57,792 ounces, the Craggiemore (Laverton) with 35,336 ounces to the end of the year 1906, and the Lancefield, with a yield in 1907 worth £25,993. Its geological characters are similar to those of the already described fields.

The various districts of Mount Margaret field have yielded, to the end of 1906, as follows:—

	Fine Ounces.	
	Alluvial.	Vein.
Mount Malcolm	1,442	663,082
Mount Morgan	345	367,333
Laverton (Mount Margaret) ..	1,233	310,091

North Coolgardie.—The North Coolgardie field is divided into four districts: Menzies, Ularring, Niagara, and Yerilla. Its geological characters are identical with those of Kalgoorlie and Coolgardie further south. The Menzies goldfield has been described by H. P. Woodward.[a] The country of the auriferous veins is a hard greenstone-schist, displaying, as is often the case, schistosity only in the zone of weathering. Both basic (amphibolite-) and acid schists occur, the latter being sericite-schist and gneiss. Numerous felsitic dykes are intrusive into the basic schists. The richer auriferous veins of the Menzies district are irregular segregation veins, occurring either as pipes or as a series of lenticular masses. The gold occurs in shoots in the quartz. The greatest depth to which a shoot has been worked is the 1,600 feet reached in the Queensland Menzies

[a] Bull. Geol. Surv. W.A., No. 22, 1906.

mine. In the Lady Shenton mine the pipes or shoots, though well-defined, persisted only to a depth of 800 feet.

The Ularring district lies in the south-west of the goldfield. Its principal centres are Ularring, Davyhurst, Mulline, and Mulwarrie. Its rocks are the greenstone schists of the "Auriferous Series." The veins occur mainly in lode-formations.[a] The gold is found in shoots.

The Niagara district has only one large mine, viz., the Cosmopolitan at Kookynie, which to the end of 1906 had obtained 238,412 fine ounces from 490,242 long tons ore. Unlike the ore-bodies of most Westralian goldfields, its veins traverse granite. The principal vein is from 6 to 10 feet in width.

The Yerilla district is in the south-east portion of the North Coolgardie field. Its chief camps are Yarri, Edjudina, and Pendinnie. At Eucalyptus, in the Edjudina district, the diabase rock is so closely intersected by quartz veins as to form an auriferous stock.

The following table shows the relative importance of the various districts of the North Coolgardie field :—

Yield to end of 1906.

	Fine Ounces.	
	Alluvial.[b]	Vein.
Menzies	950	485,217
Ularring	5	179,308
Niagara	300	394,928
Yerilla	1,018	110,177

Yilgarn.—Southern Cross, the principal district of the Yilgarn goldfield, was opened in 1887. The rocks of the Yilgarn Hills and of Southern Cross are mica-schist, mica-slate, and shaly quartzite, with many diorite dykes and quartz veins. The schistose rocks have been intruded by granite at Southern Cross itself. The country of the veins is a hornblende-schist. The principal vein is Fraser's, in which the ore occurs in lenticular shoots. The yield of gold from Yilgarn to end of 1906 has been 267.128 ounces gold from 623,677 tons ore crushed.

Coolgardie.—The Coolgardie goldfield is divided into two districts, Coolgardie and Kunanalling. The Coolgardie mines were the earliest discovered of the great mines of Western Australia. Alluvial gold was found in June, 1892, and three months later the

[a] Gibson, Bull. Geol. Surv. W.A., No. 12, 1903.

[b] The official return of alluvial gold is always less than the true output, and is often, indeed, only a small fraction of it.

rich outcrop of the Bayley's Reward Reef was uncovered by the original prospectors, Bayley and Ford.

The schists of Coolgardie belong to the main Auriferous Series of Western Australia. They lie as long narrow hornblendic and talcose belts in granitic rocks.[a] The schistose structure is developed only in weathered zones. Intrusive through the schists are numerous diorites and acid eruptive rocks that, as a rule, conform with the general strike of the enclosing rocks. The acid intrusives occur as narrow dykes trending towards the granite. In some cases they may be seen to change in the direction of their strike from a coarse granitic type to a highly quartzose rock (the *alaskite* of Spurr). These quartzose dykes pass into quartz veins that are invariably barren, although leaders or spurs from them may show gold. Vein gold occurs at Coolgardie, both in "lode-formations" and in reefs. The former are generally lenticular masses of highly altered schist, through which run numerous small quartz veinlets. These masses invariably thin out when harder country is met with, though the quartz veinlets may unite and continue as a strong low-grade reef. The boundaries of the "lode-formations" may be determined only by assay. On the whole, they have not proved of great economic importance. The quartz-reefs also occur in the schists, either as well-defined continuous veins or more generally as lenses connected in strike only by fissure planes. Lenses parallel in strike and dip often overlap both horizontally and vertically. The gold occurs in shoots of great value and is nearly always enclosed within a quartz matrix. The minerals ordinarily associated in the vein with the gold are pyrites, mispickel, sulphides of copper, and arsenopyrite. The last is considered the associate most favourable for gold. Pyrrhotite also is met with. Molybdenite and galena are rare.

The principal mines of Coolgardie in 1907 were the Bayley's and Bayley's Consols. The former had produced to the end of 1906 more than 100,000 ounces of fine gold. The majority of the Coolgardie veins failed in depth and the camp at the present time shows but little activity. In the early days of the field, rich alluvial deposits were found in the vicinity. The largest nugget unearthed weighed 607 ounces in the crude state.

The mining centres outside Coolgardie are of comparatively little importance. They are Bonnievale, where the veins are in hard grey granite, and Burbanks, where one mine had produced, to the end of 1906, gold to the amount of 126,352 fine ounces.

The Kunanalling division lies to the north of Coolgardie. It is widely known rather on account of its rich cement-deposits

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[a] Blatchford, Bull. W.A. Geol. Surv., No. 3, 1899.

than for gold-quartz veins. The cement is similar to that at Kanowna, consisting of rounded and sub-angular fragments cemented by ferruginous silicate of alumina. The gold, almost without exception, occurred in the cement, and was largely derived from neighbouring veins, though a small portion may have been deposited from solution.

Broad Arrow.—The Broad Arrow goldfield is one of the smallest of the West Australian goldfields, having an area of only 590 square miles. Its principal camps are Black Flag, Paddington, Broad Arrow, and Bardoc. The rocks are similar to those of Coolgardie, the basic schists being intruded by numerous acidic dykes. With Coolgardie, Kalgoorlie, and Kanowna, it has furnished the bulk of the placer gold of the State. Its officially recorded yield of alluvial gold has been 15,790 fine ounces, and of vein gold, 247,985 fine ounces.

East Coolgardie.—The East Coolgardie goldfield, comprising an area of only 632 square miles, includes the world-famous Kalgoorlie camp with its "Golden Mile." The chief mines of Kalgoorlie are the Great Boulder, Ivanhoe, Horseshoe, Perseverance, Oroya-Brownhill, Associated, and Lake View Consols. The deepest shaft is that of the Boulder, which is more than 2,000 feet in depth. The productive rocks of the field are comprised within a long narrow belt, flanked by granites and gneiss. The schists are, in the main, amphibolitic where they have been derived from original igneous rocks. Rocks representing original sedimentary beds occur in the form of soft graphitic shales, sandstones, jasperoid slate, and flinty quartzite. Graphite, to the extent of 5 per cent. or more, is found with the slates, and the latter, when graphitic, often contain spherical nodules of pyrite up to an inch in diameter. Sand grains may increase to grits, to fine conglomerates, and even to the coarse boulder-beds that, elsewhere, in India and South Africa, are characteristic of this type of Archæan rock. Apparently to be associated with the amphibolitic schists are chlorite-schists and massive and foliated siderite-rock. Traversing the schists are numerous intrusive dykes of felspar-porphyry, porphyrite, and peridotite.

The lodes of Kalgoorlie consist of a series of almost vertical schistose "lode-formations" that strike from north-north-west to west-north-west. They represent zones of crushing and fissuring that may reach to 100 feet in width. The deposits are lenticular, the lenses being often of great length, with generally no well-defined walls. The dip of the lodes, when not vertical, is to the west, but it may occasionally turn over to the east for short depths. The lode matter is schistose country which is highly silicified, and which is impregnated with pyrite, tellurides of gold, and

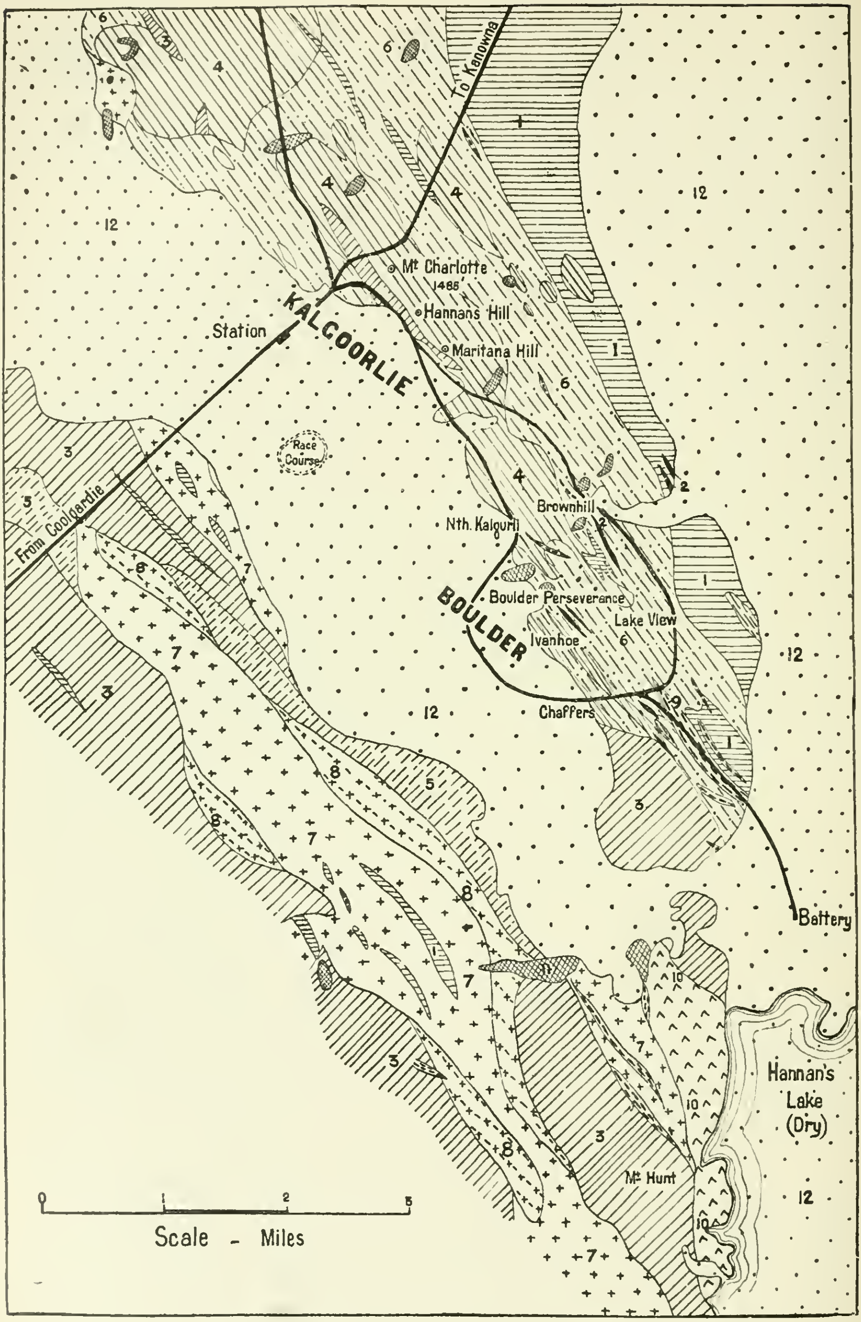

FIG. 139. GEOLOGICAL SKETCH MAP OF KALGOORLIE (*Maitland and Campbell*).
1. Slates, schists, and quartzites. 2. Graphitic schists. 3. Massive hornblende-amphibolite. 4. Massive amphibolite (with chlorite). 5. Massive amphibolite (with actinolite). 6. Foliated amphibolite. 7. Porphyrite. 8. Schisted porphyrite. 9. Felsite dykes. 10. Peridotite (with derivatives.) 11. Laterite. 12. Superficial deposits (recent).

free gold. The oxidised zone varies in depth from a few feet to more than 200 feet.

The lode system is fairly complex, several main lodes occurring with minor parallel and interlacing veins and veinlets.[a] The principal lodes or ore-bodies on the western side of the belt are the Brownhill, Australian East, Tetley's, Kalgurli East and West, Lake View Consols, and Boulder Perseverance. On the eastern side the main lodes are the Hainault, Great Boulder, Horseshoe, Boundary, Ivanhoe East, Ivanhoe New, and Ivanhoe Middle. Of all the famous shoots of Kalgoorlie, the Brownhill has probably been the most productive. This shoot passes through several mines disposed along the strike of the lode; it is estimated that more than £4,000,000 has been obtained from it. The total yield of the East Coolgardie goldfield to the end of 1906 has been 8,162,035 fine

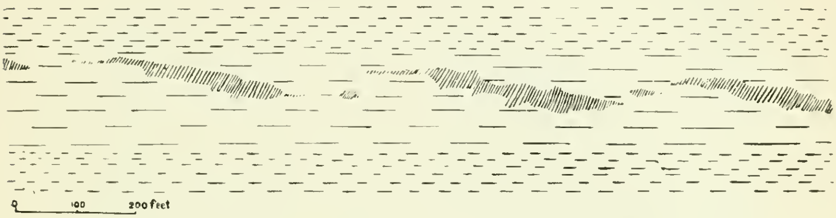

FIG. 140. ORE-BODIES IN SCHISTED BAND, LAKE VIEW CONSOLS MINE, KALGOORLIE (*Rickard*).

ounces from 7,805,455 tons of ore, in addition to 16,580 fine ounces alluvial gold, the whole being worth some £34,742,000.

Kalgoorlie competes with Cripple Creek in Colorado for the distinction of being the richest telluride goldfield in the world. The tellurides occurring are calaverite, krennerite, sylvanite, petzite, and nagyagite. Free gold is abundant in the upper levels, and has apparently been derived from the decomposition of tellurides or of auriferous pyrites. Dendritic gold is not uncommon. That produced from the oxidation of the tellurides is locally known as "paint" gold, "mustard" gold, and "sponge" gold, all three terms being sufficiently self-explanatory. A mass of "sponge" gold, weighing about 70 lbs., was taken from a vugh at the 200-foot level of the Great Boulder Proprietary mine. The fineness of this secondary gold is very high, and ranges, indeed, from 900 to 999·1, the last assay coming from the Boulder, Kalgoorlie, and representing probably the purest natural gold known, finer even than that of Mount Morgan. The average fineness of twelve samples assayed by E. C. Simpson was 917·7.

[a] Maitland, Bull. Geol. Surv. W.A., No. 4, 1900, p. 63.

At Kalgoorlie the tellurides in the deeper zones are normally massive, while the pyrite is often finely divided. Accessory or secondary minerals in the lodes are chalcopyrite, blende, galena, coloradoite, pyrargyrite, enargite, löllingite, fluorite, magnetite, rutile, calcite, dolomite, siderite, ankerite, sericite, chlorite, and roscoelite,[a] to which may be added albite[b] and tourmaline.[c] Albite is fairly common in the lode formations.

The lenses of schistose country that contain the telluride ores are often disposed *en echelon*, overlapping each other both horizontally and vertically. The width of the lodes is determined only by the width of ore removed, and that again is regulated by the costs

Fig. 141. Great Boulder Main Lode, Kalgoorlie (*Rickard*).

Quartz and calcite gangue in schistose country with one well-defined wall, *AF*.

prevailing at the given mine. The general character of the Kalgoorlie oxidised ores is indicated by the following determinations on free silica :—

Hannan's Brownhill	18·21 per cent.
Lake View Consols	28·31 ,,
Boulder Main Reef	31·06 ,,

[a] Simpson, Bull. Geol. Surv. W.A., No. 6, p. 21.

[b] Lindgren, Econ. Geol., I, 1906, p. 534.

[c] Spencer, Min. Mag., XIII, 1901-1903, p. 268.

Kalgoorlie, from the South.

The only other gangue mineral of importance is kaolin. In unoxidised ores more quartz is present. Lateral impregnation of gold in the decomposed country rock in the oxidised zone has been general and is clearly evidenced by the almost invariable rule that the stopes are often twice as wide in the oxidised portion as in the lower sulphide-telluride zone.[a]

North-East Coolgardie.—The principal camp of the North-east Coolgardie Field is Kanowna. Its rocks are highly decomposed, serpentinous, chloritic, and talcose schists, intruded by acid eruptive dykes. The granitic intrusive rocks are interlaced in places with thin auriferous gold-quartz veins. The importance of Kanowna arises rather from its alluvial deposits than from its veins. The alluvial occurs as a so-called "lead," which is nevertheless purely a surface deposit. The width of the old stream-gravel varies from 2 to 80 feet, with an average of perhaps 15 feet. Its thickness ranges from a few inches to 90 feet. The fall of the bed-rock is some 40 feet per mile. The deposits filling the old watercourse vary considerably, but the "wash" itself is made up of rounded and sub-angular pebbles of quartz cemented by secondary silica into a hard, compact rock. The overlying "pug" (kaolin) and ironstone (lateritic) gravels have also yielded minor quantities of gold. Gold is found in the quartz pebbles themselves, indicating therefore a derivation from the adjacent veins, but much gold occurs massive, arborescent, or coarsely crystalline, with clear, sharply-cut octahedra, the latter form pointing certainly to a secondary deposition from solution. The average tenor of the gravel was perhaps an ounce per ton. These secondary gold deposits occur elsewhere in the State.[b] Bulong and Kurnalpi have, for example, furnished considerable alluvial gold, while their gold-quartz veins have up to the present proved of no great importance.

The most perfect crystals found in Western Australia were the above-mentioned single octahedra embedded in asbolite (oxide of cobalt and manganese) in the Kanowna pug. The largest crystals were, however, only $\frac{1}{50}$ inch in diameter. Crystallized gold has been obtained also from Bulong, Kalgoorlie, and Red Hill—from the last in calcite. The largest alluvial nugget yet found came from Pilbara, and contained in gold 413·37 ounces (£1,348). Its fineness was, however, only 768, and it, like most West Australian nuggets, showed fairly clear evidence of direct derivation from adjacent veins.

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[a] Hoover, Trans. Amer. Inst. M.E., XXVIII, 1899, p. 763.

[b] Maitland, loc. cit. sup., 1900, p. 60; Rickard, T.A., Trans. Amer. Inst. M.E., XXVIII, 1899, p. 525.

The following are the yields to end of 1906 from the various North-East Coolgardie goldfields :—

	Fine Ounces.	
	Alluvial.	Vein.
Kanowna	103,097	404,233
Bulong	26,046	116,721
Kurnalpi	10,019	6,548

Dundas.—The Dundas goldfield lies south of Kalgoorlie. Its chief camp is Norseman, where a small auriferous belt stretches north and south for some 33 miles. The rocks are similar to those of Coolgardie, being greenstone-schists intruded by thin dykes of quartz-porphyry and felsite. These are associated with the usual banded and laminated hæmatite-quartzites. A considerable amount of gold has been obtained from deep alluvial deposits at Norseman. At Dundas, further south, a few lodes have been spasmodically worked. The official returns to end of 1906 were :—

Fine Ounces.		Tons Ore Crushed.
Alluvial.	Vein Gold.	
1,788	293,830	338,264

Phillips River.—The returns from Phillips River Goldfield to end of 1906 were :—

Alluvial.	Vein Gold.	Tons Crushed.
Ozs.	Ozs.	
286	24,268	29,003

This is the southernmost field of Western Australia. Its auriferous veins lie in schist or in granite, or at the contact between the two. The gold is largely associated with copper, and the mineral wealth of the field appears to lie in that metal rather than in gold.

Donnybrook.—The Donnybrook is an isolated goldfield lying in the extreme south-east corner of the State and not on the strike of any of the great auriferous belts. Its veins traverse hornblendic and gneissic granites near their intersection with a diorite dyke that varies in width from ¼ to 1 mile. The total product of the area to date has, however, been only 840 fine ounces.

AFRICA.

MOROCCO.

No gold mines are actively worked in Morocco, but alluvial gold in small grains and flakes has occasionally been obtained along the course of the Wadi Sus, in the Sus province, south-west Morocco. At Idaultit, in the northern portion of the same province, and at the foot of the Atlas mountains copper ores have been found carrying small quantities of gold.[a]

ALGERIA.

The gold occurrences of Algeria are of trifling importance. The pyrite mines of Kef-um-Tabul, near La Callc, in the department of Constantine, yield small quantities of gold on smelting the chalcopyrite that occurs with the pyrite. The quantity thus obtained is insignificant.[b] Another auriferous locality is reported at Oued-el-Dzeheb, near Mila, west of Constantine.[c] Vague rumours are current in the seaboard towns of the employment of large numbers of natives in gold mines in the Atlas mountains, and from time to time gold is shown in Algiers that is said to be obtained from these workings.

TUNIS.

At Sidi-Boussaib, near the ruins of Carthage, there occur alluvial gravels that contain small quantities of fine gold. The sands are derived from Pliocene sandstones and conglomerates; from these the gold is also probably derived. These placers, if, indeed, they were ever of importance, were certainly exhausted with, or perhaps even before, the foundation of Carthage, for the Second Punic War (219 B.C.) was occasioned by the desire of the Romans to obtain control of the Spanish mines, acknowledged to be the sole source of the enormous hoards of gold, silver, and copper accumulated in Carthage.

TRIPOLI.

No gold appears to be produced within Tripoli itself, but a considerable amount of gold-dust and melted gold has been exported from the country. The source of this gold is uncertain, but the

[a] Futterer, "Afrika, &c.," Berlin, 1895, p. 40.

[b] Pelatan, Les Richesses Minérales des Colonies françaises, Paris, 1902, p. 107.

[c] MacCarthey, Geog. physique, econ. et pol. de l'Algerie, Algier, 1858, p. 118.

greater part of it has probably come from Senegambia and from the Gold Coast by caravan across the Sahara desert in the ordinary course of trade.

EGYPT.

The auriferous regions of Egypt lie on the eastern side of the Nile, between that river and the Red Sea. They are grouped both to the north and to the south of the Tropic of Cancer, and for the most part to the east and south-east of Assouan. They are possibly among the oldest of the world's goldfields, for the earliest known reference to gold is contained in an edict of Menes (perhaps 3800 B.C.) which enacted that the ratio of the value of silver to gold should be fixed at 2½ to 1. An official document, dated about 2500 B.C., relates how the gold was escorted from mines between Keneh and Kosseir to Koptos on the Nile.[a]

Under the 19th dynasty (1300 B.C.) numerous gold mines were worked in the Wadi Abbas, near Rhedesia, and at Akita (Wadi Allaghi). The latter are supposed to have been opened during the reign of Setos I (1360 B.C.), who caused wells to be sunk along the road to the mines, a work that was continued by his son, Rameses the Great. A rude mining plan, probably the oldest extant, of certain of these ancient Egyptian mines, was discovered by Drovetti at Thebes, and by him taken to Turin. The particular mines represented on the plan are believed to be those of Dereheib, well known at the present day.

The ancient mines are said to have furnished a large portion of the revenue of the kings, and particularly of the annual revenue of the second Ptolemy, which was estimated at 14,800 talents, or more than four millions sterling. From the ancient mines of Hamesh it is said that several millions of tons of quartz have been extracted. Near the present Um Rus mines every reef and vein over an area of 25 square miles has been thoroughly prospected.

The first definite account of the Egyptian gold mines is given by Agatharchides (140 B.C.), who paints a moving picture of the miseries endured by the unfortunate wretches condemned to work in the Egyptian gold mines. The works of Agatharchides are lost, but fragments of them, including fortunately the following, have been preserved for us by Diodorus Siculus and others. Of that portion dealing with the gold mines the subjoined is a free abstract: "They put fire to the veins, and the stone thus loosened is carried away and crushed. An expert miner performs the work of tracing the vein, and brings the labourers to those places, dividing the work among them according to the capacity of the individual. The strongest, and those still in the prime of life, are used to break the stones, and

[a] Wallis-Budge, "The Egyptian Sudan," London, 1907, II, p. 336.

Views of Auriferous Region, Egyptian Desert.

to work in the shafts. With nothing but their own strength they break the stone with heavy iron hammers, and follow the ill-defined course of the gold-bearing vein. A light is fixed to their foreheads, and then, under the eyes of their tyrannical overseers, they break the gold-bearing stone. Children bring the broken stone out from the mines ; old men carry it to those who have to crush it,

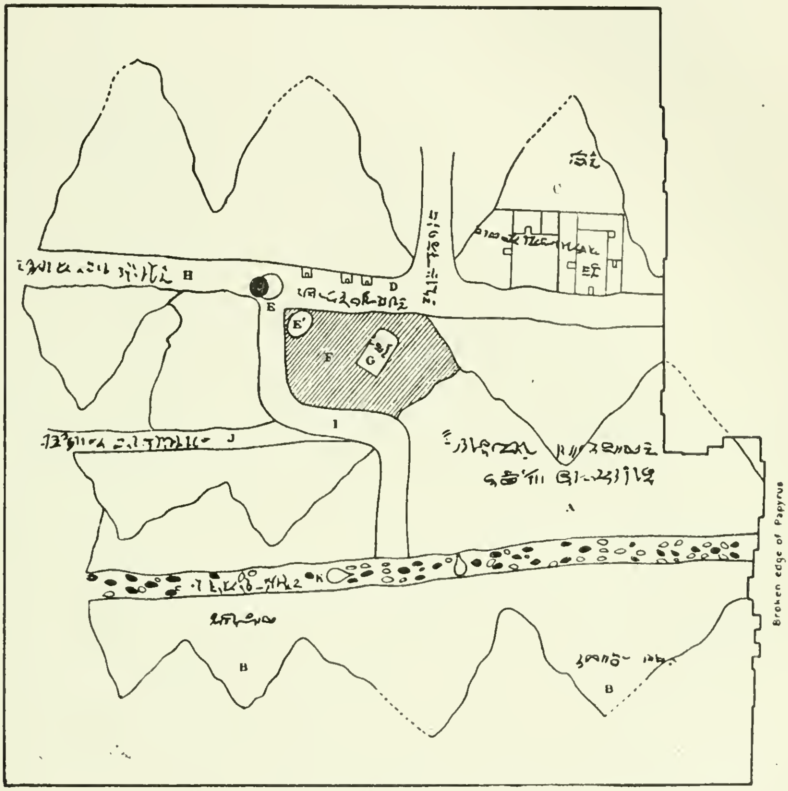

Fig. 142. Ancient Egyptian Mining Map. Supposed date, 1300 B.C.
A " Mountains in which the Gold is washed they are coloured here in red." *B* " Gold Mountains." *C* Large buildings and Temple to Ammon. *D* Gold workers' houses. *E* Well, &c., *E'* Pool of water in *F* Palace grounds of King Setos I. *G* Monument of the King. *H* Wady leading to the sea. *I* Connecting Wady. *J* Roadway to the Sea. *K* Wady with numerous wells and trees. Dotted lines indicate portions restored. Top of Map supposed to be North. Note.—Contour lines supposed to indicate hills in elevation.

a work which is effected by strong men of 30 years of age, using iron pestles in mortars hewn from the solid rock ; so they reduce it until the largest piece is no bigger than a pea. The next task is performed by women at mills placed in a line. Standing three together at one handle, and filthy and almost naked, the women work until the measure handed to them is completely reduced, and to every one of those who bear this lot death is better than life. Expert workmen . . . pour the powdered quartz on an inclined broad and polished table whereon the gold is washed and taken up with sponges. Finally, it is transferred to melters, who melt it in a clay pot, and in proportion to its quantity they add a lump of lead, grains of salt, a little alloy of silver and lead and barley bran. The mouth of the pot being carefully covered and luted round, they keep it fused five days and five nights consecutively ; . . . in the end they find none of the things that were put in together, but only a mass of molten gold, but little less than the original matter."[a]

Further, Diodorus Siculus, treating of the gold production of Egypt about 50 B.C., partly from information derived from Agatharchides, says : " On the borders of Egypt and the neighbouring countries, some districts contain many gold mines, producing quantities of gold. The soil is black, but it contains many veins white as marble and glittering with the precious metal. The Kings of Egypt condemn vast multitudes to the mines who are notorious criminals, prisoners of war, and persons convicted by false accusation—the victims of resentment. And not only the individuals themselves, but even whole families are doomed to this labour, with the view of punishing the guilty and of profiting by their toil. The vast numbers employed are bound in fetters and compelled to work day and night without intermission, and without hope of escape ; for they set over them barbarian soldiers who speak a foreign language, so that there is no possibility of conciliating them by persuasion or through familiar intercourse. No attention is paid to their persons, they have not even a piece of rag to cover themselves ; and so wretched is their condition that all who witness it deplore the excessive misery they endure. No rest, no intermission from toil is given either to the sick or maimed ; neither the weakness of age nor woman's infirmities are regarded ; all are driven to their work with the lash, till at last, overcome with the intolerable weight of their afflictions, they die in the midst of their toil. So these unhappy creatures always expect worse to come than they endure at the present, and long for death as preferable to life."

Numerous ancient circular stone mills, obviously for quartz crushing, still exist and have been described by various modern writers.[b] During the internal and foreign disturbances to which Egypt was subjected in the early centuries of the Christian era, the gold mines appear to have been almost entirely neglected. In the beginning of the ninth century the notorious adventurer Abdur-rahman-el-Omari, a descendant of the Khalifa, established himself in the neighbourhood of the mines, and there spent thirty turbulent

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[a] Floyer, Jour. Roy. As. Soc. (Lond.), XXIV. 1892, p. 825.

[b] Alford, Trans. Inst. Min. Met., X, 1902, p. 29 ; Herzig, Min. Sci. Press, Aug. 17, 1907 ; Llewellyn, "Mining Report on Egyptian Soudan," London, 1903.

years. Towards the end of this period he had no less than 60,000 camels carrying provisions to his miners from Assuan, in addition to large wheat supplies received from Aidab on the Red Sea. His principal mines were probably Um Garaiart, Gebel Aswad, and Ceiga (Saiga), all of which have been extensively worked. From this time

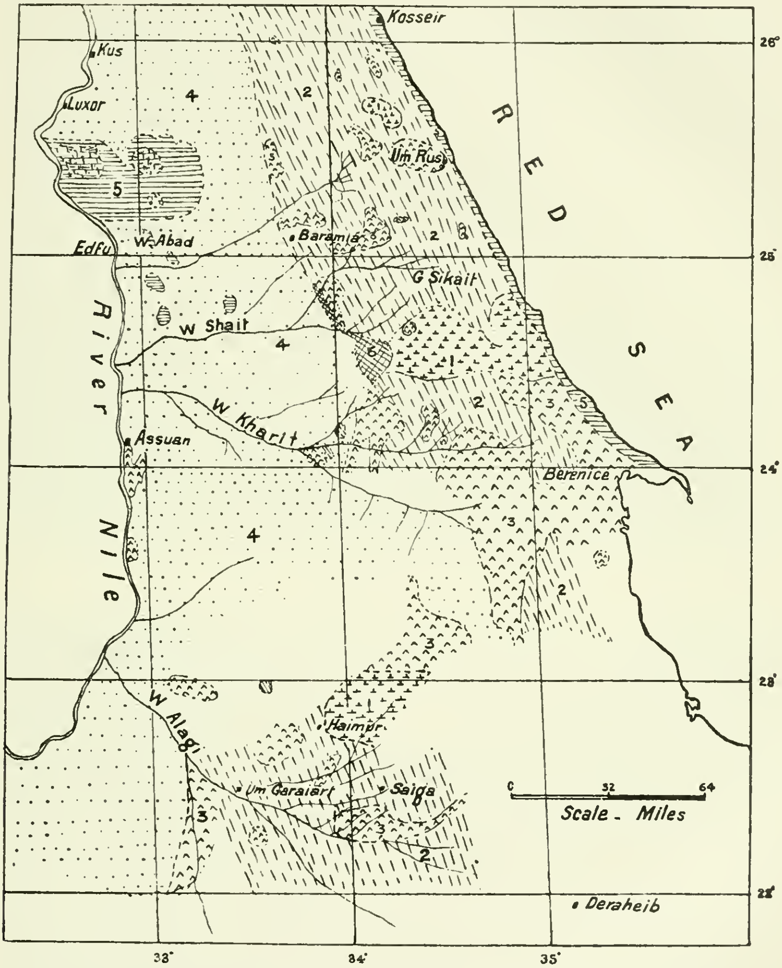

FIG. 143. GEOLOGICAL SKETCH MAP OF THE NORTHERN ATBAI DESERT (*Hume*).
1. Gneiss. 2. Schist. 3. Granite. 4. Nubian Sandstone (Cretaceous). 5. Senonian Limestone. 6. Basalt and Younger Volcanics.

onward until the beginning of the twentieth century the gold mines of Eygpt appear to have been deserted. Attention has since 1898 been directed towards the re-opening of the ancient gold mines, and a considerable amount of capital has been invested in prospecting work. The returns to date are, however, far from commensurate with the high hopes entertained in the early days of exploration. The gold-quartz veins so far worked, have proved to be more patchy in value and more uncertain in width than was at first expected.

The general geology of the auriferous region is simple. The higher ranges are hornblendic granite, containing a pink orthoclase. The lower flanking ranges are composed of a fine-grained grey granite, passing in places into gneiss, and that again into mica-schist, the whole series being traversed by dykes and intrusions of diabase, diorite, felsite, porphyry, and a very fine-grained white elvan-granite.[a] It is in the schistose rocks or in the basic gneiss close to the schists that most of the auriferous quartz occurs and a genetic relation between the veins and the intrusive rocks is generally probable. The crystalline schists that occur in this complex [b] strike about N. 60° W. and apparently overlie the gneiss. Talc- and mica-schists occur over large areas, and furnish the famous beryl mines of the northern district. In the central desert are extensive exposures of hornblende-schists, derived from original igneous rocks, but calcareous schists and graphitic schists, representing original sediments, are also present.

The Um Garaiart auriferous region (Nile Valley Company) is composed of schists and slates broken by belts and patches of diorite, granite, and syenite, and, in places, beds of dolomitic limestone. On the "Haimur" mine in this concession the veins are all contained in highly dolomitised schists varying in character from a highly siliceous rock on the one hand to a soft, white, dolomitic and felspathic rock on the other. Siliceous bands form, by their superior hardness, long, outstanding, serrated ridges. The schists are in places highly graphitic, and often contain numerous cubical pseudomorphs of hæmatite after pyrite.[c] It will at once be apparent that the general geological description of this country recalls very strongly that of the Dharwar auriferous region of India, already described. Overlying the crystalline rocks on either side of the mountains are wide expanses of the Nubian sandstone, which is again overlain, probably unconformably, by Cretaceous and Tertiary nummulitic limestones.

In the northern portion of the Atbai desert the known ancient workings are Wadi Hammama, where the gold-quartz veins occur in the "greenstone," and Eridia, where there are numerous veins from mere threads up to 30 inches in width. At Eridia are also extensive ruins of an ancient mining town. The veins occur either in a grey

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[a] Alford, "Report on Gold Mining in Egypt," London, March, 1900, p. 5.

[b] MacAlister, Geog. Jour., XVI, 1900, p. 543; Hume, Rep. Surv. Dept., Egypt, No. 1, 1907, p. 34.

[c] Sleeman, Min. Jour., May 20, 1905, p. 550.

Ancient Egyptian Quartz-crushing Mills, Nabi and Khabaseit.

granite or at the junction between an intrusive greenstone (diorite) and the granite. The ancients appear to have followed the wider ore-shoots. At Fatira, further north, the ancient workings occur in a granite country intruded both by basic and by acidic dykes, the veins occurring indifferently in or between any of the rock species. The veins of Safaga nearer the coast lie also between granite and diorite. The Jebel Jasus mines on the coast north of Kosseir appear to have been worked primarily for lead and silver, but their galena veins also carry small quantities of gold.

The Um Esh workings south of Eridia, extend along a single vein in the granite. The wider portions have been completely stoped out. The Fowakhir group of ancient workings are also in a granite that is largely intruded by basic dykes. The dykes, however, appear to be subsequent in age to the veins.

Debach is another ancient mining centre 100 miles east-south-east of Luxor. It possesses a large vein 6 to 8 feet wide in places, and assaying from 5 to 16½ dwts. It, like the Fowakhir veins, traverses a grey granite.

Um Rus has of late years received considerable attention. It lies on the coast of the Red Sea, about 8 miles from Imbarak Inlet. The old mines extend for some distance westward into the hills, but the principal workings are in the granite escarpments facing the sea. The gold-quartz veins are white, and vary from a few inches up to 4 feet in width. The country is grey granite, with numerous intrusions of white elvan-granite, felsite, felsite-porphyry, and greenstone. Other ancient workings south-west of the Rus are Umtoot and Hamesh. In both cases the rock is grey granite, with numerous basic intrusions.

The Betaan and Um Eleagha ancient mines are 25 to 30 miles south-west of Berenice on the Red Sea. Here, unlike most of the foregoing occurrences, the gold-quartz veins occur in a greenstone (diorite) that is intrusive into grey hornblendic granite. The veins are 6 to 30 inches in thickness.[a]

Still further south-west are the vast ancient workings of Deraheib on the upper course of the Wadi Allaghi. These mines, as already observed, are believed to have been worked by the Copts in 1300 B.C. Here numerous branches and veins of the main lode have been carefully followed up by the ancients. Prospecting operations on these veins during 1907 showed an average width for the principal lode of nearly 5 feet, but its grade was too low to admit of profitable working.

Two days south of Deraheib are the Oneib mines, where the largest ancient workings in the Sudan or Egypt occur. The reef

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[a] Alford, loc. cit. sup.

occurs here in a range of four slate hills, and the stone has been removed down to the level of the wadi. The crushing mills of Oneib appear to have been located at the nearest available water, viz., El Harr, half a day's journey to the north. These veins have also been found too poor to be worked by modern methods.

North of the Wadi Allaghi and east of the Um Garaiart mines are the Ceiga (Saiga) mines in mica- and talc-schists. They were probably worked by Abdur-rahman-el-Omari. The Um Garaiart mines of the Nile Valley Company are near the Wadi Allaghi, about 50 miles east of the Nile.[a] Its "Haimur" section is 8 miles north of Um Garaiart. Here mineralisation has taken place along shear planes in dolomitic and talcose schists. Quartz is the principal gangue, but calcite and dolomite also occur. The sulphides present are pyrite, mispickel, and chalcopyrite. Graphite accompanies the vein matter, especially where the latter is auriferous. The coarsest gold has always been found beside the graphitic matter.[b] Occasionally very high-grade gold-quartz has been met with. From 12 tons obtained in prospecting operations about £2,800 of gold was received.

The Um Garaiart, Um Rus, Eridia, Attola, Haimur, and Nile Valley Block E mines have been actively developed. Those of Um Garaiart, Um Rus, and Om Nabardi are the most important. At Um Rus crushing for gold commenced on March 6th, 1905. The total returns of gold from the Nile Valley and Um Rus companies amounted to £41,000 in 1905. The largest output to 1907 has been from a shoot of the Nile Valley Company, which produced about £100,000, all of which went back into the mine. No Egyptian mine has as yet paid a dividend, and many of the concessions taken up about 1900 and 1901 have now been abandoned. Of those that remain the Om Nabardi mines appear to offer the most promise. These are among the most southerly in the Atbai region, being situated in N. Lat. 21° 05′. Prospecting shafts had reached in 1907 a depth of 360 feet, and a 10-stamp mill was being erected. In 1905 the total value of the gold obtained from Egypt was £41,000 ; in 1906 the yield fell to £23,860.

BRITISH SUDAN.

Auriferous alluvial gravels occur in the south of Kordofan, especially at Tira. The gold is believed to be derived from the schists and ancient crystalline rocks of the region. The gold

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[a] Schweinfurth, "Die Wiederaufnahme des Alten Goldminen Betriebs in Aegypten und Nubien," Vossische Zeitung, Berlin, November 22, 1903.

[b] Sleeman, loc. cit. sup.

occurrences are unimportant. The crystalline rocks appear to run north-east from Tira to Tagalla. The source of the gold is doubtless those veins in the crystalline schists described by Russegger[a] as containing galena, pyrite, magnetite, mispickel, &c. Since his journey (1837) no material addition has been made to our knowledge of these deposits.

ERITREA.

In the Italian colony of Eritrea gold-quartz veins have been worked, or rather prospected, for some years, but without very successful results. The rocks are metamorphic schists similar to those of the Atbai region of Egypt. The principal mines are at Sciummegale, Madrizen, Seroa, and Barentu. The production of these mines for 1907 was about 3,215 ounces (100 kg.). Small and unimportant placer deposits are also known.

ABYSSINIA.

The gold said to come from Abyssinia is really derived from the Shankala and Beni-Shangal districts to the west of and beyond the true Abyssinian boundary, but nevertheless within a region probably recognised as being within the Abyssinian sphere of influence. These gold washings are best described by Russegger[b] and by Blundell.[c] The latter shows that the important washings commence at the junction of the Didesa with the Abai (Blue Nile), and continue down the Blue Nile and up the bed of the Dabus and its tributaries. These regions lie immediately to the south of Fazokl on the Blue Nile. The gneissic and hornblendic schists of the region have been so far denuded that a large tract of country is strewn with quartz pebbles and boulders, and numerous quartz outcrops occur. The amount of gold dust exported is estimated at £80,000 a year. The Dabus, with its affluents, is washed for something like 40 miles of its course, but in 1904 the greater number of washers (about 2,000) were employed in the lower 20 miles, nearest the Abai. This region, and that of Beni-Shangal, is estimated to furnish about three-fourths of the total quantity of Abyssinian gold. The Tumat, another tributary of the Abai, but further north, furnishes also a considerable quantity of placer gold. The general conditions indicated by the descriptions of these rivers denote the possible existence

[a] Russegger, "Reisen in Europa, Asien und Afrika, etc., in den Jahren 1835 bis 1841," IV, p. 203, Stuttgart, 1844.

[b] Loc. cit. sup.

[c] Geog. Jour., XXVII, 1906, p. 544.

of remunerative dredging ground. Much of the gold obtained here is exported from Abyssinia by way of Harar and Addis-Abbaba. In 1905-6 the amount thus exported was estimated at 4,000 ounces, of a value of £15,600.

ITALIAN SOMALILAND.

The country adjoining the Nogal river, flowing west from British Somaliland, through Italian Somaliland, has been believed by Kosmas and by Glaser[a] to be the ancient auriferous land of Punt and Sasu. Recent expeditions, as those of Bricchetti-Robecchi,[b] however, make no reference to modern gold-washings, or even to gold-occurrences. The probability of their existence is therefore remote.

BRITISH SOMALILAND.

The ranges of the Somali hinterland are Archæan gneisses, schists, and granites, but notwithstanding their resemblance to those of Egypt, they do not, so far as is yet known, furnish auriferous deposits.

FRENCH GUINEA.

Bambuk.—The auriferous district of Bambuk lies between the Falemé and the great Senegal rivers, and south of Kayes on the latter river. The valley of the Falemé is especially rich, and numerous ancient goldfields are scattered through the region contained between the two rivers. Gold occurs not only in the gravels of the rivers and valleys, but also in highly ferruginous (lateritic) conglomerate beds at a considerable depth below the surface. These deposits are worked exclusively by the natives, who dig pits of 18 to 20 feet to the pay-gravel, which is generally ferruginous, and is occasionally so indurated that it must be crushed before washing. The richest mines of the Bambuk district are at Sola, Tambaura, and Mouralia. The *massif* of the Khakidian, the mountain range between the Senegal and the Falemé, is composed, according to Arsandaux,[c] of mica-schists and quartzite, with diabase intrusives and andesitic flows and tuffs, all of which appear to have been metamorphosed, the original basic tuffs now forming amphibolite schists. The complex has been intruded by later granite and microgranite. In the neighbourhood of the Keneiba gold mines the rocks are highly schistose. The amphibolitic schists are charged with pyrites, and in their neighbourhood, and there only, the microgranites also

[a] "Die Goldländer Punt und Sasu in Somali-Lande," Das Ausland, 1890, pp. 521-528.
[b] Boll. della Soc. Geog. Ital., Rome, 1891.
[c] Bull. Soc. franc. Miner. XXVII, 1904, p. 82.

contain pyrite. These are the two auriferous rocks, and the gold that they furnish comes entirely from the pyrites. The pay-streaks in the resulting gravels are always highly ferruginous, and are formed under the conglomerate; the boulders forming the conglomerates always show evidence of intense metamorphism; they are invariably microgranites associated with basic rocks, one at least of these two rocks being always heavily charged with pyrites. Concentrated pyrite from the microgranite has assayed as high as 2¾ ounces per metric ton (85 grammes per tonne).

At Yatella, where the native workings have long been abandoned, the pay-streak was also in a ferruginous deposit, derived from an uralitised ophitic gabbro, which contains, however, no pyrites. At Sadiola, perhaps the most important of the old placer workings, the tenor of gold is not constant throughout the whole deposit, but increases gradually in depth until it reaches the permanent water-level of the country. Arsandaux, apparently with justice, concludes that the increase in value denotes the development of a zone of secondary enrichment at the water level.

The Bambuk regions were worked by or for the Portuguese as early as 1698, in which year Fort Galam was established. In 1714, Fort St. Pierre was built on the Falemé river, where gold had, however, been discovered by a French expedition forty years before. The French and Portuguese workings ceased with the conquest of Senegal by the English in 1758; from that year to 1779 little is known of the auriferous history of the region. In 1784 the Senegal gold yield was 531 lbs. The famous traveller, Mungo Park (1795-1797), describes the African methods of washing as practised in these regions.

The principal mines in 1880 were:—[a]

(*a*) Kamanan mines. These are distributed along the Falemé river, mainly in ferruginous clay, sand, and conglomerate.

(*b*) Tambaura mines. The centre of this region is Sola. Numerous shafts are here sunk about 40 feet to water level. The gold-bearing bed lies from 20 to 40 feet below the surface, and is a yellow-spotted argillaceous bed with grains of iron-ore. The gold is not always fine, but often occurs in nuggets up to 1 to 2 dwts. in weight.

(*c*) Niagalla mines. These are principally in the neighbourhood of Sadiola, 15 miles south-east of Kenieba (Long. 10° W., Lat. 11° N.). The district of Buré on the left bank (Tankisso tributary) of the Joliba or Niger river, contains auriferous deposits very like those of Labi, further west. They have for long been worked by the natives of the country. The workings lie on the slopes of the

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[a] Lamartiny, Bull. Soc. Geog. Commer. Paris, VI, 1883, p. 28.

hills. In 1886 their produce was estimated by Le Brun-Renaud[a] at £20,000.

Labi.—The Labi (Futa-Jallon) auriferous area, is situated in the mountains in the heart of the Futa-Jallon district. Gold occurs there in the alluvial gravel of Dioula, Tiolo, Bago, Kambara, Dango, &c.[b] In 1904 gold to the value of £27,499, and in 1905 £24,088, was exported, mostly from the Falemé river.

The most recent information on this region is furnished by Desplagnes,[c] who describes with some detail the auriferous deposits of the headwaters of the Bakoy river, one of the upper streams of the Senegal. Gold-mining is here of great antiquity and numerous shafts 40 to 60 feet in depth have been sunk through the overlying laterite and sands to reach the pay-gravels that lie on a bed-rock for the most part of diabase or diabase-schist. The pay-streak generally lies below a well-cemented auriferous and ferruginous conglomerate. The chief localities now worked by the native miners are at Buré and Sieke in the country between the Tankisso and the Niger. During the dry season hundreds of natives find employment in extracting and crushing the conglomerate. There are not here, as on the Falemé, any auriferous sands or gravels that yield their gold on simple washing. The whole of the pay-gravel is so thoroughly cemented that preliminary crushing is necessary. The auriferous conglomerates have been traced over an area of 31 square miles (80 sq. km.). From this region much of the gold of Guinea and the Soudan has been derived.

Remote though these regions are, they are already being exploited by French enterprise. Two dredges, treating 1,200 and 1,500 tons gravel daily, are at work on the Tankisso river. The average tenor of the gravels treated is reported at 12 to 20 grains per metric ton.[d]

LIBERIA.

Gold in unimportant quantity as fine water-worn grains is reported from the sands of the Sinoe river in the south-east of Liberia.[e]

FRENCH IVORY COAST.

The auriferous districts of Baule and Indenié both lie in the hinterland of the French Ivory Coast well beyond the dense tropical forest zone that separates them from the coast. The

[a] "Les possessions françaises de l'Afrique occidentale," Paris, 1884.
[b] Pelatan, "Les Richesses Minérales des Colonies françaises," Paris, 1902, p. 142.
[c] Bull. Soc. Geog., Paris, XVI, 1907, p. 225.
[d] Loc. cit., p. 235.
[e] Buttikofer, "Reisebilder aus Liberia," II, Leyden, 1890.

auriferous country is a continuation of that of the Wassau mines in the neighbouring Gold Coast Colony. It is, therefore, restricted mainly to the eastern portion of the Ivory Coast, but it crosses the Indenié district and the Komoe river, and reaches west to Baule, which is situated between the Sini and the White Rendama rivers. Auriferous alluvial gravels are less developed here than in the Buré and Bambuk districts already described, but on the other hand gold-quartz veins are numerous, and some show free gold at their outcrops. The principal mines of Indenié (the district between the Gold Coast frontier and the Komoe river) are at Saranu and Assikasso, situated about 200 miles from and north of the coast. The country is Archæan rock (granite, diorite, gneiss, and basic crystalline schist), all more or less covered by the thick lateritic deposits characteristic of well-watered tropical regions.

The gold occurs : (*a*) As reef gold in the schists ; (*b*) as detrital gold in the laterite ; and (*c*) as alluvial gold in the streams. The reef gold is the source of the other two. The general strike of reefs on the Ivory Coast, as in the neighbouring Gold Coast Colony, is north of east. The quartz-reefs are white and opaque, and carry pyrite, chalcopyrite, and galena. The largest native workings are near Koffikouro, in Lower Sanwi, where two shafts 40 feet deep had been sunk. Numerous old workings are also found at Akrizi and Dadieso, in the Sanwi district. The lateritic formation has been worked at Afrénu, Lower Sanwi, and at Beboum, near Saranu, mainly by bell-pits 15 to 20 feet deep. The gold is fairly coarse, and nuggets of 3 to 4 dwts. each are not uncommon.[a] In the Baule district, the Kokombo is an important mine. It was worked originally by the natives who had sunk shafts on each vein to depths of 60 to 100 feet. The ore was raised by liana ropes, crushed fine on rocks, and washed in *bateas*.[b]

In 1904 the gold industry was progressing favourably, particularly in the Sanwi and Indenié districts. The gold obtained and exported in 1905 was 707 ounces (22 kg.), of a value of £2,664 (66,000 fr.). One hundred and fifty-four men were being employed at the Akrizi mine in the Sanwi district. This mine is notable since the quartz carries free gold associated with tellurides.

Armas[c] found near Aloso, in the Sanwi district, gold associated with the quartz lenses of a gneiss rock, and also in schists penetrated by granites. Chaper[d] notes the existence of auriferous clays immediately to the east and north of the Aby Lagoon, near the coastal

[a] Truscott and Samwell, Trans. Inst. Min. Met., XII, 1903, p. 161.

[b] Pelatan, loc. cit. sup., p. 144.

[c] Ann. des Mines, II, Ser. 10, 1902, p. 472.

[d] Bull. Soc. Geol. de France, XIV, Ser. III, 1886, p. 112.

town of Assinie. As might be expected from its occurrence in clay, the gold was very fine, and the deposit poor.

GOLD COAST.

The auriferous wealth of the Gold Coast appears to have first been made known to the Western European nations as a result of a French exploring and trading expedition in 1382 A.D. The French station then founded was abandoned in 1413. In 1471, a Portuguese expedition established the present Elmina ("Oro de la Mina"). The first English expedition to the new source of gold was made in 1551. Its ships returned to England with 150 lbs. of gold-dust, much pepper, and other West African products. The first English gold-mining company to operate in the region was one formed in 1825, the outcome probably of the wide-spread desire to seek for gold that at that time found expression in the formation of so many South and Central American mining companies. It is estimated that the annual export of gold-dust from the coast in the early years of the nineteenth century was from £360,000 to £400,000 per annum. Modern mining dates from about 1880, when 9,129 ounces of a value of £32,865 were produced, but prospecting operations have been conducted on a large scale only since 1898, and the output assumed considerable proportions as a result of vigorous development only in 1903.

The following table shows the output of the Gold Coast Colony and Ashanti for the past 21 years :—

Year.	Weight. Crude Ounces.	Value. Sterling.
1887	22,546	£81,168
1888	24,030	86,510
1889	28,666	103,200
1890	25,460	91,657
1891	24,475	88,112
1892	27,446	98,806
1893	21,972	79,099
1894	21,332	76,796
1895	25,415	91,497
1896	23,940	86,186
1897	23,555	84,797
1898	17,733	63,837
1899	14,250	51,300
1900	10,557	38,007
1901	6,162	22,187
1902	26,911	96,880
1903	70,775	254,790
1904	93,548	345,608
1905	168,457	657,330
1906	225,959	877,568
1907	293,218	1,163,517

Owing to the dense jungle and to the general conditions obtaining in the colony, geological surveying is exceedingly difficult, and little information under this head is available. The reefs of the Tarkwa district, situated about 40 miles from Sekondi on the coast, are conglomerate-beds occurring in a series of sandstones and quartzites. The last at times are so coarse as to become grits. Beds of dolomite are interstratified with the quartzite. Overlying and conformable with the quartzites are arenaceous clay-slates containing a few thin fine-grained sandstone beds. These two series make up the country of the goldfield. The surrounding formations are basic igneous rocks, and schists and slates derived from them; these rocks contain white, slightly auriferous quartz reefs. The strata of the field are disposed as a long, perfect syncline, south-west of Tarkwa, and there is no doubt that the Tamsoo and Teberibi conglomerate reefs on opposite sides of the syncline are one and the same vein.[a] The pebbles of the auriferous conglomerate vary in size, and may attain 4 inches in diameter. They consist of dull-white quartz. The matrix is a white micaceous sandstone, with occasional deep green stains. At Cinnamon Bippo, to the west-north-west, large patches of talc occur in the reefs. At Busanshi, still further west, the pebbles are larger, reaching 8 inches in length.

At the Teberibi mine, on the opposite side of the syncline from Tarkwa, two reefs occur. The dip of the country and of these reefs is about 35° south-east. The principal conglomerate reef is about 50 feet thick, and contains occasional bands and wedges of sandstone. Several well-defined conglomerate bands occur in it. The pebbles vary in size up to 3 inches. They consist of white translucent and sugary quartz. The matrix consists of schistose white and pink micaceous sandstone. The second reef is 5 feet thick; little is known about it. At Mantraim the reef dips at a very low angle (8°). It is composed of blocks of rough conglomerate with large white quartz pebbles, some dark indurated slate pebbles not much rounded, and numerous wedges of sandstone. The Detchikroom reefs dip 65° S. The country is white micaceous sandstone, with auriferous conglomerate bands.

The enclosing country when examined from near the surface is a sandstone composed of quartz grains, white mica, and iron oxide. It becomes schistose at the ends of the Tarkwa syncline. Near the surface the pebbles of the conglomerate are invariably coated with white mica. They are mostly white quartz, but darker quartz and, occasionally, slate pebbles also occur. The quartz pebbles of the conglomerates are cemented by a fine-grained mixture of granular quartz, white mica, and granular hæmatite. Banded

[a] Sawyer, Trans. Inst. Min. Eng., XXII, 1902, p. 402; Id., XXIII, 1903, p. 527.

quartzites are found consisting of alternating bands of quartz and iron oxide.

The Tarkwa conglomerate pebbles occasionally contain gold. The greater portion of the gold, however, occurs in the matrix. The conglomerate beds usually contain more gold nearest the foot-wall, but the hanging-wall is occasionally worth working. No pyrites had up to 1903 been met with in the auriferous conglomerate.[a]

The dykes of the field are mainly basic igneous rocks (dolerites and diabases), forming either sheets or dykes. They are of frequent occurrence. Hornblende-diabase occurs in great abundance at Aquapim and Periperi, midway between Tarkwa and Prestea, and elsewhere in the vicinity of Busumchi. Diorite and andesite (porphyrite) also occur, mainly to the south of Tarkwa. Typical hornblende-biotite-gneiss occurs on the coast near Sekondi, but nothing of the sort was seen near Tarkwa. At Prestea, to the north-east, graphitic schists occur, and Sawyer mentions having seen rich gold-quartz from near Kumasi in Ashanti, where it was contained in graphitic schist.

The principal quartz mines of the Gold Coast Colony and Ashanti, with their yields for 1907 in ounces are : Prestea Block A (40,393), Ashanti Goldfields (35,065), Abbontiakoon Block I (22,843), Wassau (21,338), Abosso (20,692), Bibiani (19,140), Broomassie (15,867), and Akrokerri (10,716). Four mines, viz., the Abbontiakoon Block I, Wassau, Obosso, and Taquah and Abosso, are working the above-described auriferous conglomerate and produce about 34 per cent. of the total gold produce of the colony.[b] The other mines are working on fissure-veins of the normal type. At the Abosso mine the ore crushed in 1907 had an average tenor of £3 per ton, while the costs were of necessity high, varying from 33s. to 38s. The average yield at the Wassau mine was 44s. 7·65d., while the costs were 32s. 7·14d.

A considerable amount of gold is recovered by dredging. The principal dredging rivers are the Offin, Ankobra, and Birrim, on all of which dredges have been at work. The following are the yields obtained by dredging from 1905 to 1907 :—

	Ounces Gold.
1905	12,707
1906	15,154
1907	10,650

[a] Sawyer, loc. cit. sup.

[b] Wilkinson, W. F , Eng. Min. Jour., Jan. 4, 1908, p. 57.

Ashanti Goldfields Mines, West Africa.

Sheba Gold Mines, Barberton, Transvaal. (Page 448.)

TOGOLAND.

In the gneissic zones in crystalline schists near Towega veinlets of chalcedonic quartz occur, carrying about 2 grains gold per ton. This is the only auriferous occurrence in Togoland.[a]

CAMEROONS (KAMERUN).

The gneiss and mica-schists in the neighbourhood of Edea Station (Lower Sannaga River) carry gold. Aboland, immediately to the north of Kamerun and the Kamerun river, contains unimportant gold and silver veins.[b]

FRENCH CONGO.

In the south of the colony, not far from the coast, and near the village of Mayumba, a granite islet carries an outcrop of gold-quartz which has not, however, been exploited.

ANGOLA.

To the east of St. Paul de Loanda is situated the auriferous district of Golungo Alto.[c] North of the town of that name, on the Lombige river, an expedition headed by Monteiro, washed for several months for a return of only a couple of pounds of gold. The gold was 938·6 fine. According to Choffat[d] mica-schists occur in the neighbourhood.

Cuninghame[e] reports an auriferous conglomerate east of the Kunene river (*circa* S. Lat. 13° 20′; E. Long. 16°). Gold-washings have long been known to exist somewhat north of this spot in the Bailundu district. The rocks of the region are apparently schists.[f] The sands of the upper waters of the Kunene river are washed for gold, and have been said to have yielded good returns to a Brazilian miner, who had worked there for many years. Somewhat east of this region, and on the headwaters of the Kasai branch of the Congo and the Zambesi, gold has been washed by the natives.

A small goldfield is reported to occur at Kassinga in the upper valley of the Chitanda river, which joins the Kunene at Kiteve.

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[a] Schmeisser, Zeit. für prakt. Geol., XIV, 1906, p. 73.

[b] Macco, Zeit. für prakt. Geol., XI, 1903, p. 29.

[c] Monteiro, "Angola and the River Congo," London, 1875, II, p. 89.

[d] Loc. cit. inf.

[e] Geog. Jour., XXIV, 1904, p. 161.

[f] Choffat, Revista de Sciencias Naturaes, 1895, IV, No. 1.

CONGO FREE STATE.

The gold occurrences of the southern portion of the region now the Congo Free State were first described by Cameron.[a] They have also been further described by Cornet,[b] but in most detail by Buttgenbach,[c] from whose account the following is derived. The very important copper deposits of Katanga[d] contain also gold. They lie in slates, sandstones, and quartzites. The tenor in gold is however, very low, the highest assay being only about 2 dwts. per ton. To the south of Katanga there are numerous streams carrying gold. The richest placers are those of Kambove, which occur in narrow gorge-like streams, and also on the plateau overlying the violet-coloured slates through which the streams run. Seeing that placers occur only in those streams which flow from the well-known and well-defined copper belt, it is assumed that the gold has had a genesis in the original copper-pyrites of the ores that are now showing as copper-carbonates at the surface. At Fungurumé, north-west of Kambora, and at Likasi to the south-south-east there are similar occurrences of alluvial gold apparently associated with the copper belt.

Near Katanga also there exist remarkable auriferous sedimentary beds. At Ruwé, 10 miles west of Lualaba, the country is sandstone and quartzite. On its surface is spread an ordinary surface débris, but cemented more or less by limonite, the whole having a yellowish colour. This lateritic bed always contains gold, some of which is very coarse, and may weigh 1 to 2 dwts., or may reach even 6 dwts. in weight. The underlying beds are also auriferous, especially a limonitic conglomerate, from which assays showing tenors as high as 1·6 ounces per ton were obtained. The average of 24 samples taken from these beds gave : gold, 7·8 dwts. ; silver, 5·2 dwts. ; and platinum, 2·2 dwts. per ton.

The Kilo (Ruwé) goldfields, about 20 miles from the British boundary, are reported to have yielded 3,909 ounces (121·8 kg.) during the first five months of 1908. The produce of the Ruwé mines to December, 1907, had been 16,242 ounces (499 kg).[e]

In 1905, gold to the amount of 4,694 ounces (146 kg.), valued at £19,130 (478,272 francs) was obtained from the Katanga district; in 1906 the amount was nearly doubled, 8,827 ounces (275 kg.), worth £34,059, being obtained.

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[a] "Across Africa," London, 1877.

[b] Bull. Soc. Belge de geol., XVII, 1903.

[c] Ib., XVIII, 1904, p. 173.

[d] Eng. Min. Jour., April 11, 1908.

[e] Min. Jour., July 4, 1908.

BRITISH EAST AFRICA.

Gold is known to exist in small quantities in various parts of this Protectorate, but all attempts made to find deposits of economic value have hitherto resulted in failure.

UGANDA PROTECTORATE.

In September, 1908, gold was reported to have been found in appreciable quantity by a geological survey party near Lake Albert Nyanza, and near the borders of the Lado Enclave.

GERMAN EAST AFRICA.

Many rivers between the Indian Ocean and Lake Victoria Nyanza contain gold. A concession was, towards the end of 1902, granted over a number of streams flowing into Lake Victoria Nyanza, but was productive of no definite result. In 1899, in the region at the sources of the Gurumasiva tributary of the Umbekuru (*circa* S. Lat. 10° 15′; E. Long. 38°), the alluvial gold deposits of New Klondike were discovered. Two other placer fields are known, one near the Emin Pasha Gulf on Lake Victoria Nyanza (Muanza district), and the other about 150 miles to the south-west on the Iramba plateau. Rich float gold-quartz specimens have been brought from the Useraguru mountains and assayed from 2 to 6 ounces per ton. The auriferous occurrences of the Iramba plateau have at times aroused in the breasts of the German colonial administrators hopes of a rich goldfield that are as yet unfulfilled.

In the clay-slates of Manani lower grade gold-quartz veins occur, with a tenor of only about 1 dwt. per ton. Lately gold has been found in the Mssalala district about 50 miles south of Lake Victoria Nyanza.[a]

During 1904 prospecting had been carried on in the Muanza (Emin Pasha Gulf) and Iramba districts. In the former district gold-quartz veins were discovered. The value of the gold exported in 1904 was £608.

The Moama and Mara rivers here contain no gold, while the Simiju does, but not in payable quantities. Near the lake the rock is granite, but further in the interior schists with auriferous veinlets occur. For the greater part of the year the valleys of these streams are waterless.

On the Iramba plateau, made up partly of granite and partly of crystalline schists, are numerous small and irregular gold-quartz veinlets, which are poor in depth, but which have occasionally shown secondary enrichment near the surface. For

[a] Zeit. für prakt. Geol., XI, 1903, p. 194.

example, assays from the surface have yielded 130 ounces per ton, while at 30 to 60 feet deep the same vein showed tenors of only a few pennyweights.

Very similar are the veins of the Ikoma goldfield about 60 miles east of the Speke Gulf on Victoria Nyanza. At that place five parallel gold-quartz veins occur in isolated areas of hornblende-schist in the prevailing gneiss. These appear to be of fairly high grade on the surface, but are, like those of Iramba, very poor in depth. Near Sargidi village, three hours' journey north of Ikoma, occurs another vein of the same type as the foregoing.

Alluvial gold has been found north of Nguru in a more or less brecciated fragmentary deposit. Samples assayed as high as 1 ounce per ton, but the deposit nevertheless appears to have been of little consequence.[a]

Gold to the value of £1,598 was exported from German East Africa in 1906.

NYASSALAND PROTECTORATE.

Gold occurs in the Shiré Highlands, but no quartz of greater richness than 5 dwts. to the ton has yet been found. Prospecting was being carried on during 1907.

MADAGASCAR.

Gold was almost unknown in Madagascar prior to 1895, though from 1886 onward various mineral concessions had been granted to English and French capitalists. These had met with little real success despite the fact that one of the *concessionaires* had in six years obtained about 900 kg., or 28,935 ounces gold, working with natives and the batea.[b] After the fall of Antananarivo explorers spread on all sides, at first meeting with little encouragement. Since then a considerable quantity of gold has been obtained, as is shown in the subjoined table.

Year.	Kg.	Crude Ounces.
1897	72	2,315
1898	124	3,986
1899	386	12,410
1900	1,114	35,815
1901	1,045	33,597
1902	1,295	41,634
1903	1,910	61,406
1904	2,460	79,089
1905	2,291	73,655 (£274,998)
1906	2,255	72,498 (£270,613)

[a] Schmeisser, Zeit. für prakt. Geol., XIV, 1906, p. 77.

[b] Gascuel, Ann. des Mines, X., Ser. X, 1906, p. 85.

The great rise in the yield for 1900 and following years was due to the discovery of the rich placers of the Ampasary, Sakaleona, Fanantara, Mangoro, Beanandrambo, and others in the great forest belt of the eastern portion of the island.

In April, 1905, a gold-quartz vein was discovered at Ampasimba, in the eastern forest belt, 9½ miles (15 km.) from Beforona, an important village on the road from Tamatave to Antananarivo, and close to the road and railway. Other deposits were found near Fianarantsoa, and extravagant hopes based on these discoveries precipitated a "boom" in which South African capitalists joined. Detailed examination proved the deposits to be poor, and the "boom" had collapsed at the end of the year 1905.

All the gold at present produced from Madagascar is placer gold. The placers are recent, occupying either the bottoms of the valleys or the slopes up to a certain level. There are three main auriferous regions :—

(*a*) The eastern forest belt along the coast from Diego-Suarez to Fort Dauphin. Of this the richest portion is from Fenérive in the north to Manajary in the south. In 1904 this region furnished half the gold produced.

(*b*) The country in the neighbourhood of Miandrivago and of Ankavandra in the west, with prolongations north and south.

(*c*) The centre district along the line from Antananarivo to Fianarantsoa, producing in 1904 about one-sixth of the total yield. The placers are, as a rule, shallow, but the pay-streak may in places be several yards below the surface. The pebbles are of quartz, and are rarely larger than the fist. The gold occurs as scales, grains, and nuggets, but the latter are rare. The largest nugget yet found was less than 16 ounces in weight.

De Launay[a] records the occurrence of nuggets in the laterite of Madagascar. They were the largest that had been obtained there, and were doubtless in their original matrix, since they showed no indication of having been subjected to attrition. The black-sand residues are remarkable for the abundance of black and pink tourmalines, which are probably to be ascribed to the great development of pegmatite in the island. The placers are always worked in the native fashion, with native labour, the *concessionaire* merely buying the gold at a fixed price.

The veins are either lenticular and lie in schistose rocks (quartzite, mica-, pyroxene-, or amphibolite-schist), or are thin auriferous veinlets occurring in granites in the central districts.

[a] C. R. Acad. Sci., Paris, 1901, CXXXII, p. 180.

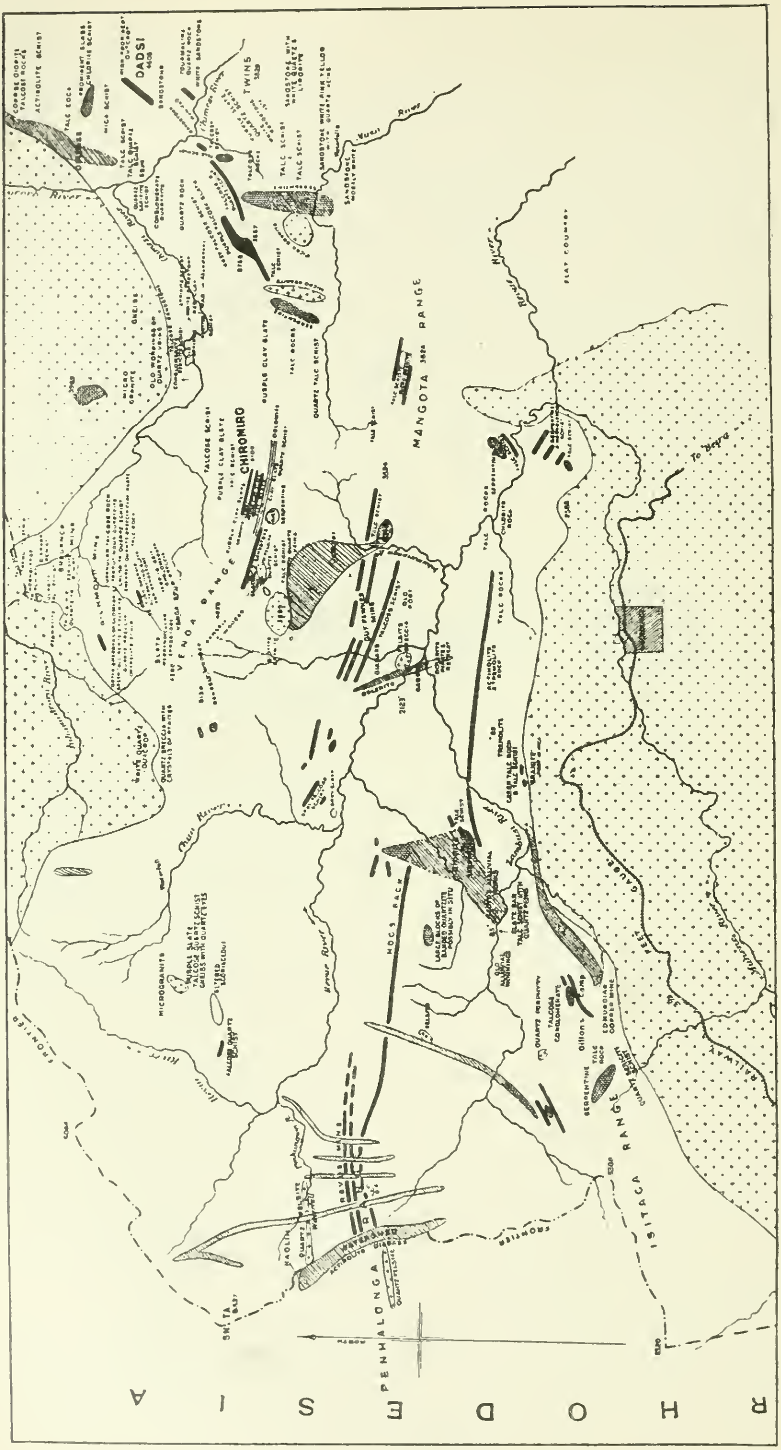

FIG. 144. GEOLOGY OF AURIFEROUS AREA IN MANICALAND (*Sawyer*).

Numerous examples of both types occur, but none are at present of economic importance. In 1904, Lacroix found, south-east of Ambositra, grains of native gold *in situ* in a pyroxene-schist.

PORTUGUESE EAST AFRICA.

The Portuguese Manica goldfields lie to the north of Macequece, on the Beira-Salisbury railway. On the west they are bounded by the Rhodesian eastern frontier. The mines are, therefore, situated in the country at the head of the Revue river and its tributaries. The auriferous rocks are continued west into Rhodesia, there forming the Umtali goldfield. The Manica goldfield has an area of about 180 square miles. The country of the veins is Archæan metamorphic schist derived apparently both from igneous and sedimentary members.[a] The members are talc-schists, chlorite-schists, sericite-schists (derived from rhyolites), amphibolite-schists, quartz-schists, and mica-schists. Felsites and rhyolites, often much sheared, are interbedded with these. Of undoubted sedimentary origin are, however, the clay-slates, sandstones, quartzites, grits, conglomerates, and limestones. Traversing these and forming characteristic landmarks and features in the landscape are laminated quartzites, or, rather, quartzose rocks banded with limonite (hæmatite), magnetite, and white quartz. The lamellæ vary in thickness from that of a sheet of paper to an inch, and are often greatly contorted and crumpled.[b] They may be compared with similar rocks found in the Archæan schists of India, Western Australia, and Rhodesia. Chlorite-schists are found with flat and rounded pebbles forming breccias, boulder beds, or conglomerates. All these rocks obviously belong to the Swaziland Series.

The fundamental rock of the country is here, as further south in the Transvaal, a gneissoid granite. Basic igneous rocks (diabase) are very abundant, occurring principally as dykes. Gold is found in these rocks ; close to the Rhodesian frontier a diabase dyke contains secondary quartz, with visible gold, pyrite, and galena. Quartz-diabase rock has also been noted. The most conspicuous member of the whole series is the above-mentioned banded hæmatite-quartzite, the strike of which is always parallel in direction with the planes of foliation. Graphite-schist occurs on Venga Mount, north of Macequece, where dolomitic limestone also is found. Throughout the schists are numerous quartz veinlets carrying from 1 dwt. 5 grains to 30 ounces to the ton. The average tenor of the richer veins is 6 to 7 ounces per ton. They lie in the vicinity of the Revue and Zambusi rivers. The associates are the ordinary sulphides, but

[a] Sawyer, Trans. Inst. M.E., XIX, 1900, p. 265; Id., ib., XXV, 1903, p. 627.

[b] Sawyer, loc. cit., p. 275.

from the Bragancia and Richmond mines Couyat[a] describes specimens of quartz covered with mimetite, vanadinite, and wulfenite, all due to the decomposition of the galena of the lodes. In 1905 2,139 ounces gold valued at £7,198, and in 1906 2,918 ounces, worth £9,622, were obtained in Manicaland.

The principal auriferous region in Portuguese Nyassaland is on the Rarico river, a tributary of the Lujende. In the northern Tete district the Chifumbase reef is being worked on a small scale. Its initial crushings have shown tenors of about 5 dwts. gold per ton.

RHODESIA.

North-Eastern Rhodesia.—The British colony now known as North-Eastern Rhodesia, formed a portion of the ancient kingdom of Monomotapa, for the conquest of which, and for the confiscation of whose gold mines, lying west of Tete, a strong Portuguese expedition set out in 1569. The expedition failed in its object, but forty years later the mines of Monomotapa were amicably ceded to the Portuguese. The mines worked by them in subsequent years were Pamba (north of Zumbo on the Zambesi), Missale (north of Tete on the Portuguese frontier), Mano, Java (south of Missale), and others. At Pamba the gold occurs in a lode in talcose mica-schist. A diorite dyke runs parallel with the lode for a considerable distance.[b] The great mass of North-Eastern Rhodesia is granite, but it contains, as do the countries to the south, long, narrow, apparently vertical, belts of Archæan schists, that lie generally between granite ranges. Often, as at Fort Jamieson, they occur in small and isolated patches, forming the tops of the hills. The granite is gneissic, and appears to bear much the same relations to the schists as have been observed in the gneisses and schists of Southern Rhodesia. At Sesaré are vertical gneisses with quartz-mica-schists striking north-north-east. They are in places highly impregnated with copper. One of the members of the series is a band of coarsely crystalline limestone which may be traced for 50 miles. The Archæan schists at Sesaré appear to have been lying in north-east and south-west folds when the granite was forced into them. The schists are the auriferous rocks of the country.[c] In July and August of 1907, the Sesaré mine, milling with a small 10-head battery, produced 167 and 232 ounces gold respectively. At Missale, the tenor of the quartz is said to be about 10 dwts. per ton.

Southern Rhodesia.—The discovery in 1866 of ancient ruins of Sabæan architecture and of ancient gold mines at Zimbabwe, in

[a] Couyat, Bull. de Museum d'Histoire Naturelle, Paris, 1906, p. 74.
[b] Lett, Min. Jour., February 15, 1902, p. 221; Id., ib., August 22, 1908, p. 231.
[c] Wallace, Geog. Jour., XXIX, 1907, p. 389.

Auriferous Series, Rhodesia. Giant Mines of Rhodesia.

the south-east portion of Southern Rhodesia, and in other places throughout the country has given rise to the hypothesis that Rhodesia is the Ophir of Scripture. Considerable, and at times acrimonious discussion has been waged on the question, which is fortunately of purely academic interest. According to Portuguese records gold workings existed in Rhodesia in the sixteenth century, and the gold workings of the Manica fields were mentioned by da Silva in 1788. The natives (Mashona) appear to have worked for gold, but only in the crudest of fashions. Numerous old workings have been described by Messrs. Hall and Neal.[a] These are especially numerous in the vicinity of Buluwayo, where they occur mainly as open-cuts, which rarely reach below water-level. Still, instances are known, as at the Globe and Phœnix, where the quartz-veins have been followed to depths of more than 200 feet. The quartz was shattered by "fire-setting," and was then extracted by means of iron and stone tools.[b]

The modern history of these goldfields dates from 1865, when ancient workings were recognised by Henry Hartley. In the following year he discovered the Tati goldfields, now within the Bechuanaland Protectorate. For the next four or five years ineffectual attempts were made to open up goldfields, but no measure of success was attained until 1891, when extensive prospecting was entered upon. Mining progress was, however, greatly hindered during the next decade by the successive Mashona, Matabele, and Boer wars. It is only during the years of the present century that, notwithstanding the great expenditure of capital, the true character of Rhodesian gold-quartz veins has been recognised, with a corresponding increase in output. The veins are on the whole small, but of fair grade. Large veins do occur, and though low in tenor are of increasing importance. The former type necessitates the employment of small capitals, with correspondingly low management costs.

The central plateau of Southern Rhodesia, on an average perhaps 4,000 feet above sea-level, is prolonged both to the south-west and to the north-east along a line connecting Buluwayo and Salisbury. The rocks of the plateau are Archæan (Buluwayo) schists and granites, the latter being considered by Mennell intrusive into and through the former. The Buluwayo schists are to be regarded as made up of highly altered sedimentary rocks into which, before final metamorphism took place, there have been intruded great masses of generally basic igneous rock. The oldest rocks of the series appear to be mica and talc schists and gneisses. These are now closely associated with epidiorites and hornblende- and

[a] "Ancient Ruins of Rhodesia," London, 1902, p. 73.

[b] Mennell, "The Rhodesian Miner's Handbook," Buluwayo, 1908, p. 51.

chlorite-schists, obviously basic intrusions. The younger rocks of the complex (Banded Ironstone Series of Mennell) are sheared conglomeratic and arenaceous beds, phyllites, and gneissic bands, the last of which may have resulted from the crushing of acid intrusions or tuffs. The most characteristic bed of the series is, however, the "banded ironstone," which is obviously a similar rock to that known as "calico-rock" in the Transvaal, and as banded hæmatite-magnetite-quartzites in Southern India, and as laminated quartzites in Western Australia. Faulting and crush-phenomena are frequent throughout the Buluwayo schists, and apparently determine the occurrence of the quartz-reefs and auriferous impregnations from which the gold of Rhodesia is obtained. Occasionally the rocks themselves may be impregnated with gold, as in the hornblendic gneiss ("diorite") of the Lomagunda district, and in the similar rock of the Kimberley mine in the Mazoe district. In Matabeleland, near Buluwayo, the banded ironstones are auriferous. Basic rocks are largely intrusive into the Buluwayo schists, and are mainly dolerite and diabase.[a]

All the leading Rhodesian gold mines are, therefore, within the schistose areas, but are nevertheless generally close to the granite. Both auriferous quartz-veins and auriferous impregnations of rock occur, and in fairly equal numbers. Of the former, the Surprise, Globe and Phœnix, Tebekwe, Penhalonga, Antenior, Morven, Killarney, and East Gwanda mines are examples; of the latter, the Wanderer, Ayrshire, Eldorado, Jumbo, Grant, Riverslea, Gaika, and Sabiwa are typical. The following grouping is adopted by Mennell :—[b]

I. *Reefs.*—(*a*) In the basement rocks: Globe and Phœnix, Surprise, Tebekwe, Bonsor.
- (*b*) In banded ironstone: Camperdown (upper reef), Bristol, Veracity.
- (*c*) In conglomerate: Bell, Abercorn.
- (*d*) In epidiorite, &c.: Antenior, Beatrice, Killarney, Sheba, Jessie, Joker.
- (*e*) In granulite: Valley.
- (*f*) At granite contacts: Geelong, Colleen Bawn, Battlefields, Washington.

II. *Impregnations.*—(*a*) In basement schists: Gaika.
- (*b*) In banded ironstone: Wanderer, Sabiwa, Camperdown (lower reef), Concession Hill, Giant (partly).

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[a] Gregory, Trans. Inst. M.E., XXXI, 1906, p. 47; Id., Trans. Inst. Min. Met., XV, 1906, p. 563; Mennell, "Geology of Southern Rhodesia," Rep. No. 2, Buluwayo Museum, 1904, p. 42; Id., Fifth Ann. Rep. Buluwayo Museum, 1907; Id., Trans. Geol. Soc. S.A., VIII, 1906, p. 82; Chalmers and Hatch, Geol. Mag., 1897, pp. 193-203.

[b] "Mineral Wealth of Rhodesia," Buluwayo, 1907, p. 26.

(c) In conglomerate: Eldorado, &c., Riverslea.
(d) In granulite: Ayrshire, Bushtick.
(e) In chlorite- and talc-schist: Giant (chiefly).
(f) In granite: Commonwealth.

The impregnations are an interesting class of deposit. At the Wanderer mine, which treats a larger quantity of ore than any other mine in Rhodesia, and at the lowest working cost (6s. 9d. per ton), the ore-body is a much-crushed zone of banded ironstone, situated at a contact with the Conglomerate Series. The workable width of the zone reaches in places 60 feet, with a tenor of 3 to 4 dwts. per ton. The Conglomerate Series is being actively prospected, especially in the Lomagundi and Sebakwe districts.

The matrix of the Ayrshire lode has been the subject of considerable speculation.[a] It is an impregnated band of hornblende-biotite-granulite or gneiss situated about 50 to 200 feet distant from the granite. According to Mennell it is doubtless a mixed rock, resulting from injection of granitic material into the schists and from contact-metamorphism by intrusive granitic material. As described by Spurr, the rock is composed principally of felspar (oligoclase-albite) and a pale green hornblende. Quartz is also abundant, and there is some biotite. Magnetite and epidote are always present. The free gold grains are almost entirely confined to a band of hornblende, containing much magnetite, that is situated between two bands composed chiefly of quartz and felspar grains. It is evident that the hornblende, magnetite, and gold are of contemporaneous deposition. As a rule, the gold is set with a long axis of the grain parallel with the cleavage, but not necessarily along a cleavage plane. The rock is a hornblende-biotite-gneiss derived from the metamorphism of a pre-existing, probably basic, igneous rock, in which the gold had previously been deposited. The country in which the hornblende-gneisses occur is hornblende-schist. The Ayrshire mine working on this ore treats 8,000 tons of 6 dwt. ore monthly. The Commonwealth mine is an example of auriferous impregnation of a normal granite. The granite carries pyrite. The rocks of the Globe and Phœnix, Sebakwe district, are described by Gregory as mica-diorite-schists. The gold is generally free, and is associated with pyrite and jamesonite. The Gaika, somewhat to the south of the Globe and Phœnix, is in the same rock, which is here altered even further to talc-dolomite-schists, containing also epidote, sphene, and calcite.

The Rhodesian auriferous conglomerates are richest at the Eldorado and Rowdy Boys mines, Lomagundi, near the Hunyani

[a] Berrington, Eng. Min. Jour., July 11, 1903; Spurr, Ib., Oct. 3, 1903.

river. They are probably sedimentary conglomerates; they have been traced for a distance of 2½ miles, and in places have a tenor of an ounce gold per ton. Other sedimentary conglomerates occur in the Sebakwe and the Selukwe districts, but these have not so far proved notably auriferous. There are also in Southern Rhodesia pseudo-conglomerates, which are in reality crush-conglomerates. These occur at the Tebekwe mine, Selukwe, and at the Wanderer mine.

The Penhalonga mine, which promises to be the principal producer in Southern Rhodesia, lies 10½ miles north of Umtali on the eastern border of Rhodesia. Its ore-body varies in width from 25 to 50 feet, of which some 8 to 20 feet may be economically worked. It is made up of a series of quartz lenticles occupying a zone of crushing in soft chloritic schists of the Swaziland Series. In the oxidised portion of the lode crocoisite (chromate of lead) was abundant. In depth this mineral gave place to galena, with which blende, pyrite and chalcopyrite are associated.[a]

Mennell records the existence of tellurium in arsenopyrite from the Lomagundi mine as denoted by analysis, but the telluride minerals do not appear to have been isolated.[b]

The placer deposits of Southern Rhodesia are not extensive, nor are they, so far as is known, of high grade, especially in the high veldt. The valuable accessible alluvial deposits have probably been long ago worked out by the ancients.

The following is the total gold yield of Southern Rhodesia to the end of 1907:—

	Crude ounces.
To 1898 inclusive	24,555·65
1899	65,303·65
1900	91,940·40
1901	172,061·43
1902	194,169·31
1903	231,872·26
1904	267,737·37
1905	409,836·44
1906	553,985·58
1907	612,052·38
	2,623,514·47

This amount of gold has a probable value of some £9,330,000. The average yield of the quartz crushed during 1905 and 1906 was 28·95s. per ton.

[a] Townsend, Min. Jour., April 4, 1908.

[b] Mennell, Proc. Rhod. Scientific Assn., III, 1902, p. 21.

Auriferous Series, Rhodesia. (Globe and Phœnix Mine.)

The subjoined table shows the relative importance of the principal gold mines of Rhodesia as estimated from their yield for the month of September, 1907[a]:—

OUTPUT OF RHODESIAN MINES IN SEPTEMBER, 1907.

	Tons milled.	Value.
MATABELELAND.		
Gwanda	8,203	£12,032
Globe and Phœnix	6,000	12,618
Selukwe	6,410	8,002
Surprise	2,926	4,214
Nelly	1,700	4,819
Wanderer	16,368	7,777
MASHONALAND.		
Battlefields	1,535	5,410
Giant	4,322	9,375
Beatrice	1,525	2,550
Ayrshire	8,000	10,170
Eldorado..	2,584	5,652
Jumbo	1,752	7,275
Penhalonga	7,900	6,780
Rezende	3,700	5,257

BECHUANALAND PROTECTORATE.

The only fields of any importance within this protectorate are those of the Tati district. They were discovered by Henry Hartley and Carl Mauch in 1866 and were worked by the London and Limpopo Company from 1869 to 1872. During that time they yielded only some 2,000 ounces. They have recently been worked by English capital, but with no great measure of success. Their veins lie in country similar to that of Southern Rhodesia.

TRANSVAAL.

Witwatersrand.—One of the most remarkable of modern goldfields, both from an economic and from a scientific point of view, lies within the Transvaal Colony. The richness, actual and potential, of the Witwatersrand goldfield has, during the last decade, at times directly, more often indirectly, swayed the course of high politics in Europe. The connected chain of mines that lies partly west and partly east of Johannesburg, produces one-third of the world's annual supply of gold, and considerably more than

[a] Wilkinson, W. F., Eng. Min. Jour., Jan. 4, 1908.

the whole output of the next gold-producing country—the United States, with its numerous rich fields, vein and placer. The mines are spread along a belt for some 62 miles, from Randfontein on the west to Holfontein on the east. Of this distance a length of some 12¼ miles near Johannesburg yields 76 per cent. of the gold won. The conglomerate beds have, however, been proved by outcrops and by borings for 164 miles; their continuity is concealed for 123 miles, and is interrupted by faults and dykes for 31 miles, making a total of 308 miles of actual and of probable extension. The district derives its name from a ridge (the Witwatersrand) that rises a few hundred feet above the general level (5,500 feet) of the plateau or High Veldt, and forms, indeed, the main divide between streams flowing to the India and to the Atlantic Oceans. The range or rather ridge, in conformity with the strike of the underlying strata, has a general east and west trend. It, as well as the High Veldt in the neighbourhood, carried a very scanty arboreal vegetation that speedily disappeared on the advent of the miner.

The presence of gold in the Witwatersrand appears to have been discovered on the farm Langlaagte by one Arnold in 1885, and a small five-stamp battery was shortly afterwards erected on the spot. It was soon found that the gold was confined to the conglomerate outcrop which was even then traced for many miles. To it was given the term "banket," of Boer origin, and signifying almond-rock, owing to the fancied resemblance of the white quartz pebbles within the brown oxidised matrix to the almonds in that confection. In 1886 several farms were proclaimed open to mining, and in the same year a great "rush" set in towards the Witwatersrand. Johannesburg was marked off. It owed its name to the circumstance that each of the four Boer dignitaries who selected the town-site owned the prenomen of Johannes. A boom, speedily followed by the inevitable panic, took place early in 1899, and for four years the Rand, as it is familiarly known, was looked on with some disfavour. The steady development of the reefs during the period of depression and more especially the steadily increasing gold-yield brought about a complete restoration of confidence. In 1895-6 a considerable amount of British and foreign capital was invested. The mine returns and share values alike increased until the declaration of war towards the end of 1899. More or less steady work was resumed in 1902, the richer patches and mines having been during the war spasmodically worked by the Boer Government. In 1904 the annual yield exceeded by 44,000 ounces the highest previous return, and each succeeding year has since shown a material increase.

The following table indicates the gold production, since 1884, both of the Witwatersrand district and of the Transvaal generally :—

TRANSVAAL GOLD PRODUCTION.*

Year.	Witwatersrand District.			Outside Mines. Value.	Transvaal Total.
	Tons Milled.	Value.	Value per Ton Milled.		
			Shillings.		
1884–9	1,000,000	£2,440,000	48·83	£238,231	£2,678,231
1890	702,838	1,735,491	47·4	134,154	1,869,645
1891	1,175,465	2,556,328	44·2	367,977	2,924,305
1892	1,921,260	4,297,610	43·4	243,461	4,541,071
1893	2,215,413	5,187,206	47·0	293,292	5,480,498
1894	2,027,365	6,963,100	49·2	704,052	7,667,152
1895	3,456,575	7,840,779	45·2	728,776	8,569,555
1896	4,011,697	7,864,341	39·2	739,480	8,603,821
1897	5,325,355	10,583,616	39·74	1,070,109	11,653,725
1898	7,331,446	15,141,376	41·3	1,099,254	16,240,630
1899	6,763,533	15,089,561	43·84	661,220	15,750,781
1900	552.929	1,464,634	65·82	....	1,464,634
1901	412,006	1,014,687	49·25	81,364	1,096,051
1902	3,416,813	7,179,074	42·00	74,591	7,253,665
1903	6,105,016	12,146,307	39·79	442,941	12,589,248
1904	8,058,295	15,539,219	38·46	515,590	16,054,809
1905	11,160,422	19,991,658	35·82	810,416	20,802,074
1906	13,571,554	23,615,400	34·8	964,587	24,579,987
1907	15,383,000	26,421,837	34·2	982,081	27,403,918
Total ..	.. ..	£187,072,224	....	£10,151,576	£197,223,800

The dividends paid since 1887 are shown in the subjoined table :

DIVIDEND LIST OF TRANSVAAL GOLD-MINING COMPANIES.*

Year.	Dividends.	Year.	Dividends.	Year.	Dividends.
1887	£12,976	1894	£1,527,284	1901†	£415,813
1888	112,802	1895	2,046,852	1902†	2,121,126
1889	432,541	1896	1,513,682	1903	3,345,502
1890	254,551	1897	2,707,181	1904	3,877,624
1891	334,698	1898	4,848,238	1905	4,832,436
1892	879,320	1899†	2,946,358	1906	5,735,161
1893	955,358	1900†	......	1907	6,937,187
† War period, Oct. 11, 1899, to May 31, 1902.				Total...	£45,836,690

* Chamber of Mines Reports, Johannesburg.

The "outside mines" of the first table includes all those not on the northern limb of the Witwatersrand syncline, and not in the immediate neighbourhood of Johannesburg. They are distributed over the goldfields of Heidelberg, Klerksdorp, Barberton, Lydenburg, and Pietersburg, with a few minor fields. Their comparative importance is best shown by the following table :—

GOLD YIELD OF "OUTSIDE FIELDS" FOR YEAR ENDING 30TH JUNE, 1906.[a]

District.	Ounces.	Value.
Pretoria :—Barberton, Lydenburg and Pietersburg ..	126,899	£539,030
Heidelberg	33,933	144,139
Klerksdorp	18,366	78,021

The largest individual "outside mines" are the Nigel in the Heidelberg district, and the Glynn's Lydenburg and Transvaal G.M. Estates, both in the Lydenburg district.

In 1907 there were, on the Rand line, 67 producing mines, crushing their ore through 8,255 stamps. During the financial year ending June 30th, 1907, they produced gold to the value of £26,640,490, the distribution of which was apportioned as follows :—

Working costs	£17,000,000 ..	63·8	per cent.
Dividends	6,750,000 ..	25·3	,,
Reserve fund	2,209,490 ..	8·6	,,
Profit tax	600,000 ..	2·3	,,
	£26,640,490	100·0	,,

The geology of the southern and south-western areas of the Transvaal is, in its general features, now fairly well known. The oldest rock in the neighbourhood of the Witwatersrand is the granite that lies to the north. It is regarded by Jorissen,[b] and also by Hatch and Corstorphine,[c] as intrusive into the Swaziland (Archæan) schists, so extensively developed to the west, north, and east of the Transvaal. Overlying the granite, and after a great separating unconformity, are the beds of the Witwatersrand System, consisting of a series of slates, quartzites, and conglomerates, subdivided into an upper and a lower division. These lie to the south of the granitic area, and are, from the present point of view, the most important in the Transvaal. They are bent into a syncline, some 30 miles in breadth and more than 100 miles in length. Succeeding the Witwatersrand System, are great flows of amygdaloidal diabase lavas. These in their turn are overlain by the conglomerates, quartzites, dolomites, and shales of the Potchefstroom System,

[a] Ann. Rep. Govt. Mines Dept., Transvaal, 1906, Table XI.

[b] Trans. Geol. Soc. S.A., VII, 1905, p. 30.

[c] "Geology of South Africa," London, 1905, from whence most of the succeeding geological details are derived.

subdivided into the Black Reef, Dolomite, and Pretoria Series. The beds of the Potchefstroom System, together with minor deposits of Dwyka and Ecca beds of much later age, fill the Witwatersrand syncline between its northern and southern limbs. The general relation of the older beds is shown in the following table :—[a]

Age.	System.	Series.	
Devonian	Waterberg	Waterberg.	
	Potchefstroom	Pretoria. Dolomite. Black Reef.	
	Ventersdorp	Klipriversberg Amygdaloid, Boulder Beds, and Volcanic Breccias.	
Cambrian or Pre-Cambrian	Witwatersrand	Upper Division	Elsburg. Kimberley. Bird. Main Reef.
		Lower Division	Doornfontein Slates to Orange Grove Quartzite.
Archæan		Swaziland. Intrusive Granite.	

The basal member of the lower division of the Witwatersrand System is the Orange Grove Quartzite, which outcrops as an escarpment 300 feet in height overlooking the granite to the north. There is, of course, a great unconformity in time between the igneous and the sedimentary rock, and a still greater where the basal member of the Witwatersrand System rests directly on the Swaziland schists. Overlying the Orange Grove Quartzite comes the highly ferruginous (with magnetite) Water Tower Slate, succeeded in its turn by the Ripple-marked Quartzite and by the Red Slates—soft red ferruginous beds. Next in order of upward succession is a peculiar felspathic quartzite bed, probably an original arkose. The rusty weathering of the felspar has suggested the term Speckled Bed. Above the Speckled Bed lie the Hospital Hill Slates containing, near their base, characteristically contorted and striped bands of red jasperoid quartz, white quartz and specular iron and magnetite, resembling often the "calico-rock" (banded

[a] Based on Hatch and Corstorphine, loc. cit., p. 114.

hæmatite-magnetite-quartzite) of the Swaziland schists, with which they have often been confounded, and recalling strongly the features of the Bijawar rocks of northern India. South of the slates are the Hospital Hill Quartzites, followed by the readily-weathered slates of the Doornfontein Beds and the Red Bar, completing the sequence of the Lower Division on the northern limb of the syncline. In a section across the Central Rand the width of the outcrop of the division is some 2½ miles. With a southerly dip of 45° to 85°, the individual thickness of the beds is estimated as follows :—

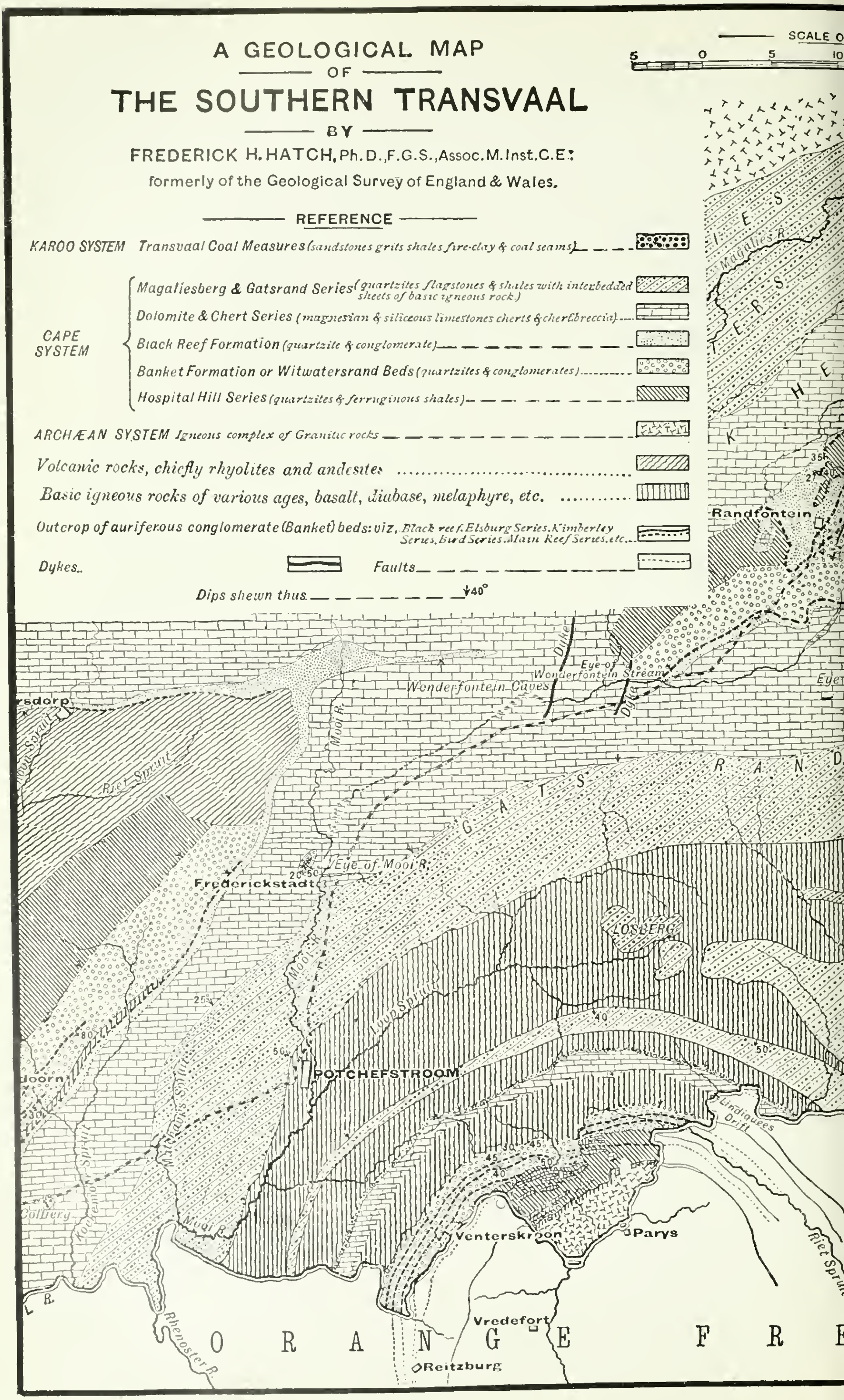
	Feet.
Red Bar	450
Doornfontein Beds (Slates and Quartzites)	5,500
Hospital Hill Quartzite	1,400
Hospital Hill Slate	620
Speckled Bed	20
Red Slate	1,800
Ripple-marked Quartzite	60
Water Tower Slate	1,400
Orange Grove Quartzite	1,400
	12,650

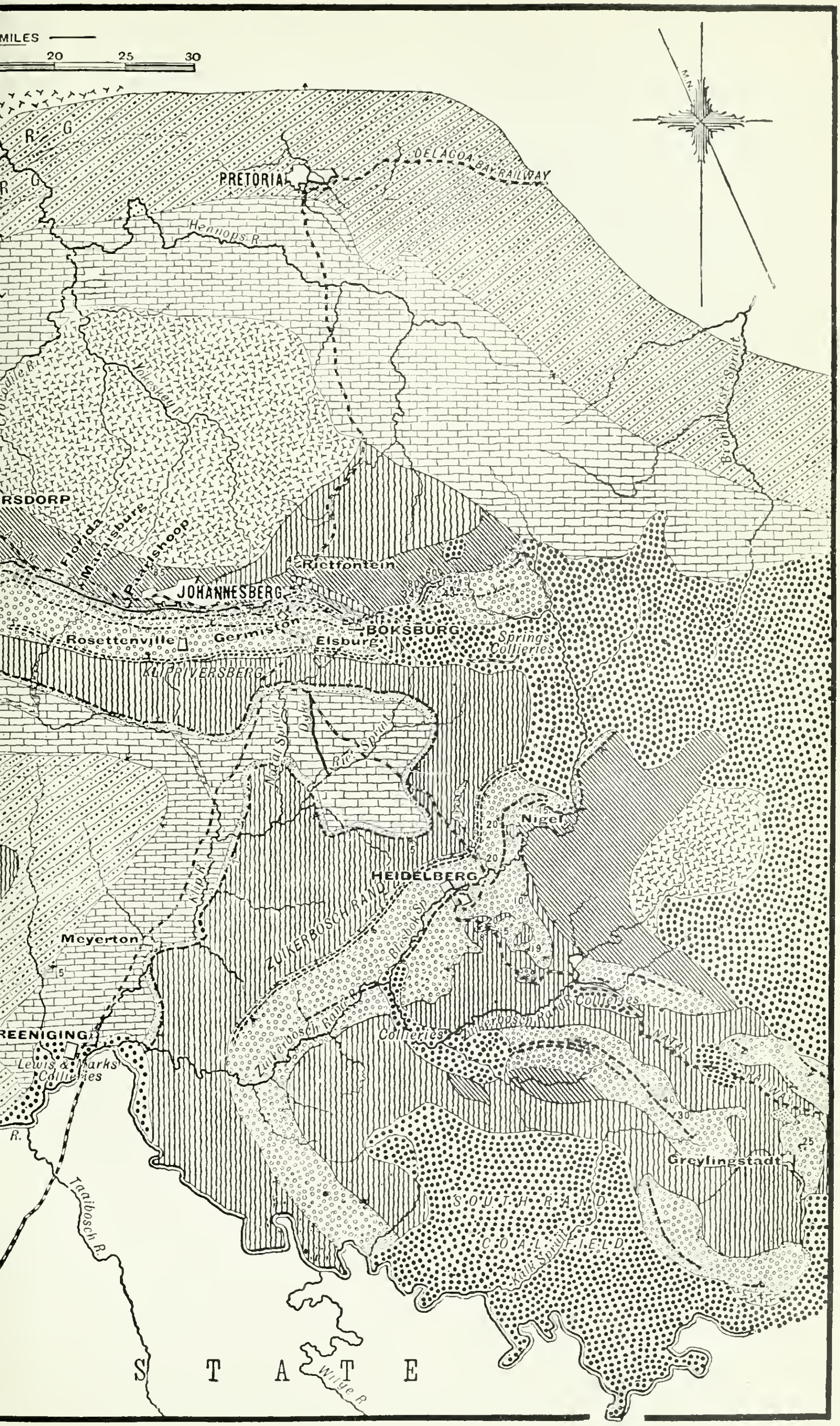
Both to the east and to the west of the above section, the thicknesses of the several beds vary considerably, and other beds, having no representatives in the foregoing section, may in other sections be intercalated.

While the Lower Division consists mainly of slates, with few coarser beds, the Upper Division, considered broadly, is made up of alternating conglomerates, grits, and quartzites, the conglomerate members carrying the auriferous content for which the beds are famous. The Main Reef Series (conglomerate), economically by far the most important member of the whole group, lies at the bottom of the division. The chief conglomerate bands of the Upper Division occur on five horizons well separated by finer quartzites and grits, and are in descending order :—

Elsburg Series.
Kimberley Series.
Bird Reef Series.
Livingstone Reef Series.
Main Reef Series.

The Main Reef Series has naturally been followed with great care, and has been traced over a length of 46 miles. Its thickness varies considerably, but may be said to range above and below 120 feet. Its pebbles are mainly of white or smoky quartz embedded in a quartzitic matrix. When considered broadly, the beds, both of


A GEOLOGICAL MAP
OF
THE SOUTHERN TRANSVAAL
BY
FREDERICK H. HATCH, Ph.D., F.G.S., Assoc.M.Inst.C.E.
formerly of the Geological Survey of England & Wales.
REFERENCE
KAROO SYSTEM Transvaal Coal Measures (sandstones grits shales fire-clay & coal seams)
CAPE SYSTEM
Magaliesberg & Gatsrand Series (quartzites flagstones & shales with interbedded sheets of basic igneous rock.)
Dolomite & Chert Series (magnesian & siliceous limestones cherts & chert breccia)
Black Reef Formation (quartzite & conglomerate)
Banket Formation or Witwatersrand Beds (quartzites & conglomerates)
Hospital Hill Series (quartzites & ferruginous shales)
ARCHÆAN SYSTEM Igneous complex of Granitic rocks
Volcanic rocks, chiefly rhyolites and andesites
Basic igneous rocks of various ages, basalt, diabase, melaphyre, etc.
Outcrop of auriferous conglomerate (Banket) beds: viz, Black reef. Elsburg Series. Kimberley Series. Bird Series. Main Reef Series. etc.
Dykes..
Faults
Dips shewn thus 40°
SCALE O
5 0 5 10
Magalies R.
Randfontein
Wonderfontein Caves
Eye of Wonderfontein Stream
Dyke
Mooi R.
Riet Spruit
G A T S R A N D
Eye of Mooi R.
Frederickstadt
LOSBERG
Loop Spruit
POTCHEFSTROOM
Mooi R.
Lindiques Drift
Venterskroon
Parys
Vredefort
Reitzburg
Rhenoster R.
Riet Spruit
O R A N G E F R E


MILES
20
25
30
PRETORIA
DELAGOA BAY RAILWAY
Hennops R.
Bronkhorst Spruit
RSDORP
Florida
Maraisburg
Rietfontein
JOHANNESBERG
Germiston
BOKSBURG
Rosettenville
Elsburg
Springs Collieries
KLIPRIVERSBERG
Rietspruit
Nigel
HEIDELBERG
ZUIKERBOSCH RAND
Blesbok Sp.
Klip R.
Meyerton
REENIGING
Lewis & Marks Collieries
Collieries
Greylingstadt
SOUTH RAND
COAL FIELD
Kalk Spruit
Taaibosch R.
Wilge R.
S T A T E

conglomerate and of intervening quartzite, assume a somewhat lenticular character, as might indeed be expected from a consideration of their origin, which is generally believed to be littoral.

In a typical section across the Central Rand, the Main Reef Series consists of three workable beds of conglomerate named, in ascending order, the Main Reef, the Main Reef Leader, and the South Reef. Other, but non-payable, conglomerate bands are found in some mines within the Main Reef series, viz., the North Reef, some 30 feet below the Main Reef; the Middle Reef, between the Main Reef Leader and the South Reef; and the South Reef Leader, about 2 feet below the footwall of the South Reef.

The Livingstone, Bird Reef, and Kimberley Series of similar conglomerates are of no present economic value. The Elsburg Series, consisting of the usual alternations of conglomerate and quartzite, succeeds the thick quartzites lying above the Kimberley Series. Whether they do so conformably is, however, a moot point. The balance of evidence appears to be in favour of an unconformity. The Elsburg Series contains gold, but not in sufficient quantities to warrant mining operations on it. The following typical sections[a] indicate the general relations of conglomerates and quartzites:—

I.—Section through the Aurora Mine.

	Feet.
Elsburg Series (including intervening quartzites) ..	3,000
Quartzites, with intervening conglomerates	4,440
Slates and Quartzites	1,450
Bird Reef Series	100
Quartzites	1,700
Main Reef Series	160
	10,850

II.—Section through Simmer and Jack Mine and the Rand Victoria Borehole.

	Feet.
Quartzites above Elsburg Series	1,400
Elsburg Series	2,800
Quartzites	1,800
Kimberley Series (including quartzite)	1,800
Slates	500
Quartzite (in part dyke)	800
Bird Reef Series (including quartzite)	300
Quartzite to footwall of Main Reef Series (including Livingstone Reef Series)	1,700
	11,100

Above the Elsburg Series, but separated from it by a great unconformity, lie the acid and basic lavas, tuffs, breccias, and conglomerates of the Ventersdorp System. The predominant basic

[a] Hatch and Corstorphine, loc. cit., pp. 123, 124.

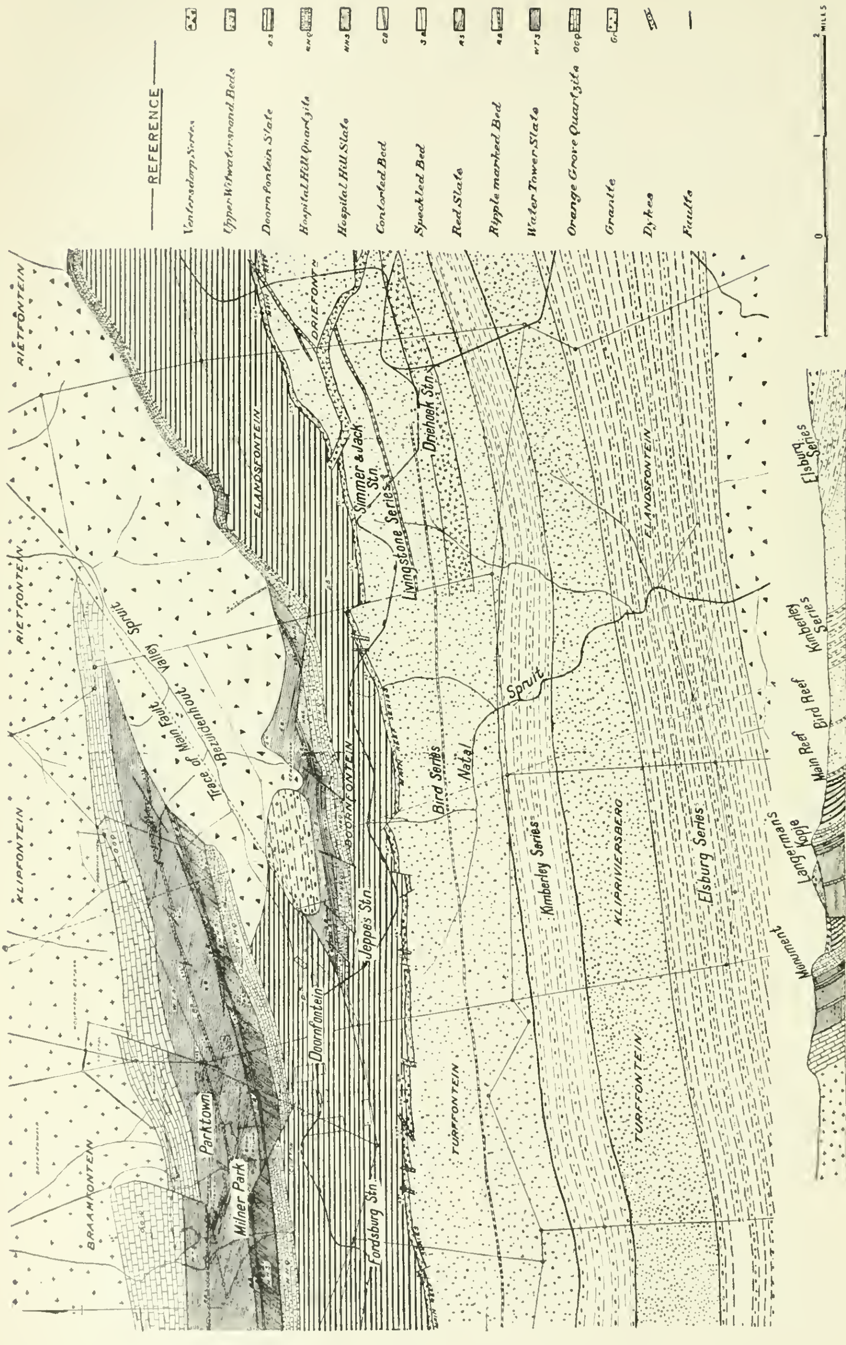


FIG. 145. GEOLOGY OF WITWATERSRAND IMMEDIATELY EAST AND SOUTH-EAST OF JOHANNESBURG (*Hatch and Corstorphine*).

lavas are amygdaloidal and porphyritic diabases (Klipriversberg amygdaloid). These are probably a later manifestation of the same volcanic energy that, during the deposition of the conglomerates and quartzites of the Witwatersrand System, laid down contemporaneously with them (as is perhaps proved by the presence of amygdaloids) extensive flows of diabase. These are especially well developed in the Eastern Rand, where one flow, lying over the Bird Reef Series, reaches a thickness of 150 feet. Basic dykes, intrusive through the Witwatersrand Beds, are numerous. They include norites and diorites.[a] The normal type is, however, an uralitised diabase.

Above the rocks of the Ventersdorp System there occur, within the area shown on the accompanying map, the Black Reef, Dolomite, and Pretoria Series of the Potchefstroom System. Of these the Black Reef Series is auriferous, but has been little worked except at Klerksdorp.

As may be seen from an inspection of the map, the Witwatersrand Beds are irregularly exposed over an area 180 miles long from east to west, and 100 miles broad from north to south. The Johannesburg mines are situated towards the north-eastern corner of this area, where the older beds have been exposed along a north-east to south-west anticlinal axis by the denudation of the Dolomite and Black Reef Series. Passing south-west from Krugersdorp along the strike of the beds, the endlong pitch of the anticlinal axis is found to carry the older beds beneath the Black Reef and Dolomite Series to reappear again some 16 miles east of Ventersdorp, as a wrapping round an Archæan granitic mass in the High Veldt. Here the sedimentary beds dip away from the granite, certainly on the north and east, and possibly also on the south-west. The south-eastern limb of this anticline, or, as it may more conveniently and simply be termed, the north-western limb of the main syncline, extends from Klerksdorp in the south-west to Boksburg in the north-east. The south-eastern synclinal limb is not so well defined as the preceding, but is nevertheless strongly exposed in the Heidelberg and Venterskroon districts, disappearing beneath younger beds along the Vaal River in the neighbourhood of Vereeniging.

The auriferous conglomerates of the Nigel Series in the Heidelberg district have been definitely identified with the Van Ryn Reef Series—the eastern continuation of the Main Reef Series beyond the Boksburg break. The most easterly exposure of the Witwatersrand beds is near Springs, but they have been proved by boreholes to continue a little farther east beneath the overlying strata,

[a] Henderson, "Petrographical and Geological Investigations of Certain Transvaal Norites, Gabbros, Pyroxenites, and other South African Rocks," London, 1898.

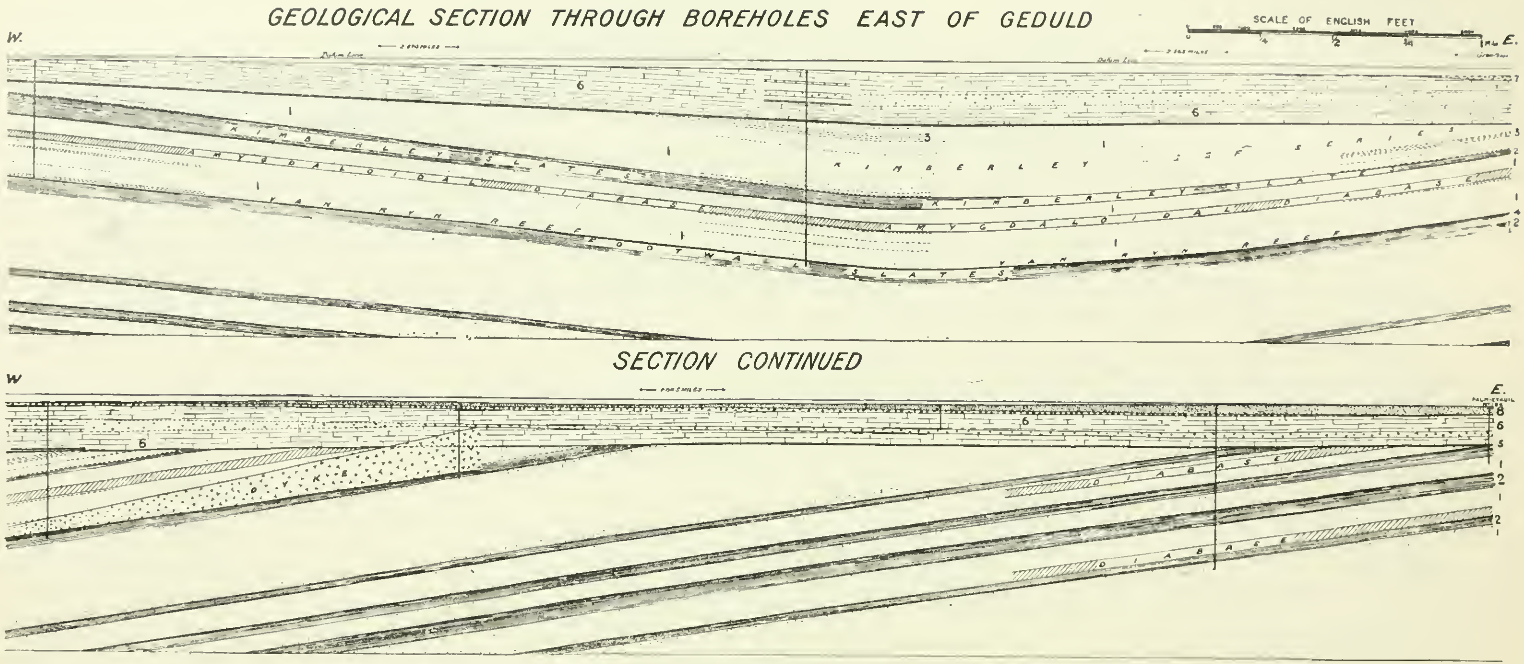


Fig. 146. Section through syncline, Witwatersrand Beds, East of Geduld (*Hatch*).

1. Quartzites. 2. Slates. 3. Conglomerates. 4. Van Ryn Reef. 5. Black Reef Series. 6. Dolomite Series. 7. Dwyka Series. 8. Ecca Series.

cutting out against a hidden granite ridge. They are here very flat, and are apparently disposed to form an eastern side to the basin.[a]

The dip of the Main Reef Series varies with the position of the cross-section. In most cases it is more than 45°, and may reach 75°, especially near the outcrop, but in depth it shows a decided tendency to flatten, and in the deeper mines the average dip is probably slightly less than 30°. The typical "banket" is com-

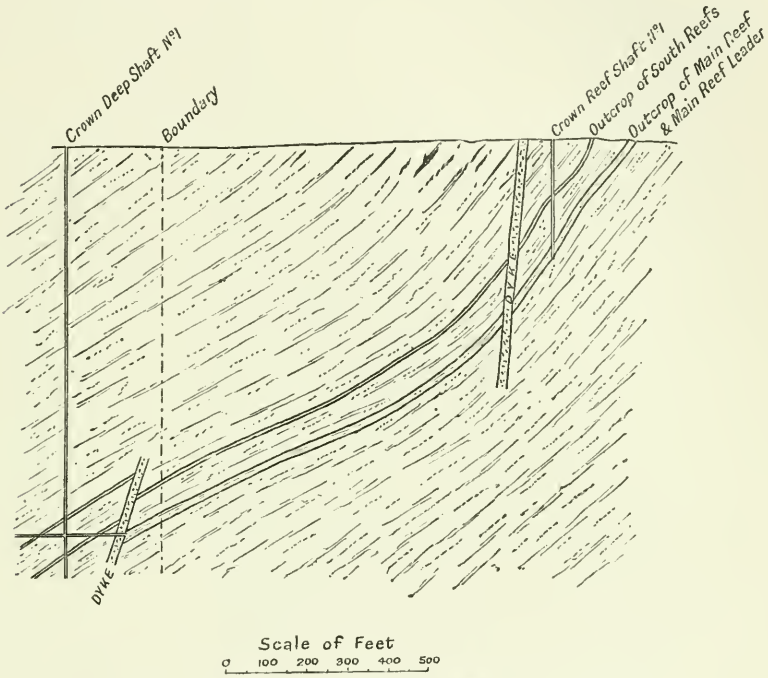


Fig. 147. Section showing Faulting of Main Reef (*Hatch*).

posed of fairly well rounded pebbles and small boulders of quartz and quartzite of an average diameter of perhaps 1 to 2 inches, together with more angular and elongated fragments of slate and chert. Becker[b] has concluded from the general shape and disposition of the pebbles that they were deposited on marine beaches, and are not river-laid conglomerates. The pebbles are embedded in a siliceous cement made up of quartz grains that are themselves cemented by siliceous impregnations, making a mass so compacted that fracturing takes place often with greater ease across than around the pebbles.

[a] Hatch, Trans. Geol. Soc. S.A., VII, 1905, p. 58.

[b] 18th Ann. Rep. U.S. Geol. Surv., Pt. V, 1897, p. 160.

The gold occurs in the siliceous cement in exceedingly fine, irregular, angular particles rarely visible to the naked eye. It is often associated with, and is found resting on, crystals of pyrite. In many cases rounded particles of pyrite may be bounded by gold particles. The rounded grains and small masses of pyrite are of interest, since they simulate rounded water-worn fragments, and have, indeed, on that account, given rise to the theory of a placer origin for the pyrite as well as for the gold of the banket. No original gold grains, or, to be precise, only a few exceedingly minute particles, have been found within the pebbles of the conglomerate, though numerous instances are recorded of secondary auriferous deposition along fracture planes within the pebbles.

Few questions relating to the deposition of gold have, of late years, been more keenly discussed than the origin of the gold of the Witwatersrand conglomerate. Various theories have from time to time been advanced to account for its widespread presence throughout the cement of the conglomerate in such relatively large quantities. Of these, two only have survived and alone demand consideration in this place. The first is the hypothesis of placer origin, which assumes that the gold is contemporaneous in deposition with the conglomerate, and that it has its representatives in modern auriferous "leads" and gravels. The second hypothesis assumes that the gold is subsequent in deposition to the conglomerate, and that it was introduced by percolating siliceous, and possibly also sulphide-bearing, waters; and that in actual mode of deposition it differs little from ordinary fissure vein filling. The arguments for the placer hypothesis were most clearly and succinctly set forth by Becker[a] in 1897, but they had previously been advocated by many writers. Of late years they have been resuscitated, with certain modifications, by Gregory,[b] who, in order to account for the extreme fineness of the gold, assumes that the original placer gold has been dissolved and re-deposited *in situ*. On the other hand, the impregnation hypothesis is strongly supported by the majority of those geologists who have had the inestimable advantage of having been brought daily into contact with the numerous problems of economic geology afforded by these conglomerates. The case for the impregnation hypothesis is outlined by Hatch and Corstorphine,[c] who summarise the main arguments in support as follows:—

(1) The gold is practically confined to the matrix of the conglomerate occurring there in association with other minerals of secondary origin; the rare cases in which gold occurs in

[a] Loc. cit. sup.

[b] Adv. Sheets, Trans. Inst. Min. and Met., 1907.

[c] Loc. cit., p. 146.

Johannesburg, from the North.

the pebbles are obviously instances of infiltrations along cracks, a fact which in itself lends support to the impregnation theory.

(2) It occurs in crystalline particles often surrounding or lying in close association with pyrite crystals or marcasite concretions, which are of secondary origin.

(3) It is uniformly distributed to a remarkable degree.

(4) It is restricted to certain definite beds.

While there is therefore much to be said on both sides, the general evidence at present available is certainly in favour of the infiltration hypothesis. The subject has been dealt with as fully as possible in an earlier section of this volume, whither the student is now referred for further details.

Heidelberg and Klerksdorp.—The Heidelberg and Klerksdorp goldfields of the "outside" districts require no detailed mention. The gold of the former is derived almost entirely from the Nigel Reef Series, which, as has already been seen, is the extension in the southern limb of the Main Reef Series, from which it indeed differs in no material respect. The Klerksdorp field, on the other hand, lies on the northern side, or, rather, the north-western side of the syncline, for the axis of folding curves here southward. Its mines have never been very successful; of them the Buffelsdoorn has been the most productive. The reefs are greatly disturbed by diabase dykes. The chief auriferous areas are those of Wolverand, Boscherand, and Buffelsdoorn. The pay-reef of the last has been 3 to 4 feet wide. In this case, however, gold also occurs in the overlying quartzite in streaks associated with carbonaceous and pyritous seams. The Black Reef Series has been extensively worked at Klerksdorp. The outcrop of banket occurring at Venterskroon, between Heidelberg and Klerksdorp, is auriferous, but is extremely low in grade.

Bloemhof.—In the extreme south-west of the colony at Bloemhof gold-quartz has been found in the banded ironstone-schists of rocks that are probably a part of the Swaziland System. The prospect of successful mining in these veins, particularly on Goudplatts Farm, was favourably regarded in 1906.[a]

Pietersburg.—Of similar character are the veins of the Pietersburg district, lying towards the north of the colony, in the area formerly known as the Marabastad goldfield. These have been spasmodically worked for many years, but have never yielded any mines of economic importance. The veins are small and

[a] Rep. Transvaal Mines Dept., 1906, p. 54.

erratic, and may be worked only by individual miners, or by small companies. The country is the Mount Maré schist or phyllite, with which is well developed the banded hæmatite-magnetite-quartz rock—the "calico rock" of the miners—so characteristic of the Swaziland schists, as, indeed, of most auriferous Archæan schistose areas. A huge mass of auriferous conglomerate is being mined at Haenertsburg, east of Pietersburg.

Zoutspansberg.—In the far north of the colony, north of the Olifants River, is the Zoutspansberg district, including the Murchison and Klein Letaba goldfields. In the former the auriferous quartz veins occur in hornblende- and chlorite-schists. Occasionally the country itself is impregnated with auriferous pyrite. Associated in the quartz with the gold are stibnite and chalcopyrite. The gold content of the veins diminishes notably in depth. The Klein Letaba field is 30 miles further north, but its veins are in Swaziland schists similar to those of the Murchison Range. The veins are parallel to the foliation. They are of little present importance.[a]

Barberton.—The Barberton (De Kaap) goldfields are by far the most important of those occurring in the Swaziland schists within the Transvaal. They lie in the neighbourhood of Barberton in the east of the Transvaal. The rocks of the district are highly tilted chloritic-schists, sericite-schists, argillites, and the characteristic banded hæmatite-magnetite-quartz rock that stands out in bold relief, and forms the serrated mountain ridges. Representatives of original sedimentary and also of igneous rocks are present. The former are black and greenish indurated shales, with thin beds of pale grey quartzites. Near the top of this series is the above-mentioned banded ferruginous rock, known to the miners of Barberton as "bacon rock." The igneous rocks are mainly sheared diabase, obviously intrusive into the older sedimentary series. The general dip of the foliation is northwards, in which direction the schists give place to a granite or to a diorite. Veins appear to have been formed for the most part along shear-zones. At the Mount Morgan mine, 12 miles south-west of Barberton, the auriferous zone is made up of small stringers of grey quartz lying in a sheared belt in the softer shales, near the laminated "bacon rock." Pyritous impregnation of the country is common, but occurs seldom in the quartzites and frequently in the black shales.[b]

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[a] Steuart, Trans. Inst. M.E., 1900, XVII, p. 338; Bordeaux, Ann. des Mines, XIV, 1898, p. 95; Merinsky, Min. Jour., 1905, p. 629.

[b] Kynaston, Rep. Geol. Surv. Transvaal, 1905, p. 61.

The Sheba, north-east of Barberton, has always been the most prominent of the Barberton mines. Its vein-zone has an average width of 120 feet, and is continuous along the strike for a great distance. The pay-ore, however, is restricted to shoots. The main Sheba shoot is 300 feet long, and has been worked for 1,200 feet on

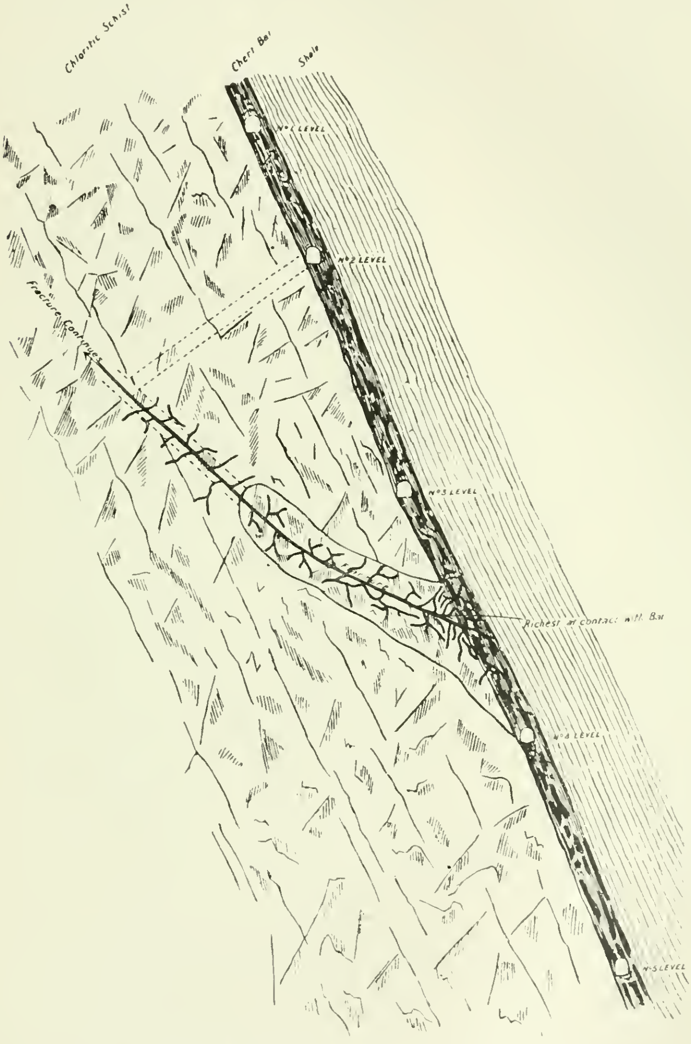

FIG. 148. ENRICHMENT NEAR CONTACT OF FRACTURE AND CHERT VEIN, ZWARTKOPJE MINE, BARBERTON (*Weldon*).

its pitch. Mineralisation in the case of the Sheba zone appears to have taken place along and beneath the footwall contact of a quartzite bed with an underlying slate, the latter having been silicified and impregnated for some depth below the quartzite.

This selective silicification was possibly due to the relative permeability of the two beds, but much more probably arose from the greater tendency of the less siliceous stratum to undergo metasomatic replacement by siliceous waters. Recent workings, as shown in the accompanying section, have been carried on in the neighbourhood of fractures from whence impregnation has proceeded.

On Moodie's Range, south-west of Barberton, well-defined fissure veins occur in chloritic and sericitic schists, intruded by dioritic or diabasic dykes. The principal veins are the Ivy and the Pioneer, both occurring along fault-planes. The gold is found in well-defined shoots in massive white quartz.[a]

An outlying auriferous area of no present economic value is the Komati Goldfield at Steynsdorp, south of Barberton. The veins of this field are also in the Swaziland schists. They are small, and have given rich outcrop yields that have not continued in depth. An auriferous quartz vein occurs in the quartzites of the Black Reef Series (the conglomerates of which are also at times slightly auriferous) at Kromdraai, ten miles north of Krugersdorp.[b]

The gold yield of the Pretoria district proper for 1907, viz., 266 ounces, was derived from a small gold-quartz vein in the Pretoria quartzites, 30 miles west of the capital.

Malmani.—Auriferous deposits in the great Dolomite Formation that underlies the Pretoria Series, occur both in the west and in the east of the colony. The locus of the former occurrence is Malmani, 20 miles north-east of Mafeking. Its gold-quartz veins strike with the formation, but dip vertically. The veins are filled either with quartz or with a brecciated dolomite cemented by quartz. Tremolite frequently occurs as a gangue mineral. The numerous carbonates and oxides found indicate the presence of blende, galena, chalcopyrite, and pyrite in depth, but the veins, owing to the great quantities of water met with, have not been worked to greater depths than 100 to 150 feet.[c]

Lydenburg.—The Lydenburg (Pilgrim's Rest) goldfields lie on the High Veldt in the east of the Transvaal in or near the great more or less meridional escarpment of the northern Drakensberg, here 2,000 feet in height. They are among the oldest goldfields in the Transvaal, their placer deposits having been discovered

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[a] Bordeaux, Ann. des Mines, XI, 1897, p. 296; Krause, Zeit. für prakt. Geol., 1897, p. 22.

[b] Dörffel, Trans. Geol. Soc. S.A., VI, 1904, p. 101.

[c] Hatch, Trans. Geol. Soc. S.A., VII, 1905, p. 3.

PENHALONGA MINES. UMTALI GOLDFIELD, RHODESIA. (Page 431.)

GENERAL CHARACTER OF COUNTRY NEAR GLYNN'S LYDENBURG MINE, TRANSVAAL. (From a water-colour.)

as early as 1868, or, according to another authority, in 1870. It is estimated that gold to the value of nearly half-a-million pounds sterling was obtained from the alluvial in the earlier years of the field. The placer deposits are now almost exhausted, but the ore-bodies from whence the alluvial gold had been derived, furnish from year to year a fairly regular yield of gold.

The Swaziland schists and granites lie along the foot of the great escarpment, some 12 miles east of Pilgrim's Rest. They are overlain unconformably by the beds of the Transvaal System, as shown in the subjoined table, in which the uppermost beds are the youngest:—[a]

Megaliesberg Quartzites	Pretoria Series.	Transvaal System.
Shales with intrusive igneous sheets		
Daspoort Quartzite Series		
Shales with intrusive igneous sheets		
Timeball Hill Quartzite Series		
Shales with intrusive rocks		
Dolomitic Limestone and Chert	Dolomite Series.	
Thin band of Quartzite		
Dolomitic Limestone and Chert		
Shaly Sandstones		
Quartzites and Sandstones	Black Reef Series.	
Shaly Sandstones		
Quartzites and Sandstones		
Older Granite		Swaziland System.

Diabasic igneous rocks are abundant, and occur both as vertical dykes traversing the nearly horizontal members of the Transvaal System, and also as sills or sheets intercalated in the strata. It is notable that elsewhere in the colony diabasic intrusions are rare in the Dolomite Series.[b] In addition to the diabase, diorite and gabbro also occur. Auriferous horizons are found both in the Black Reef and in the Dolomite Series. Those of the former, though rich near the outcrop, do not continue to carry gold when driven on, and are of no present economic importance. In the Dolomite Series, however, there are several horizons at which rich ore-bodies have been developed. These reefs are practically horizontal, their dip, when they possess any, being to the west at 5° to 7°. They appear to be siliceous replacements of interbedded dolomitic limestones, and as such are analogous to those described elsewhere in this volume from Rico, Colorado, and from Mercur, Utah.

The two principal reefs near Pilgrim's Rest are the Upper Dolomite, or Theta Reef, and the Lower Dolomite, or Beta Reef. The former is on an horizon 100 feet below the base of the Pretoria Series; the latter is 300 feet below the Theta Reef. About 20 feet above the Theta Reef is a sheet of diabase from 20 to 60 feet in

[a] Hall, Rep. Geol. Surv. Transvaal, 1906, p. 75.

[b] Thord-Gray, Trans. Geol. Soc. S.A., VIII, 1906, p. 67.

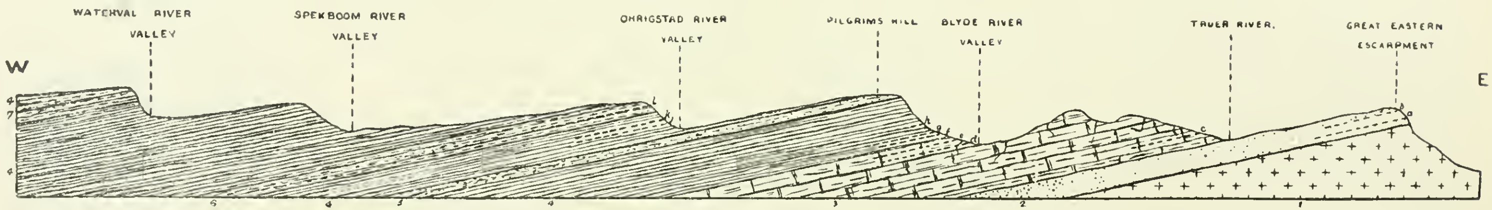
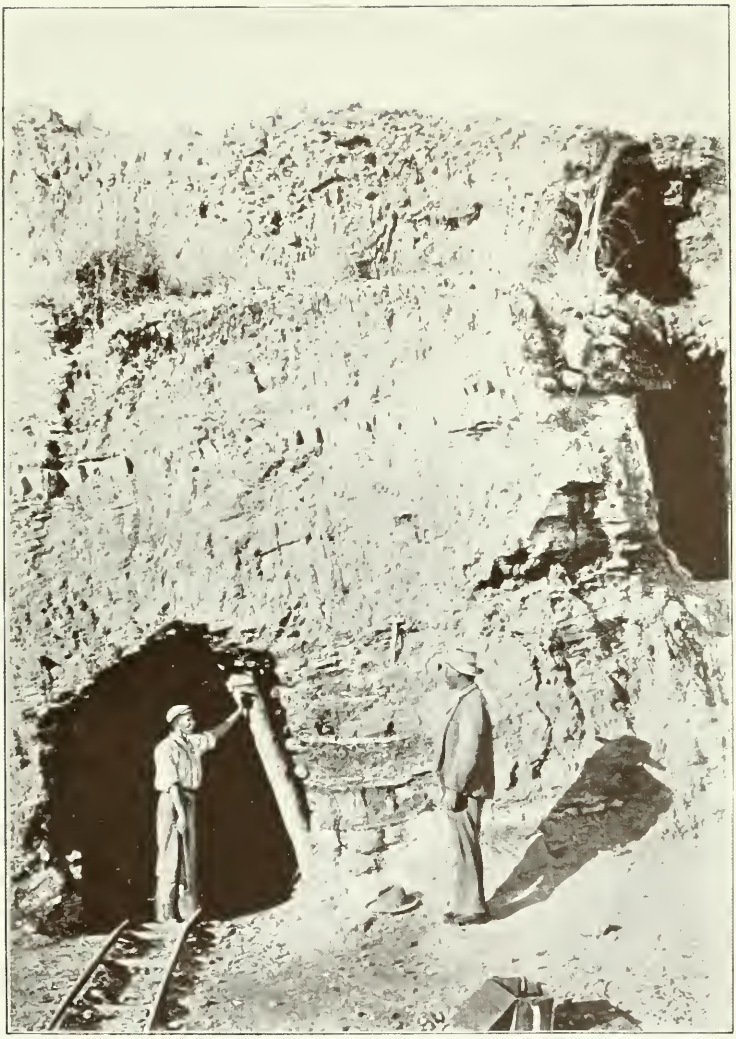


FIG. 149. DIAGRAMMATIC SECTION ACROSS THE CENTRAL LYDENBURG DISTRICT (*Hall*).

1. Older Granite. 2. Black Reef Series. 3. Dolomite. 4. Shales and Diabase. 5. Timeball Quartzite. 6. Daspoort Quartzite. 7. Megaliesburg Quartzite. *a*. Sherwell Reef. *b*. Op de Berg Reef. *c*. Glynn's Reef. *d*. Beta Reef. *e*. Theta Reef. *f*. Bevet's Reef. *g*. Shale Reef. *h*. Languages Reef. *j*. Davidson's Reef. *k*. Button Reef. *l*. Finsbury or Sterkspruit Reef.



THETA REEF, CLEWER MINE, PILGRIM'S REST.
(Transvaal Geological Survey.)

(Thickness of reef: from feet of figures to hammer-head; Dolomite and Chert series overlying.)

thickness, which overlies almost directly a thin quartz seam known as the "indicator." The same relation of auriferous horizon to diabase sheet is observable in the case of the Beta Reef, where the diabase sill is only some 10 feet overhead and the intervening space is occupied by black earthy manganese ores underlain by chert. The already mentioned veins in the Black Reef Series are likewise associated with diabase sills.

The Theta Reef varies in thickness from an inch or two to 12 to 15 feet. Where thickest it has often been richest. Since it is nearly horizontal, it has been worked on a longwall system, similar to that employed in blocking out flat coal seams. In places the Theta Reef was very rich, assaying more than 50 ounces gold per ton. The length of the outcrop of the Theta Reef along its strike is at least 20 miles, while those of the various reefs in the Dolomite Series taken together are estimated by Thord-Gray to reach 90 miles. The pay-ore is whitish-yellow to rusty-brown quartz. As is evidenced by the honeycombed and cellular character of the quartz pyrite was formerly present in some quantity. The vein occasionally becomes earthy in character, a feature considered to be indicative of high values. The principal mines working on these reefs are the Clewer, Peach Tree, Theta, and Jubilee on the Theta Reef; and the Beta, Chi, and Psi on the Beta Reef. The Clewer mine has been the most productive.

Twenty miles south of Pilgrim's Rest is the Glynn's Lydenburg mine, situated on the Sabie river. The geological features are here similar to those at Pilgrim's Rest. Two auriferous horizons are known in the Dolomite Series, of which the upper reef, 150 feet above the Kantoor sandstone, is the more important. It is about 12 inches thick and consists of a series of quartz layers separated by partings of impure brown limonite. Visible gold is rare. One of the most characteristic features in connection with the ore-body is the presence of a chert band 18 inches below the footwall of the reef, the intervening rock being composed mainly of brown earthy limonite. The average assay value of a portion of the reef was 38 dwts. gold over a thickness of 15 inches.

Somewhat similar auriferous occurrences are those of Barrett's Berlyn and Coetzestroom. The denudation of these and similar ore-bodies furnished the placer gold of Mac-Mac, Kaapsche Hop, and Spitzkop. At the Duivel's Kantoor they furnished particles and large masses of highly crystalline gold, the latter varying in weight from 1 dwt. to 50 ounces. The gold was associated with quartz and with pseudomorphs of limonite after pyrite. The gold itself also formed encrusting pseudomorphs after pyrite.[a]

[a] Louis, "Ore Deposits," London, 1896, p. 737.

A little placer gold has been obtained in the Kaap, Queen's, and Crocodile rivers, and a dredge was working in 1907 below the junction of the Queen's and the North Kaap rivers.

At Vryheid a little alluvial gold has been obtained. It results from the degradation of "banket" reefs of the Witwatersrand type.[a]

Swaziland.—The Swaziland Protectorate has produced a considerable amount of gold, mainly from Forbes Reef, east-north-east of Steynsdorp, and from the MacLachlan and Pigg's Peak mines, south-west of Barberton, and across the boundary from the Transvaal. The first-named is a low-grade open-quarry mine in slates traversed by auriferous quartz veins. Its tenor is only 3 to 4 dwts. per ton. To 1896 it had, nevertheless, produced 36,000 ounces. The Pigg's Peak occurrence, lying south-east of Barberton, is in an impregnated quartzitic rock, and at times yields rich chimneys and pockets. In 1890, 60 tons yielded 3,000 ounces, but the general tenor is certainly less than half an ounce. The MacLachlan Reef lies in schists veined with quartz.[b]

During 1906-1907 the gold yield of Swaziland was 2,166 ounces.

NATAL.

Gold-mining is of little present importance in Natal. Small gold-quartz veins have from time to time been found, and have given pockets at the surface that have raised hopes of permanence in depth —hopes that have never been realised.

Natal is divided for administration purposes into four mining districts. In the Northern district gold is found along the Pongola river. The Pongola goldfield, east of Paulpietersburg, as well as the small goldfield on the Mona tributary of the Black Umfulosi, is in a conglomerate or "banket" formation, very similar to that of Witwatersrand. Similar gold occurrences are noted from the Insuzi Valley, and from the neighbourhood of Melmoth to the east.[c] They were widely prospected about 1895, but without result. At the Nondweni goldfield on the White Umfulosi, and also near Melmoth, gold-quartz is found in Archæan schists.

In the Eastern district, "banket" reefs occur in the Nkandhla district between the White Umfulosi and the Tugela rivers. Gold-quartz veins are found in the crystalline schists that flank the granites in the neighbourhood of Nkandhla. The principal auriferous

[a] Denny, Trans. Aust. Inst. M.E., III., 1896, p. 88.

[b] Bordeaux, Ann. des Mines, XI, 1897, p. 299.

[c] Hedges, Rep. Mines Dept. Natal, 1903, p. 41; Anderson, 2nd Rep. Natal Geol. Surv., 1904, p. 134.

Mill Creek, Frankfort, Transvaal.
(Transvaal Geological Survey.)

A. Bevet's Reef. B. "Theta" (Beta) Reef.

areas in the foregoing districts are Upper Insuzi, Lower Insuzi, Vungwini, Melmoth, and Eshowe. At Signal Hill, close to Eshowe, wire-gold has been found in the schists.

In the South-western district, at Chaka's Kraal, reefs occur in Palæozoic sandstones.[a] These veins were rich at the surface, but gave out in depth. Near Chaka's Kraal a slightly auriferous conglomerate has been found, which did not yield anything of promise on further prospecting. The veins of the Umzinto goldfields traverse schists and gneisses of the Swaziland Series. The quartz was pyritous, but carried free gold near the surface. The veins were extremely irregular in extension and content. A crushing made in 1892 yielded about 29 ounces from 60 tons quartz. The field is now abandoned. The small Dumisa goldfield in the south was in 1907 the only gold-producing field. In that year it yielded about 800 ounces.

Natal in 1904 produced no gold. In 1905 its yield was only 108 ounces, and in 1906 some 73 ounces.

GERMAN SOUTH-WEST AFRICA.

Gold is known in trifling quantities from many widely separated water-channels in German South-west Africa. Its principal occurrences are, however, in veins associated with sulphides. It has been reported from the Lower Kuisib (near Walfisch Bay), associated with bismuth and wolfram.[b] Voit,[c] however, failed to find bismuth or wolfram in the so-called wolfram-bismuth veins of Usis. Gold is widely distributed with copper sulphide in the amphibolitic members of the metamorphic schists and gneisses (Namaqualand schists), which are the dominant rocks of the country. These auriferous occurrences are situated at Hussab, on the right bank of the lower Swakop; at the Pot mine, further up the Swakop; and in the neighbourhood of Otyikango (Barmen), far up the Swakop near Windhoek. Kuntz[d] found near Rehoboth, south of Windhoek, samples of copper-ore giving 62 per cent. copper and 11 dwts. gold per ton. The amount of ore available was trifling. In other auriferous veins, the gold-content is much less, being generally about 2 dwts. per ton. The free gold found at the outcrops of the veins is itself due to decomposition of the pyrites, and to secondary surface enrichment, since even the low tenors noted decrease materially with increase of depth.

[a] Anderson, 1st Ann. Rep. Natal Geol. Surv., 1901, p. 92.
[b] Macco, Zeit. für prakt. Geol., XI, 1903, p. 30.
[c] Trans. Geol. Soc. S.A., VII, 1905, p. 88.
[d] Trans. Geol. Soc. S.A., VII, 1905, p. 74.

CAPE COLONY.

Traces of gold occur in several places within the limits of Cape Colony. An interesting occurrence of gold is from near Craddock, where it is associated with prehnite in nests in volcanic rocks.[a] Auriferous veins have also been reported from this neighbourhood.

Two well-known occurrences of more than mineralogical importance are, however, those of the Millwood goldfield, Knysna district, and the Prince Albert goldfield further north across the Olifants River and the Zwarte Bergen. The former lies in the Outeniqua Mountains, very near the south coast of the colony. Its gold-quartz veins traverse both the Table Mountain sandstones and the conformably overlying slates.[b] In the latter, the veins are massive and continuous, containing pyrite and chalcopyrite. They are parallel to the strike of the beds, and dip in the same direction, but at a slightly greater angle. In the sandstone the veins are much more variable in size and extension. The quartz of the Table Mountain sandstone contains gold, pyrite, blende, galena, and sometimes carbonate of iron. The mineral content of these veins would appear to have been derived from a bed of auriferous conglomerate that occurs near the top of the Table Mountain series in the immediate vicinity. Assays of this conglomerate have given as much as 2 dwts. per ton. It is, however, exceedingly hard and indurated. It dips under the Bokkeveld slates reappearing on the other side of the syncline.[c] From the proclamation of the fields in 1887 to March, 1905, 3,370 ounces had been registered as coming from the placer deposits derived from the above-described veins. Schwartz concludes with some justice, that the nuggets have grown *in situ*, and have not been derived as such from the reefs. Alluvial gold occurs in the Poverty Flats, an old river gravel, and also in both the rivers draining the Millwood area, viz., the Gowkamma (Homtini) and the Knysna.

The Prince Albert goldfield is entirely a placer field. The first nugget was picked up there in 1871. It weighed 2½ ounces, and was found among the earth that had been thrown out by an aardvaark digging a hole. In 1891 another nugget of 7 dwts. was found, and the area was then proclaimed a goldfield. The yield was, however, very small, only 504 ounces having been obtained to the end of the year 1891. The gold area is itself on the Karroo formation, one that, so far as is known, carries no gold-veins. It is, therefore,

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[a] Louis, Jour. Min. Soc., X, 1893, p. 245.

[b] Schwartz, Trans. Phil. Soc. S.A., XV, 1904, p. 43; Id., Geol. Mag., Dec., V, II, 1905, p. 369; Sawyer, Parliamentary Rep., Cape Colony, G. 45, 1893.

[c] Schwartz, Geol. Mag. cit. sup., p. 375.

considered probable that the gold has been originally derived from the Table Mountain sandstone of the Zwarte Bergen to the south, from, indeed, such auriferous conglomerates as have been described as occurring in the Knysna area.[a]

Rogers[b] records the finding of a solitary nugget of gold in the Witteberg (Cape) beds at Kragga Poort, near Constable.

Cape Colony produced 98 ounces gold in 1905, and 291 ounces in 1906.

[a] Schwartz, Trans. Phil. Soc. S.A., XV, 1904, p. 56.

[b] "Geology of Cape Colony," London, 1905, p. 145.

NORTH AMERICA.

BRITISH NORTH AMERICA.—NEWFOUNDLAND.

Several auriferous localities are marked on the large-scale map of Newfoundland, issued by the Geological Survey Department of that island.[a] The Rose Blanche gold-quartz veins are on the south coast, 30 miles east of Cape Ray. They are of great size, but are low-grade. The country of the veins is of Laurentian age, and granites are intrusive in the neighbourhood. Twenty miles further east, and still near the coast, are the bornite deposits of Cinq Cerf, which, near the surface, contained free gold in very coarse flakes. The deposit is not now worked.

The gold yield of Newfoundland is at present confined to that recovered as a by-product from the important copper-ores of Tilt Cove, Baie Verte, York Harbour, &c., containing about 1·5 dwts. gold per ton. On this basis the total annual yield of Newfoundland is estimated at between 6,000 and 7,000 ounces fine gold.[b] The rocks of the district form a complex of metamorphosed Archæan serpentines, diorites, and dolerites, through which granite is intrusive. Veins in similar rocks were worked during 1906 for their gold content at Goldenville on Ming's Bight, between White Bay and Notre Dame Bay, in the north of the island. No crushings have as yet been made from Goldenville, but tests show a value of 44s. 6d. ($10.68) per ton. At Sopp's Arm, near the head of White Bay, auriferous veins occur near the junction of Silurian and Cambro-Silurian rocks. Through the latter, basic igneous rocks are intrusive. The veins have been worked on a small scale, but were abandoned in 1905, when their tenor had fallen to 3 dwts. per ton.

DOMINION OF CANADA.

The history of gold in Canada is almost entirely confined to the second half of the nineteenth century. Though the gold of the Chaudière region in Quebec was known as far back as 1823, it was only with the alluvial discoveries of the Cariboo district in British Columbia in 1857, and the opening of the gold-quartz mines of Nova Scotia in 1860, that Canada may be said to have entered the ranks

[a] Howley, Toronto, 1907; Scale, 1 inch = 6·9 miles.

[b] Howley, Min. Statist. Newfoundland, St. Johns, 1905, p. 18.

of gold-producing countries. Broadly speaking, the placer and the vein deposits of Canada are well separated. Of the former only three are of importance, and these all lie in the far west, or the far north-west, of the Dominion, and on the Pacific slope of the continent. All three, Klondyke, Atlin, and Cariboo, present the same general features. The richer gravels are Tertiary. The deposits of the latter two have been profoundly affected by glacial agencies, sometimes suffering erosion from the ice-sheet, sometimes being buried deep below glacial debris. The Canadian vein-deposits lie also in three main regions ; in southern British Columbia, where they owe their origin to the Upper Mesozoic and Lower Tertiary vulcanicity that has, further south, given so many rich gold, silver, and copper fields to the Western United States ; in Ontario, where they may be said to mark the northern limit of the great Appalachian metalliferous belt ; and in Nova Scotia, where they present a remarkable vein type, paralleled only on the Bendigo goldfield of Australia. The western vein-deposits have also been markedly affected during the glacial epoch. If ever they possessed zones of surface enrichment, and that such was the case is at least doubtful, these have disappeared before the great ice-plane. The outstanding feature of Canadian ore-bodies—a feature that must be due largely also to post-glacial climatic conditions—is therefore their lack of secondarily enriched oxidation zones.

The gold-yield of Canada from the year 1895, when the Yukon fields were discovered, is shown below.[a]

GOLD PRODUCTION OF CANADA.

Year.	Fine Ounces.	Value, Dollars.	Value, Sterling.
1895	100,806	$2,083,674	£427,153
1896	133,274	2,754,774	564,729
1897	291,582	6,027,016	1,235,538
1898	666,445	13,775,420	2,823,961
1899	1,028,620	21,261,584	4,358,625
1900	1,350,176	27,908,153	5,721,171
1901	1,167,320	24,128,503	4,946,343
1902	1,032,253	21,336,667	4,374,017
1903	911,639	18,843,590	3,862,936
1904	796,445	16,462,517	3,374,816
1905	700,863	14,486,833	2,969,801
1906	581,709	12,023,932	2,464,906
1907	401,000*	8,264,765	1,704,276
	9,162,132	$189,357,428	£38,828,272

* Estimated.

[a] Ann. Rep. Geol. Surv. Canada, 1904, p. 8; Min. Industry, 1906, p. 886.

FIG. 150. GEOLOGY OF NOVA SCOTIA, SHOWING DISTRIBUTION OF AURIFEROUS SERIES.

NOVA SCOTIA.

The auriferous rocks of Nova Scotia are confined to a broad belt lying along the south or Atlantic coast, not only of the mainland, but also of Cape Breton. In the latter division, however, they reach as far north as Whycocomagh, north of Bras d'Or Lake, and are, moreover, in strata of greater age (pre-Cambrian) than those of the mainland. The earliest recorded discovery of gold in Nova Scotia occurred in 1860, and appears to have been another of the direct results of the world-wide prospecting engendered by the great gold discoveries in California in 1849, and in Australia in 1852. The gold-quartz veins first worked were those of Tangier, on the coast some 40 miles east of Halifax.

The auriferous zone of the mainland extends from Cape Canso in the east to Bear Cove and Cape St. Mary on the west, a distance of 280 miles. Its greatest width across the strike of its stratified rocks is 75 miles, along a line south-east from the head of St. Mary's Bay, in the extreme west of the peninsula. The average width of the auriferous zone is much less, and may be taken at 30 miles. Of the total area, quite one-half, or some 3,000 to 3,500 square miles, is composed of granite, which is practically non-auriferous. The remainder of the region is occupied by a single series of sedimentary strata referred by most authorities to the Lower Cambrian, and, indeed, resembling closely the Lower Cambrian bed-rock of the auriferous alluvial gravels of the Chaudière in Quebec.

The granite is younger than, and was intruded into the sedimentaries towards the close of the Silurian (Oriskany).[a] From the highest to the lowest the various members of the series appear to be conformable. Their total thickness is more than 15,000 feet. The series has been named by Woodman[b] the Meguma Series. Together with other geologists, he divides the beds into two formations—an upper, about 4,000 feet in thickness, made up almost entirely of dark-coloured soft slates, and termed the Halifax formation, and a lower, or Goldenville formation, 11,000 feet thick, composed mainly of quartzites, but containing numerous beds of slate and a few conglomerates. This nomenclature has apparently been accepted by Faribault,[c] to whom the greater part of the detailed geological work that has been carried on in Nova Scotia is to be ascribed. The Halifax or upper formation is not notably auriferous. All the gold-quartz veins hitherto worked have been in the Goldenville

[a] Faribault, Jour. Canad. Min. Inst., II, 1899, pp. 119, 162; Id., Mining Soc. Nova Scotia, Halifax, 1900.

[b] Amer. Geol., XXXIII, 1904, p. 365.

[c] Loc. cit. sup., p. 369.

formation, and more especially in a zone about 5,000 feet in thickness, and from 2,800 to 8,000 feet below the base of the Halifax formation.[a]

The whole Meguma Series has been thrown into a series of somewhat sharp, more or less parallel, folds by pressure along a meridional or a north-west—south-east line. The distance between the anticlinal axes varies considerably, but an average distance appears to be about three miles, since eleven anticlines occur, for example, in a distance of 35 miles between Sheet Harbour and

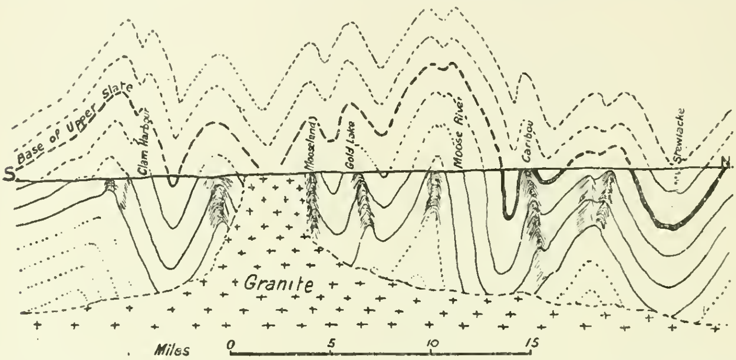

Fig. 151. Diagrammatic Section across Auriferous Rocks of Nova Scotia (*Faribault*).

Caledonia. The dips of the strata are generally from 75° to 90°, and are rarely under 45°. The anticlinal axes are characterised by the occurrence of structural elliptical domes of varying extent, from which the strata pitch both ways on the strike. These domes occur along the anticlinal axes at distances varying from 10 to 25 miles, and on them nearly all the auriferous districts are situated. Of 21 such domes mapped by Faribault in the district east of Halifax, no less than 14 have been worked for gold, while six show auriferous quartz, and the remaining dome has not yet been proved.

As the sedimentary beds were being folded, a considerable amount of slipping and sliding took place, especially at the contact between beds of different composition, as between quartzite (locally termed " whin ") and slate. A section across an anticlinal axis will therefore show the various beds disposed in a vertical series of super-imposed parabolic curves with intervening spaces. It is filling these original spaces and along their steeper lateral continuations that the Nova Scotian quartz veins have been developed. Normally they occur between slickensided planes of contact of slate and quartzite, but they are also found entirely within slate beds and, much more rarely, entirely within beds of quartzite. The quartz veins have often an extension in strike of many thousands of feet,

[a] Gilpin, "Minerals of Nova Scotia," Halifax, 1901, p. 20.

while they have been worked to vertical depths of 700 feet. They are often numerous on both sides of an anticlinal axis. At Goldenville no less than 55 veins are known to the north of the axis within a width of 1,300 feet, while 50 occur on the south side within a belt 500 feet wide. The Nova Scotian gold-quartz veins, are therefore entirely similar in form to the more famous " saddle reefs " of Bendigo. In the Salmon river district, a thick vein was worked on the crest of the anticline. On being followed down, it split a few feet from the surface into two " legs," both of which thinned in depth. Owing probably to the great denudation to which the country has been subjected, and to the great number of parallel veins exposed

FIG. 152. ROLL IN NIGGER VEIN, TANGIER (*Packard*).

at the surface, no serious attempt has as yet been made to explore the " centre country " after the Australian fashion, viz., by sinking shafts on or near the anticlinal axis.

Ordinarily, the veins are contact-bedded veins, but cross veins or droppers from the bedded veins (locally termed " angulars ") are met with. These are, as a rule, parallel with the strike, but cut across the dip of the strata. The average thickness of the richer veins, both bedded and cross, is from 1 to 2 feet only, but a thickness of 15 feet may be attained.

By far the most remarkable phenomenon displayed by a Nova Scotian gold-quartz vein is a peculiar crenulation or corrugation of its whole width. The corrugation varies from broad open folds to close overturned ones, and the degree of crumpling may be said to vary inversely as the thickness of the vein. The cross veins are also crenulated, but not so frequently as bedded veins. Corrugation is also less frequent in veins in thin bedded quartzite than in slate. It never occurs in thick bedded quartzites. Where the corrugations are well marked and large, the terms " barrel quartz " or " rolls " are used.[a] The corrugations then present the appearance of a number of barrels or logs of wood laid side by side. The corrugations are normally horizontal, and lie with their length parallel to

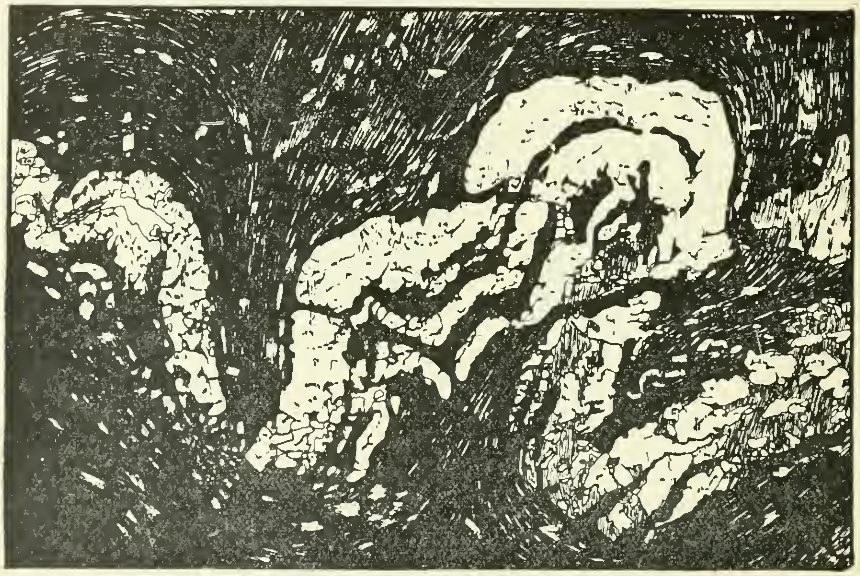

Fig. 153. Crenulated Quartz Vein, Moose River District, Nova Scotia.

the axis of the anticline. They are, however, inclined somewhat to the horizon when on the pitch of a dome. The lamination of the adjacent slates follow very closely the corrugations of the quartz vein. Woodman[b] maintains that the phenomenon is certainly not due to sliding or to metasomatic replacement, and believes it to arise from the sinuous course of the fissures in which the quartz has been deposited. Faribault, on the other hand, supposes the corrugations and foldings of the quartz veins to be due to the differential

[a] Packard, Min. Sci. Press, Oct. 5, 1907.

[b] Proc. Trans. Nova Scotia Inst. Sci., XI, 1903, p. 67.

movement of thick beds of quartzite, thus crumpling, curving, and buckling the intervening softer slate beds with their contained quartz veins.

It seems at least to be certain from the distortion and shearing of the pyrite of the slates that mineralisation was complete before general metamorphism, which is entirely dynamic, took place. The granites of the region took no part in the formation and mineralisation of the quartz veins, which were formed before the igneous intrusion.

The vein matrix is always quartz. Pyrite, chalcopyrite, galena, and blende are fairly common in veins, while pyrite and arsenopyrite also occur in the country, especially in the slates. Gold occurs both in the sedimentary rocks and in veins. In the former it is found rarely in the " whin " or quartzite, more often as thin plates in slate. In veins it is of economic importance only when it occurs in " shoots," or " pay-streaks," or pockets. Often the gold is richer in the " rolls " or swellings, in which case the pay-streaks are also horizontal or slightly inclined, and parallel to the anticlinal axis. The pay-streaks vary in width from 20 to 60 feet.

Stibnite and native antimony veins were discovered in 1880 at West Gore, Hants County, north-east of Halifax. It was only after the stibnite had been worked and exported for some years that its auriferous character was discovered.[a] Most of the gold is free, even in ore assaying 10 ounces per ton. The veins are being worked by the Dominion Antimony Company, which in 1905 shipped to England 527 tons, and in 1906 782½ tons antimony ore, obtaining therefrom 1,233 and 1,032 ounces fine gold respectively.

The Cape Breton auriferous occurrences are interesting as occurring in rocks older than those of the mainland. At Middle River, Whycocomagh, and Cheticamp districts, heavily mineralised zones occur in the pre-Cambrian schists. In 1907 rich ore was found in the first-named district by the Great Bras d'Or Mining Company, and considerable hopes are entertained of successful mining in these rocks. As they may be presumed to underlie the rocks of the mainland, it may have been from them that the latter derived by ascending solutions their metalliferous content.

At Gay's River a Lower Carboniferous conglomerate overlying the auriferous slates is known to contain gold, and has, indeed, been worked on a small scale.[b]

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[a] Jour. Min. Soc. Nova Scotia, VI, p. 80; Rep. Dept. Mines Nova Scotia, 1905, p. 69; Ib., 1906, p. 68.

[b] Becker, U.S. Geol. Surv., 18th Ann. Rep., 1896-7, Pt. V, p. 178; Poole, Proc. Trans. Nov. Scot. Inst. Sci., XI, 1904, p. 236.

Alluvial gold exists in most of the streams flowing over or from the auriferous vein areas. These gravels have never been of great economic importance. The alluvial gold appears to have been derived, not only from the free gold of the above-described veins, but also, and particularly in the Cape Breton pre-Cambrian area, from auriferous pyrite of a grade too low to warrant working under existing circumstances. A remarkable instance of wave concentration occurs at the Ovens, near Lunenburg, about 35 miles west-south-west of Halifax. Gold-quartz veins are there exposed in cliffs of soft easily-eroded slates. The gold derived therefrom is concentrated by wave-action in rifts in the slate shelves formed by denudation. In 1861-2 no less than 2,500 ounces were thus recovered, and small quantities have since been obtained from time to time.

The principal districts now being worked are Mount Uniacke, Renfrew, Oldham, Waverley, and Montagu, all near Halifax, to the north and to the east ; Caribou, Tangier, Salmon River, Sherbrooke, Wine Harbour, and Stormont, towards the east of the peninsula ; and Middle River, near Bras d'Or Lake, Cape Breton.

The following table shows the gold production of Nova Scotia by districts between the years 1862-1905 inclusive.[a]

NOVA SCOTIA GOLD PRODUCTION, 1862-1905.

District.	Tons Crushed.	Total Yield. Ounces.	Value. Sterling.
Caribou and Moose River, from 1869 ..	179,090	53,424	£208,086
Montagu	28,939	41,865	163,063
Oldham	52,394	56,139	218,662
Renfrew	52,149	44,991	175,241
Sherbrooke (Goldenville)	294,846	152,055	592,255
Stormont	305,795	86,335	336,273
Tangier	50,542	23,922	93,176
Uniacke, from 1866	62,971	43,438	169,293
Waverley	155,520	69,981	272,574
Brookfield, from 1887	92,754	38,441	149,729
Salmon River, from 1883	118,440	41,700	162,420
Whiteburn, from 1887	6,831	9,758	38,006
Lake Catcha, from 1882	26,724	26,352	102,640
Rawdon, from 1887..	12,189	9,606	37,416
Wine Harbour	70,205	33,562	130,723
Fifteen Mile Stream, from 1883	36,456	17,059	66,444
Malaga	20,896	19,294	75,148
Other districts	121,908	66,782	260,118
	1,688,649	834,704	£3,251,167

[a] Ann. Mines Rep. Nova Scotia, 1906, "Economic Minerals," p. 15.

TOTAL YIELD OF GOLD OF NOVA SCOTIA FROM 1862.

Years.	Crude Ounces.*
1862–1870	177,549
1871–1880	133,058
1881–1890	196,067
1891–1900	237,048
1901	30,537
1902	28,279
1903	25,198
1904	14,280
1905	15,549
1906	14,079
1907	15,006
	Total.. 886,650 = £3,452,500

* Average value per crude ounce, £3·895 = $19.

NEW BRUNSWICK.

Alluvial gold in small quantities has been found in several streams in New Brunswick, and more particularly in the tributaries of the Tobique and the Little South-west Miramichi rivers. The rocks of the neighbourhood are Cambro-Silurian, underlain by quartzites, slates, and glossy phyllites of probable Cambrian age.[a] No auriferous veins have as yet been discovered in this neighbourhood, but from the resemblance of the rocks to those of the Chaudière region of Quebec and to those of Nova Scotia, together with the existence of alluvial gold, their occurrence is considered probable. Gold-quartz veins are, however, known further south at St. Stephen, near Woodstock, where they occur in graphitic slate. These veins are apparently of no economic importance. At Lauwigewank certain conglomerates are slightly auriferous.[b]

QUEBEC.

The gold-bearing region of south-eastern Quebec (Eastern Townships) lies mainly along the upper waters of the Chaudière and its tributaries. The Chaudière joins the St. Lawrence from the south about 8 miles above Quebec. Though discovered only some 80 years ago this goldfield is the oldest in Canada. The first gold appears to have been obtained in 1823 or 1824 near the mouth of the Gilbert river. Ten years later a nugget weighing 2·2 ounces was found some distance further down the Chaudière. Mining operations were not, however, commenced until 1847, but partly

[a] Bailey, Ann. Rep. Geol. Surv. Canada, X, N.S., 1897, p. 37M.

[b] Ann. Rep. Geol. Surv. Canada, 1890-1, p. 146.

owing to inexperience and extravagance and partly from the irksome seigneurial restrictions under which work had to be carried on, the earlier workings were futile and only desultory attempts to recover the placer gold were made during the next 16 years. In 1863 very rich gravels were found on the Gilbert river. Four men are reported to have obtained, by simple panning, 72 ounces of gold in one day, a yield equivalent to 18 ounces per cubic yard. A nugget found at that time weighed 10 ounces. The richer gravels were panned and the poorer treated in "long-toms" or short sluices. One of the latter returned 12 ounces in one day and 10 ounces another day. The news of these rich deposits soon spread and a considerable number of men engaged in the work. About that time it was officially recorded that gold to the value of £29,231 ($142,581) had been obtained. Two large nuggets, one of 52·55 ounces and another of about 42 ounces ($821.56 value), were included in the foregoing return. At that time also, alluvial mining in the frozen ground was practised in winter. Alluvial washing has since been carried on intermittently. In 1900, and also in 1906, no gold was produced. Owing to the nature of the leases under which the Chaudière alluvials have been worked, it is difficult, and perhaps now impossible, to obtain accurate returns of the total gold produced. The Gilbert valley alone is estimated to have yielded, between 1862 and 1894, more than £200,000 ($1,000,000) gold. Messrs. Lockwood & Co., from 1868 to 1894, obtained from the Chaudière 3,664 ounces gold, while other parties working on Lockwood's leases between 1876 and July 1st, 1880, recovered gold to the value of £88,725 ($432,806). The Canada Company, from July 1st, 1880, to June, 1887, obtained 8,926 ounces. The total value of the gold recovered from the Eastern Townships to date has been estimated at £400,000 ($2,000,000).[a]

From the Riviere du Loup, a right-hand tributary of the Chaudière, a considerable quantity of placer gold has been taken since 1852. Of the attempts made on a large scale on this stream, some have been for a time successful, but all works have eventually proved unprofitable and have been abandoned. The pre-glacial gravels in this region at times reach a thickness of 45 feet. As in the Gilbert valley, the gold is coarse and nuggetty, averaging 865 fine. The Famine river gravels between the Gilbert and the Du Loup have been worked for gold, as also have those of Riviere des Plantes, Mill River, Slate Creek, Bras, Pozer, Samson, and Gosselin streams, all tributaries of the Chaudière.

In the main valley of the Chaudière gold is found in appreciable quantity in few places. The narrower and shallower reaches, as

[a] Lindgren, Trans. Am. Inst. M.E., XXXIII, 1903, p. 841.

near the Devil's Rapids and the Chaudière Falls, have given fair returns, obtained mainly by "crevicing." On the main stream gold does not occur below Bisson, a few miles below Beauce Junction.

Beyond the limits of the Chaudière basin other auriferous localities lie to the south-west. These are the Long Ditton stream, at the head of the St. Francis river, and within a few miles of the New Hampshire boundary line; the St. Francis river in the neighbourhood of Dudswell Lake; Lambton township on the south end of St. Francis Lake; and the vicinity of Magog and Massawippi rivers, both left-hand tributaries of the St. Francis. These deposits display the same characters as those of the Chaudière.

The auriferous gravels of the Eastern townships contain both pre-glacial and post-glacial members. The former are much the richer, especially when they lie in the beds of the present streams. High-level gravels occur and contain gold, as in the Gilbert valley, but in quantities too minute to warrant exploitation. The pay-dirt in the former case lies immediately on bed-rock, and is covered by a considerable thickness of gravel. Gold is not evenly distributed in and over the bed-rock, but appears rather to occur in very ill-defined "leads." Owing to the great changes in the climate and to the oscillations of the surface of the region, the pre-glacial gravels have been subjected to a great amount of denudation, both subærial and glacial. In the valleys and lower grounds they are buried beneath great accumulations of boulder-clay and other detrital products of the ice age.[a] In addition they are often overlain by post-glacial fluviatile deposits, that, when derived from auriferous gravels, may, in rare cases, be themselves of economic value.

Beneath, and in the neighbourhood of the auriferous gravels the rocks are pre-Cambrian (Huronian) schists, and Cambrian and Cambro-Silurian slates and quartzites.[b] In these, and especially in the first-mentioned, veins and veinlets of faintly auriferous quartz occur, and from them, the gold of the alluvials, coarse though it be, has been derived. The Huronian schists are the auriferous rocks of the Ontario region, and similar Cambrian strata are, as has already been seen, auriferous in Nova Scotia. It is important to note that intrusive diabases occur in all those areas where gold has been observed in the quartz veins of south-eastern Quebec, as at Leeds, Dudswell, Westbury, the Sherbrooke anticlinal, &c.[c] In 1864 quartz veins were worked at the Devil's Rapids and the Gilbert river, but proved unpayable.

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[a] Chalmers, Ann. Rep. Geol. Surv. Canada, X, 1897, p. 70J.

[b] Dresser, Jour. Can. Min. Inst., VIII, 1905, p. 259.

[c] Ells, Jour. Can. Min. Inst., I, 1896, p. 109.

In north-eastern Quebec gold was found in 1905-6 in a large quartz vein on Portage Island, Chibogomo district.[a] Near Larder Lake in western Quebec, auriferous areas occur in the Keewatin (Huronian) schists, east and north-east of Lake Temiskaming, with geological features closely resembling those of the Lake of the Woods and Rainy river districts of Ontario. So far, no payable mines have been developed. The gold-quartz veins, unlike those of the Ontario districts, are independent of the schistosity.[b]

The following table shows the official figures for the gold output of Quebec since 1877 inclusive.[c] This gold is alluvial and was wholly obtained from the Eastern Townships placers:—

1877—1880	£17,864
1881—1890	23,424
1891—1900	15,552
1901	615
1902	1,655
1903	761
1904	594
1905	Nil.
1906	Nil.
1907	Nil.
Total	£60,465

ONTARIO.

The Archæan rocks of Ontario, lying immediately to the west and to the north of the Great Lakes, contain numerous auriferous veins, none of which have so far proved of economic importance. The relations of the various members of the Archæan complex have been worked out for the Ontario mining districts by A. C. Lawson,[d] who groups the rocks under two great divisions—the Huronian and the Laurentian. The latter is purely a petrological term and includes those granites, granite-gneisses, and syenite-gneisses apparently younger than and intrusive into the Huronian rocks. The latter are disposed in great mesh-like bands and have been divided into an upper (Keewatin) and a lower (Coutchiching) series. The Coutchiching rocks are not auriferous, and require no further mention. The Keewatin greenstone-schists, derived apparently from basic lavas and ashes, are essentially the auriferous rocks of the province. They are hornblendic, chloritic, and sericitic.[e] Through both the Laurentian and the Huronian

[a] Obalski, Jour. Can. Min. Inst., IX, 1906, p. 218.

[b] Brock, Can. Min. Jour., Jan., 1908.

[c] Ann. Rep. Geol. Surv. Canada, 1906.

[d] Ann. Rep. Geol. Surv. Can., III, 1897-8, pp. 1-182F.

[e] Coleman, Rep. Bur. Mines, Ont., VI, p. 114.

rocks still younger granites are intrusive. The most promising auriferous veins occur at or near the contact of Laurentian and Huronian rocks, but a few isolated veins are found completely within the former, and far more within the latter. Gold is also recorded as occurring (presumably with pyrites) in felsite dykes and associated veins in the Bully Boy mine, Camp Bay.[a] The Keewatin schists when pyritous are themselves auriferous. In the Western Ontario districts the matrix of the gold is quartz. Free-milling ore occurs near the outcrops, but the gold is generally associated with sulphides, and particularly with pyrite, galena, stibnite, chalcopyrite, and blende. The last-named, contrary to general experience elsewhere, appears to denote an increase in gold tenor.[b] The earliest important find of gold in western Ontario was made at the Huronian mine, Moss township, in 1871. This vein is interesting as containing fine specimens of sylvanite (telluride of gold and silver). It is associated with a " dioritic " rock.[c] The Gold Creek mine, Lake of the Woods district, has yielded hessite (silver telluride). Its gold is free-milling and 70 to 90 per cent. may be recovered by ordinary amalgamation.

The auriferous districts of Ontario are : (*a*) Rainy River and Sturgeon Lake, west of Lake Superior ; (*b*) the north shore of Lake Superior, east of Nipigon ; (*c*) Michipicoten ; (*d*) from Sudbury west to Ansonia ; (*e*) Lake Wahnapitae ; (*f*) Parry Sound, Lake Huron ; (*g*) Peterborough, Hastings, Addington, and Frontenac counties, eastern Ontario. The more important mines of western Ontario are the Sultana, Mikado, Regina, and Black Eagle. The two first have reached depths of 600 to 700 feet and have each produced to 1904 more than £100,000 ($500,000) gold. The Sultana mine lies on the north shore of the Lake of the Woods, seven miles south of Rat Portage. It was first worked in 1882. The ore-bodies may be briefly described as lenticular masses of quartz of varying size, interbedded in the Keewatin schists at or near the contact of the schists with granitoid gneiss. Lenses lying near the contact are, as a rule, richer than those further away, and are also larger. On the adjoining Burley mine a shaft has been sunk in the lake bed, the depth of bed-rock below water-level being about 32 feet.[d] There are no well-defined walls limiting the width of the schist zone in which the quartz lenses occur. The Sultana ores average in value 33s. 4d. ($8) per ton. Those of the Eldorado in a sheared granite zone are somewhat lower in value, being worth a little more than

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[a] Brent, Jour. Can. Min. Inst., VI, 1903, p. 327.

[b] Merritt, Trans. Inst. M.E., X, 1896, p. 305.

[c] Merritt, loc. cit. sup.

[d] Smith, Jour. Can. Min. Inst., II, 1899, p. 87.

£1 ($5) per ton. Even the richer ores of western Ontario range below 41s. ($10) per ton.

The districts of Michipicoten, Wahnapitae, and Parry Sound resemble closely in geological and mineralogical features the foregoing districts of the Rainy River region.

Gold-mining in eastern Ontario dates back to 1865, when gold was discovered in the Marmora district. Since then no great amount of work has been done, except on three or four mines, of which the two most important are the Belmont and the Deloro. The country of these and other eastern Ontario mines is dolomitic or talcose schist with quartzite. The schists in the immediate vicinity of the veins are often cut by basic dykes,[a] the whole being intruded by granite, with which, according to Knight,[b] the ore-deposits are in genetic connection. The gangue is quartz and dolomite, principally the former, and the gold is associated entirely with mispickel, generally occurring scattered through the mispickel, but occasionally in grains and scales on the crystal faces of the latter. The arsenical pyrites occurs to such an extent that the veins are worked rather for their arsenic than for the gold. The ore-bodies are lenticular and follow the strike and bedding of the talcose schist in which they lie. The Belmont mine, from 1897 to 1904, recovered 16,789·79 ounces gold worth £59,307 ($289,302). The Deloro mine in the five years from 1899 to 1903 treated 35,877 tons ore for gold worth £37,291 ($181,907), and arsenic worth £26,440 ($128,975), or a total value of 36s. 1d. ($8·66) per ton.

The recently discovered auriferous deposits of Larder Lake lie about 34 miles north of Lake Temiskaming and 3½ miles west of the Quebec boundary line. They are essentially irregular quartz-stringers and veins in a rusty-brown dolomitic limestone belonging to the Keewatin series of greenstones, lime-silicate rocks, schists, dolomites, cherts, etc. At Abitibi Lake, auriferous veins are found traversing diabase.[c]

The only placer deposits yet known in Ontario are those along the Vermilion and Wahnapitae rivers. On the former river they have a length of 40 miles with a breadth of three. They are, on the whole, much too low-grade to be worked at present, but as there are many places where the average value is 6d. to 7½d. (12 to 15 cents) per cubic yard, they may constitute a dredging asset for the future.[d] The total gold yield of Ontario to the end of 1907 is officially

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[a] Wells, Jour. Can. Min. Inst., II, 1897, p. 127.

[b] Ib., VII, 1904, p. 210.

[c] Brock, 16th Rep. Bur. Mines, Ontario, 1907, pp. 207, 219.

[d] Miller, Trans. Amer. Inst. M.E., XXXIII, 1903, p. 1078.

estimated at £524,452 ($2,557,002).' Returns from 1891 are as follows :—

Years.	Fine Ounces.	Value, Dollars.	Value, Sterling.
1891–1900	68,453	$1,414,988	£290.072
1901	11,845	244,837	50,192
1902	11,119	229,828	47,115
1903	10,383	188,553	38,638
1904	2,285	40,108	8,219
1905	5,770	99,157	20,524
1906	3,926	66,392	13,605
1907	3,200*	66,399	13,606

* Estimated.

BRITISH COLUMBIA.

Gold was reported from British Columbia, or Oregon, as the Northern Pacific coast was then termed, as early as 1850. In that year gold-quartz veins were found in Palæozoic rocks of indeterminate age, both on Vancouver and on Queen Charlotte Islands. These proved unimportant, and no great attention was paid to the gold deposits of the region until 1857, when the discovery of rich gravels on the Fraser, Thompson, and Columbia rivers precipitated so great a "rush" from California that the value of property in San Francisco was depreciated by nearly 100 per cent. The rush was short-lived, but so many of the hardier miners were left behind that it became necessary to form the district into a Crown Colony. In 1858, the first year of real production, the gold output was a little more than £141,000. In 1868 the annual yield had risen to more than £800,000, nearly all of which was from the Fraser river and its tributaries, and more especially from Williams and Lightning Creek, Cariboo district. This district, after half a century of work, still remains the most important placer region in British Columbia. In 1872 the rich deposits of the Cassiar district, at the head-waters of the Dease river, were discovered. They have since yielded more than a million pounds sterling in alluvial gold. With the rush to Granite Creek, Similkameen, there occurred the last of the notable placer discoveries of British Columbia. Few of these placer deposits now offer huge fortunes or even indeed a mere livelihood to individual miners unassisted by machinery. All are being worked by companies possessing sufficient capital for the purchase and erection of expensive hydraulic plant, steam shovels, or dredges. In most cases water to command the gravels is brought from great distances, often as great as 30 miles.

The auriferous streams of the Cariboo district lie for the most part within a radius of 20 miles from Barkerville. The area forms a portion of the watershed of the Fraser, being drained by its tributaries, the Quesnelle, Cottonwood, and Willow rivers. The alluvials have been in the past exceedingly rich, quite as much so as the better-known gravels of the Yukon. Williams Creek, Cariboo district, is reported to have yielded upwards of £5,000,000 from a length of 2½ miles of stream bed.[a] Lightning Creek has been quite as rich. The bed-rocks of the region are the crystalline Cariboo schists of Lower Palæozoic age.[b] The schists contain low-grade pyritous gold-quartz veins with a little galena. The sulphides themselves occasionally carry high values in gold, but in no vein yet discovered has gold been found comparable in size with the coarse nuggets of the gravels. In one vein alone, viz., Perkins Ledge on Burns Mount, has free-milling gold-quartz been seen. The Cariboo schists, especially along vein fissures, are often graphitic.

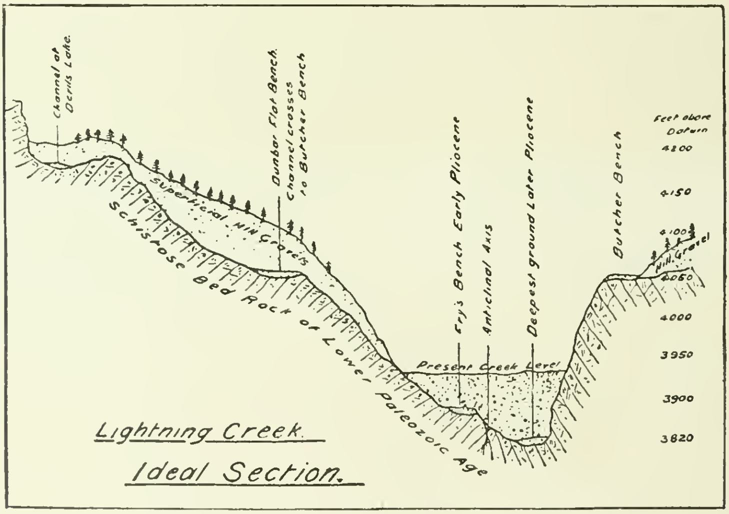

FIG. 154. SECTION THROUGH LIGHTNING CREEK, CARIBOO (*Atkin*).

Much of the gold of Cariboo has been derived from "benches," as the remnants of ancient river terraces left high up on the valley sides are termed. The present drainage system differs considerably from that of pre-glacial times. The older gravels and those of the valley bottoms are pre-glacial and upper Tertiary. The gold of the richer streams—Williams, Lightning, Lowhee, Grouse, &c.—is exceedingly coarse. At places on Lightning Creek no gold particles weighing less than 10 grains were found. The largest nugget from Cariboo was taken from Butcher Bench on Lightning Creek and

[a] Brewer, Mines and Minerals, July, 1904.
[b] Atkin, Q.J.G.S., LX, 1904, p. 389; Id., Geol. Mag., II, 1905, p. 104; Id., loc. cit., III, 1906, p. 514.

Williams Creek, Cariboo.

Hydraulic Sluicing, Cunningham Creek, Cariboo.

weighed about 40 ounces. The gold nuggets in the rich shallow creek-deposits vary greatly in appearance in different creeks, and even in different parts of the same stream. Nuggets from the higher reaches are generally large and angular, but become smaller and smoother as they descend the streams. The alluvial gold is supposed by Atkin to have been derived from pre-glacial surface secondary enrichments at vein outcrops. Quartz boulders containing both gold and pyrite have been found in the wash.

The Cariboo gravels are now wholly worked by large companies, the Cariboo Gold Mining Company (formerly Cariboo Consolidated Company) probably operating on a larger scale than any other alluvial mine in the world. Its fluming and races are more than 33 miles long and deliver 5,000 miner's inches (7,500 cubic feet per minute) of water under a head of 400 feet. The gravels treated vary in value from 10d. to 3s. 10d. per cubic yard. This company from June 1st, 1894, to June 22nd, 1904, recovered gold to the value of £252,957 ($1,233,936). The new company is increasing the water supply, as lack of water has always been a drawback on this as on other British Columbian placer fields. The deposits still to be treated vary in depth from 400 to 600 feet, and it is estimated that there are yet available 500,000,000 cubic yards of gravel. The value of the pay-gravel treated on Lightning Creek in 1905 and 1906 appeared to vary between 9s. 3d. ($2.22) and 16s. 6d. ($3.96) per cubic yard, but notwithstanding these high values, and the generally high tenor of the average gravel treated (5 to 6 grains per cubic yard), none of the larger companies have paid dividends. A considerable portion of the gravel is cemented and requires crushing before treatment.

In recent years several attempts have been made to recover the gold of the "bars" of the Fraser river by dredging. "Dipper," clam-shell, and suction dredges have all been tried and have all failed. Only moderate success has as yet been attained with bucket dredges, their breakdown being attributable in most cases to faulty design. High water in the Fraser river occurs in June, low water in March. The current is swift and in flood time may attain 15 knots per hour. The breaking away of ice barriers constitutes a serious menace to dredges. Very little silt is found in the river bed, which is tightly packed with boulders. Strong machinery is therefore required to break through to the gravel beneath. Since the stream is very deep, dredging is practicable only on the beaches and "bars." Behind the latter, dredging may be carried on nearly all the year round. The general tenor of the gravel to be dredged is estimated at 5 grains gold per cubic yard.[a]

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[a] Stringer, Min. Jour., March 16, 1907.

The Atlin division of the Cassiar district is in the extreme north of British Columbia, and its auriferous streams flow into Atlin Lake from the east. The earliest recorded discovery was made on Pine Creek early in 1898 by McLaren and Miller. Old and rotted sluice boxes have been found in the neighbourhood, and it is commonly believed that the deposits were known prior to that year. The bed-rocks of the gold-bearing gravels are the "Gold Series" of Gwillim.[a] They are Palæozoic slates, actinolite- and biotite-schists, and magnesian rocks (dunite, peridotite, magnesite, serpentine), together with younger greenstones (andesitic). In Pine Creek valley are numerous diabasic dykes and some small areas of diorite which may be related to the greenstone. The schists occur only near the granite contact. Well-defined pyritous quartz veins cross the slates of the Gold Series. While their tenor in gold is low, it is probably from them and from the auriferous pyrites of the biotite-slates that the gold of the streams has been derived. An interesting occurrence of gold in the pyritous biotite-slates is reported from Wright Creek, falling into Surprise Lake. Here the stream flows over heavily mineralised slates and gold is found deep down within the bed-rock. It is not clear, however, whether the gold is alluvial and has sunk into crevices, or whether it is derived from the decomposition of the pyrites.[b] The latter is, however, probably the case. A similar area of auriferous pyritous-rock crosses Pine Creek, near Willow. Gwillim[c] concludes that the placer gold is derived from the country rather than from the veins. The auriferous alluvial belt lies to the east of Atlin Lake, and covers an area of 150 square miles. The gravels are pre-glacial, glacial, and post-glacial. The first are the richest, though local concentrations may occur in the last.

The old gravels of Atlin are in a state of advanced decomposition, appearing as shining pebbles in a paste of yellowish mud. Most of the gold lies on bed-rock or within 8 feet above it. The grains are for the most part coarse, and of the size and shape of flax seed. The largest nuggets yet found have been 83 ounces (with some quartz), $36\frac{1}{2}$ ounces, and $28\frac{3}{4}$ ounces respectively. The principal creeks now being worked are Pine, Spruce, Willow, Birch, Boulder, and McKee. Steam shovels are used to handle the gravels. That on Pine Creek, with $1\frac{3}{4}$ yard dipper, is capable of moving 3,000 cubic yards in 24 hours. Working night and day from August 15th to October 25th, 1906 (71 days), with 36 men, this plant recovered more than £5,000 ($25,000) gold. Steam shovels are also employed on Spruce Creek, the principal tributary of Pine Creek. On McKee

[a] Ann. Rep. Geol. Surv. Canada, XII, 1899, p. 16B.
[b] Loc. cit., p. 43B.
[c] Jour. Can. Min. Inst., V, 1902, p. 30.

Creek the bed-rock surface, also to be worked by steam shovel (5 cubic yards dipper), varies in value from 12s. 6d. ($3) to 50s. ($12) per square yard, an average being perhaps 18s. 9d. ($4·50). All the gravel, whether moved by steam-shovel, or otherwise, is sluiced. Two dredges have been erected, but both have failed completely owing to adverse local conditions.

Other mining divisions of British Columbia of less importance, in which placer gold is being recovered, are the Liard, Stikine, and Skeena, south and south-west of Atlin, and with geological conditions similar to those of Atlin; the Lilloet division, along the benches of the Fraser river and in Bridge river and Cayuse Creek; and the Fort Steele division of East Kootenay. In the last-named the first alluvial discoveries were on Wild Horse Creek, joining the Kootenay at Fort Steele. This stream is reported to have yielded for two years 1 to 1½ ounces of gold per man per day. It was worked out by the end of 1866. The yield of placer gold in British Columbia for 1907 was £169,740 ($828,000), while the total value of the placer yield from 1852 to 1907 inclusive has been £14,257,566 ($69,549,103).

The important gold lodes of the province are all situated in the south and the south-east, generally only a few miles north of the international boundary. Of these, the best known are those of Rossland, five miles north of the boundary, in the West Kootenay district. The town and mines are on Red Mountain at the head of Trail Creek, and are at an average altitude of 3,140 feet above sea-level. The lodes were found in the summer of 1890, all the principal mines of the present time being staked on the same day. One, and as it eventually proved, the richest, was given away for the price of the recording fees ($12.50). The field suffered for several years from lack of transport facilities, but in 1896 it was connected by railway with the outside world. Mining and milling costs have of late years been considerably reduced by the construction of another railway, giving cheap fuel, and by the introduction of electric power. From 1894 to 1905 inclusive 2,212,271 tons (long) have been smelted for a yield of £6,837,065 ($33,351,536) or £3·625 ($17.68) per ton. Of this value a considerable proportion is derived from the copper and silver content of the ore. The following table[a] of typical assays shows the average proportion in metals of the ore now being treated:—

Gold. Ounces per ton.	Silver. Ounces per ton.	Copper. Per cent.
·441	·5	1·15
·5	·3	·9
·4	·54	·7
1·18	2·318	3·62

[a] Brock, Rep. Geol. Surv. Canada, No. 939, 1906, p. 18.

The basement rocks of the Rossland area are Lower Carboniferous sedimentaries (clays, limestones, and quartzites) interstratified with tuffs and lava flows. Through these have been intruded a succession of igneous rocks. The oldest were augite-porphyrite agglomerates and lavas. They were followed by monzonite, which in its turn was intruded by apophyses of granodiorite. The intrusions range in age from Upper Mesozoic to Lower Tertiary. The eruptions were continued through the Tertiary period, furnishing andesites at the surface and, at depth in the mines, mica-lamprophyre dykes of differing and uncertain age. Some, indeed, cut and fault the ore-bodies. The whole area has been subjected to comparatively recent glaciation.

The Rossland ore-bodies may occur in any of the country rocks, with the exception of the later dykes. Augite-porphyrite and the coarser grey granitoid rocks (monzonite) are the most favourable. All the proven productive zones are situated near or between exposures of alkali-syenite (alaskite). The remainder of the stratified rock is mineralised, but too diffusely to be of economic importance. The ore deposits occur in fissure veins formed by fracture, or by fracture and replacement, and also in zones of fissuring and shearing, in which the ore is found in a close network of veinlets. The two foregoing have furnished the more important ore-bodies, but irregular impregnations in the country are also met with and are worked. The gangue is mainly country, with occasional quartz and calcite. The ores occur :—

(*a*) As massive pyrrhotite and chalcopyrite with pyrite and arsenopyrite. Free gold, though rarely visible, occurs in this matrix, as also does galena and blende. Small quantities of nickel (·65 per cent.) and cobalt (·59 per cent.) are at times recognised.

(*b*) As massive pyrrhotite with very little copper and gold.

(*c*) As pyrite, marcasite, and arsenopyrite veins with occasional argentiferous galena and blende.

(*d*) As impregnations of arsenopyrite, pyrrhotite, pyrite, molybdenite, chalcopyrite, bismuthinite, and native gold, especially in the neighbourhood of pegmatitic or aplitic alkali-syenite dykes (Grant, Jumbo).

(*e*) As gold-bearing quartz veins (O.K. and I.X.L.).

In typical ores the highest value is in gold, followed by copper, and then by silver. The proportion of free gold does not appear to diminish in depth, nor does the gold accompany any specified mineral, though in some places an increase in the amount of chalcopyrite denotes an increase in gold tenor. The chief lodes of Rossland are the Le Roi—Centre Star, Main, South, and Josie. Sharply defined walls are lacking, and the width of a lode is determined often only by economic considerations. Within the lodes, shoots or pay-streaks, often lenticular and of great size, furnish much of the ore, and are most common when the lode is intersected by faults and dykes.

The ore deposits were formed by aqueous, mineral-laden solutions of high temperature. According to Brock, no secondary sulphide enrichment of importance has taken place. This view is not, however, supported by MacDonald,[a] who regards the shoots as zones of secondary enrichment. The total costs of the mining and smelting of Rossland ores lies between 31s. 6d. ($7.56) and 41s. 8d. ($10.00) per ton. To the end of 1903 the Rossland mines had paid £487,285 ($2,377,500) in dividends.

The Boundary district lies to the west of Rossland, and derives its name from its proximity to the international frontier. Its wealth lies in its large low-grade copper sulphide deposits, rather than in gold, but gold-quartz veins of no great size are found in the neighbourhood of the copper lodes. The country is limestone, hornblende-schist, and tuff, the two last being calcareous. All are intruded by alkali-syenite (pulaskite) dykes. The sulphide lodes are usually confined within well-defined walls and contain chalcopyrite, pyrite, arsenopyrite, galena, and blende. Tetrahedrite and rich silver-sulphides also occur.[b] There is a complete absence of oxidation at the outcrop of these lodes—a general characteristic of British Columbia ore, and largely due to the recent glacial erosion of the surface. About one-third only of the value of the product of the Boundary mines is derived from gold. The annual output of the district is large, and has steadily grown from 390,000 tons in 1901 to 1,160,000 tons in 1906. The ores are entirely self-fluxing and require neither double smelting nor addition of foreign fluxes or metals. The principal mines are the Granby, the British Columbia Copper Company, and the Dominion Copper Company. The first-named furnishes the great bulk of the ore sent to the smelters from the Boundary district, and is indeed the largest, in point of tonnage treated, of metal mines within the Dominion. It rivals the famous Ducktown (Tennessee) copper mines in this respect, and also in lowness of costs. Its ores contain from 5s. to 6s. worth of gold

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[a] Eng. Min. Jour., Aug. 8, 1903.

[b] Brock, Ann. Rep. Geol. Surv. Canada, XV, 1902, p. 92A.

and silver and 27 to 30 pounds copper per ton. Returns from the Granby mines for the last two years available are:—[a]

	1905.	1906.
Tons smelted	590,120	832,346
Copper sold (lbs.).. ..	14,237,622	19,939,004
Gold, fine ounces	42,884	50,020
Silver, fine ounces	212,180	316,947
Net profit per ton ..	6s. 8d.	10s. 1d.

In November, 1907, the mine was closed down for some months owing to the then low price of copper (£63 per ton).

Other vein-gold districts in British Columbia are Nelson (including the Ymir and Athabasca mines), Coast (with Vancouver Island) and Revelstoke. These present no characteristics warranting special mention. The output of vein gold for the province during 1907 was £831,316 ($4,055,200), of which 95 per cent. was a smelter product, only two stamp batteries (at Ymir, Nelson, and at Yale) being in operation. The total yield of vein gold in British Columbia to the end of 1907 has been £9,239,534 ($45,070,897).

The producing gold districts of British Columbia in 1906 were the following:—[b]

District.	Division.	Value of Alluvial Gold.	Value of Vein Gold.	Total Value.
Cariboo	Cariboo	£72,939	....	£72,939
	Quesnel	8,118	....	8,118
	Omineca	2,050	....	2,050
Cassiar	Atlin	93,275	....	93,275
	Liard, Stikine, Skeena ..	9,020	£8	9,028
East Kootenay ..	Fort Steele	2,132	....	2,132
	Windermere Golden ..	....	42	42
West Kootenay ..	Nelson	205	49,480	49,685
	Ainsworth..	....	80	80
	Slocan	....	292	292
	Trail Creek	....	446,431	446,431
	Revelstoke, Trout Lake and Larder	820	8,678	9,498
Lilloet	Lilloet	3,444	720	4,164
Yale..	Boundary	676	398,842	399,518
	Similkameen, Nicola, and Vernon	512	25	537
	Yale, Ashcroft, and Kamloops	1,025	911	1,936
Coast	Nanaimo, Alberni, Clayoquot, Quatsino, New Westminster, and Victoria	205	43,772	43,977
		£194,421	£949,281	£1,143,702

[a] Rickard. Forbes, Min. Sci. Press, April 20, 1907.
[b] Ann. Rep. Bur. Mines, British Columbia, 1906.

YUKON.

Gold has been known from the Yukon river since 1869. The alluvial deposits earliest worked in this region were far up the Yukon on the Big Salmon, Lewes, Pelly, and Stewart rivers, about 200 miles north and north-east of Atlin Lake. The first-named was actively worked in 1881; the last, and up to then the richest,

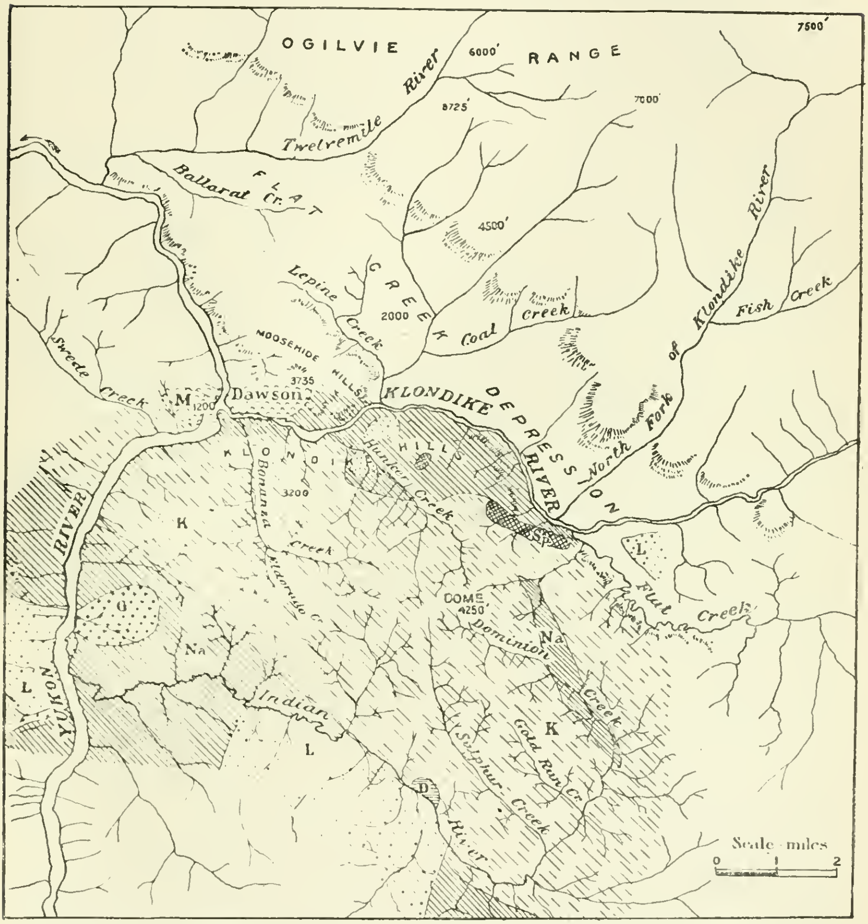

FIG. 155. SKETCH MAP SHOWING GEOLOGY IN THE VICINITY OF KLONDIKE (*McConnell*).
Older Rocks: *Na.* Nasina series. *M.* Moosehide group. *K.* Klondike series.
Younger Rocks: *G.* Granite. *Sp.* Serpentine. *D.* Diabase. *L.* Lower Tertiary (Kenai series).

from 1885 to 1886. In the latter year the placers of the Fortymile region, the greater part of which afterwards proved to be in Alaskan territory, were discovered, and soon after, those of the Sixtymile river, the last being entirely within Canadian jurisdiction. This last stream furnished most of the gold of the Yukon until 1897, when the surpassing richness of the streams in the neighbourhood of the Klondike river became generally known, and set in motion the most extraordinary rush of recent years—one that, as usual, meant fortunes for the few and desperate privation for the many. Nothing like it had happened since the great Australian rushes of the 'fifties. Its occurrence is, however, of too recent date to warrant a description in this place.

The Klondike goldfields lie immediately to the south of the 64th parallel of north latitude, and 50 miles east of the international boundary. The auriferous area is about 800 square miles in extent. It lies between the Klondike river on the north and the Indian river on the south and is bounded on the west by the Yukon itself, and largely on the east by Dominion Creek, a tributary of Indian river. It is thus an almost complete physiographic unit. Its maximum elevation is the Dome, 4,250 feet above sea-level, and 3,060 feet above Dawson, the chief town of the Yukon, situated on that river at the mouth of the Klondike tributary. All the streams in this area are auriferous, but only a few are sufficiently rich to warrant exploitation under existing circumstances. The existence of gold in the region appears to have been known in 1894, but the extraordinary richness of some of the valleys was not suspected until two years later, when Carmack, returning from visiting a brother prospector on Goldbottom Creek, made his famous discovery on Bonanza Creek.

The oldest and most important rocks in the district are metamorphic schists, partly of sedimentary and partly of igneous origin. Their age is uncertain and they are possibly Cambrian or pre-Cambrian.[a] They have been divided by McConnell[b] into the Nasina and Klondike series, and with them is grouped the Moosehide diabase, exposed only in the immediate neighbourhood of Dawson. The Nasina series are ancient sedimentary rocks—sands and sandy clays—now altered to quartzites and quartz-mica-schists, associated in places with bands of green chlorite- and actinolite-schist, the latter probably representing original, more or less basic igneous intrusions. The rocks of the Nasina series occur both to the south and to the north of the main auriferous area, and are probably the oldest in the district. The Klondike series of originally widely-differing igneous rocks—quartz-porphyries, granite-porphyries, and basic porphyritic rocks[c]—now converted into light-coloured sericite- and green chlorite-schists, are important as being the country of the gold veins from whence the alluvial

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[a] Tyrrell, Econ. Geol., II, 1907, p. 345.

[b] Ann. Rep. Geol. Surv. Canada, XIV, 1901, p. 12B.

[c] Barlow, Ib., p. 19B.

gold has been derived. They occupy the greater portion of the auriferous area outlined above, lying across it as a north-west to south-east belt with an average width of some 16 miles. South-east of the Dome the belt is bounded on the north by Flat Creek, and on the south by Indian river. The series is intruded by numerous dykes and stocks of quartz-porphyry, rhyolite, and andesite, so much younger that they are still unaltered by dynamo-metamorphism. Schists similar to these occur in other auriferous districts in the Yukon province, as in the Fortymile district, on Henderson Creek, and in the Stewart Valley. Their general age is believed by McConnell to be that of the Pelly gneisses (Archæan), and the sericite-schists of the Klondike themselves indeed show a gradual transition to augen-gneisses along a section from Eldorado Creek to Indian river. The relation of the Moosehide diabase to the rocks of the Klondike series is uncertain, but as the diabase seems to have undergone less metamorphism than the latter, it may merely represent a later manifestation of the same volcanic activity.

Unaltered Tertiary sediments of no great importance occur in the area. The more recent massive and intrusive igneous rocks are granites; andesite dykes, stocks, and remnants of flows; diabase stocks and dykes; and quartz-porphyries shading into rhyolites. The foregoing is the apparent order of succession, the granite being the oldest rock. The andesites are of Lower Tertiary age, and on the left bank of the Yukon are traversed by a broad diabase dyke. Most of the foregoing are seen intrusive through the schists.

The auriferous gravels of the Klondike may be classified in descending order in general altitude as follows:—

(*a*) High-level Gravels ..	.. .. ..	Klondike River Gravels.
	"White Channel" Gravels	Yellow Gravels. White Gravels.
(*b*) Gravels at intermediate levels ..	.. .. ..	Terrace Gravels.
(*c*) Low-level Gravels ..	.. .. ..	Gulch Gravels. Creek Gravels. River Gravels.

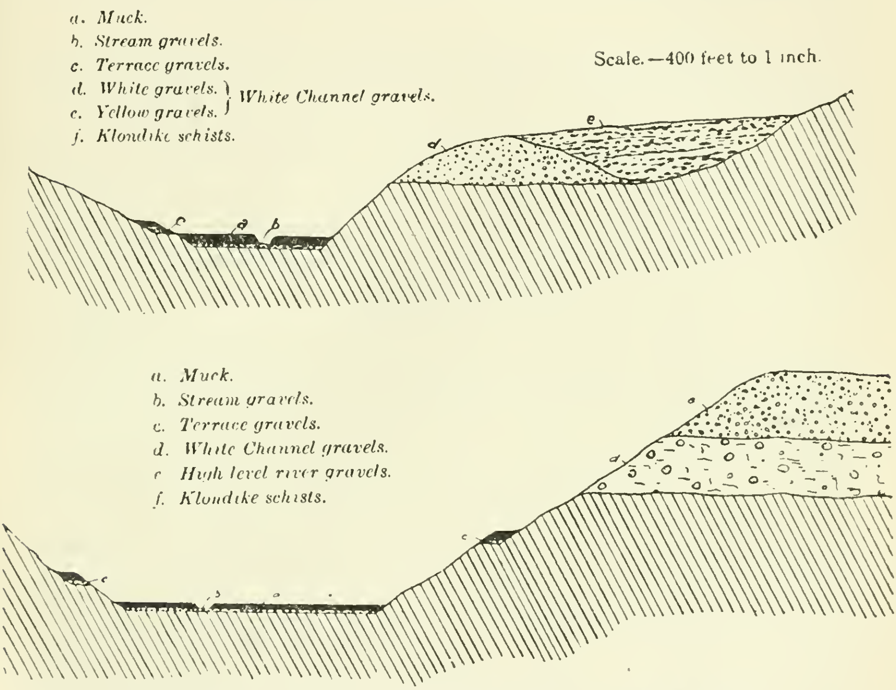
The high-level gravels lie at elevations of 150 to 300 feet above the present valley bottoms and are the remnants of a Pliocene valley gravel deposited before the whole country received the comparatively recent uplift (500 to 700 feet) that by increasing the grade of its streams enabled them to deepen their valleys. These high-level gravels may be separated into ancient local creek gravels and the ancient river gravels of the Klondike stream. The latter overlie the former and have a thickness of 150 to 175 feet, but, since their material has been brought from outside the auriferous area, are of little economic importance. The high-level creek gravels, on the other hand, have a considerable value, and have furnished much of the Klondike gold. They are subdivided into upper and lower members, the former being rusty yellow gravels restricted in area, the latter, white and more widely distributed. The white gravels are composed of rounded quartz pebbles, with rounded, sub-angular, or wedge-shaped boulders of quartz, often 2 or 3 feet in diameter, all packed in a matrix of angular grains of quartz and sericite. Pebbles of sericite-schist are common. These gravels are locally known as "white channel" gravels. No fossil remains have been found in them. They vary in thickness from a few feet to 150 feet, and in width from 100 feet to ½-mile or more. The "white channel" gravels have, as has been stated, furnished much of the gold of the Klondike, not only to direct mining, but also by degradation to the lower-lying valley deposits. Their course in the richer valleys is easily traced by the horizontal white band of tailings sweeping round the hill slopes. They are regarded as stream deposits by McConnell. In character they certainly resemble closely the auriferous river gravels now being deposited in New Zealand by the snow-fed rivers, Clutha and Kawarau. These streams have remarkably even gradient and a fairly swift current, while their dêbris is derived from the degradation of a somewhat easily disintegrated mica-schist area.

The terrace gravels lying on the valley slopes below the "white channel" are also remnants of former valley bottoms through which the streams have cut during a rapid deepening of their beds. They are irregular in extent, seldom exceeding a few yards in width and a few hundred yards in length. They occur at various altitudes and may be considered to mark periods of temporary cessation of uplift.

The low-level gravels occupy the bottom of the existing valleys. Their material, together with their gold, has been derived from the decomposed schists on the valley slopes, from the high-level gravels, and from the terrace gravels. They lie on decomposed schist bed-rock, and are covered by black frozen "muck" (silt, vegetable matter, and ice, the last often forming 75 per cent. of the mass) of a thickness of 2 to 30 feet. The Gulch gravels occupy the upper portions of the main creek valleys and of the small tributary valleys. Owing, of course, to the shorter distance they have travelled, their boulders and pebbles are larger and more angular than those of the creek gravels. The only river gravels yet proven to contain gold in remunerative quantities are those bordering the Klondike river below the mouth of Hunker Valley.

The principal auriferous streams all flow from and over the sericite-schists of the Klondike series. The richest is undoubtedly

Bonanza Creek, with its main tributary, Eldorado Creek. Along these two streams the valley bottom gravels are the most productive. These are followed in economic importance by the white channel gravels, and then at a long interval by the terrace gravels. Some of the earlier claims (which were limited in length of channel to 500 feet) were exceedingly rich. A claim on Bonanza Creek only 80 feet in length yielded over £60,000 ($300,000) gold, another (No. 17) of full length, on Eldorado Creek, had yielded up to the end of 1902 no less than £300,000 ($1,500,000). The Eldorado has, indeed, proved the richest creek in the Klondike district, and is



Figs. 156 and 157. Ideal sections across Bonanza Valley (*McConnell*).

possibly the richest ever discovered. To 1902 a total value of £5,000,000 ($25,000,000) had been recovered from it, and more has since been obtained. It is estimated that only ·5 per cent. of the total bulk (250,000,000 cubic yards) of the gravels on Bonanza Creek has been or may be worked by drifting, the remainder being left to be treated by hydraulic methods or by dredges. The side gulches of the main streams are also productive. The gold, especially of Eldorado, is coarse and rough, with numerous nuggets which nearly always contain grains and fragments of quartz. The nuggets are often partially crystallized, the common form being bulky octahedral crystals. The average value of the gold is 68s. 4d. ($16.40) per ounce on Bonanza Creek, and less—65s. ($15.60)—on Eldorado Creek.

Hunker Creek resembles Bonanza Creek in its general characters. Its principal tributaries are Goldbottom and Last Chance creeks. The latter is famous for the great quantity of crystallized gold obtained in its upper course. Its gold is comparatively low-grade, being worth only 60s. 5d. to 62s. 6d. ($14.50 to $15.00) per ounce. Other auriferous valleys on the north side of the region are Bear Creek and Allgold Creek. The former flows directly into the Klondike river, the latter falling first into Flat Creek.

On the south side, Dominion Creek is the most important of those joining the Indian river. Like most of the other streams, its gold high up its valley is coarse, rough, and nuggetty, becoming small, smooth, and waterworn as it descends the stream. Other streams of minor importance are Gold Run, Sulphur, Quartz, and Eureka creeks. The gold from the last is very coarse, nuggets varying in weight from $1\frac{1}{2}$ to $3\frac{1}{2}$ ounces being recorded. The largest nugget yet found in the Klondike district weighed 85 ounces.[a]

McConnell[b] concludes that the greater part of the Klondike gold is detrital in character and is entirely local in origin. Numerous lenticular auriferous quartz-veins seam the sericite-schists, and while the great majority of these are too small and too low-grade to be worked, nevertheless a short lens of quartz found at the head of Victoria Gulch was studded at one end with numerous grains and small nuggets of gold, some of the latter being well crystallized and very like those found in the gravels. The gold was only at or near the surface of the vein, little being in the interior of the quartz. A boulder found on Bonanza Creek and weighing 60 ounces yielded no less than 20 ounces gold. A small quartz vein in the Victoria Gulch mine that showed no visible gold yet assayed 2,625 ounces gold and 3,267 ounces silver per ton![c] The silicified country rock, mostly sericitic schists, adjoining the auriferous vein was also found to be auriferous. There is thus ample evidence of the occurrence of gold in the local veins. Yet not all of the alluvial gold is detrital. In Miller Creek a boulder was found whose upper surface was covered with thin specks and scales of crystallized gold, dendritically arranged. The boulder itself was well rounded, while the gold-crystal edges were sharp and unworn. Similar gold has been obtained from Eldorado and other creeks.

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[a] Min. Jour., Nov., 1907.

[b] Loc. cit. sup., p. 61B.

[c] McConnell, loc. cit., p. 64B.

The quartz veins are often pegmatitic in character, inasmuch as they contain occasional felspar crystals. Such veins when followed along their strike have been seen to gradually change to a normal pegmatite, as described by Spurr[a] for the Fortymile district in Alaska. In other quartz veins pyrite and magnetite are present with rarer chalcopyrite, galena, and gold. Pyrite is also very common in the alluvial gravels. The Tertiary sedimentaries north of Indian river have attracted considerable attention from prospectors by reason of their contained auriferous conglomerates. These, where tested, appeared to have an average value of only 9s. 4d. ($2.24) per ton, and are, of course, unworkable.

Nearly all the alluvial gold of the Klondike accessible to the individual miner has now been exhausted, and small parties of men with small claims have been superseded by large and wealthy companies possessing extensive areas. The costly primitive methods of sinking and drifting with subsequent hand-sluicing have almost completely been abandoned. In their place an extensive use is being made of machinery. The gravels are moved by steam scrapers, steam shovels, self-dumping buckets ("Dawson carriers"), and dredges. The latter are proving successful, their chief obstacle being frozen gravel. By an extensive use of "steam points" ahead of the dredge, this difficulty is largely overcome. Lack of water, due mainly to the physiographic isolation of the auriferous area, has prevented the treatment of the gravels, and especially of those of the White Channel, by hydraulic sluicing. A large amount of capital is now being expended in conserving water, and in the construction of long water-races both to command the gravels and for the generation of electric power. It is therefore probable that, though the phenomenal returns of the past may never again be approached, the Klondike region will produce large quantities of gold for many years to come. To reach the field the arduous and dangerous journey of the late 'nineties has no longer to be faced. White Horse, below the notorious rapids of the same name on the Lewes river, is reached after a railway journey of 12 hours from Skaguay at the head of Lynn Canal. From White Horse the journey to Dawson is made in two days by river steamers. The neighbourhood of Dawson is well roaded, and working costs are thus greatly reduced.

An interesting vein occurrence is reported from the Gold Reef mine near Taku Arm to the west of Atlin Lake, South Yukon. Dykes of greenish porphyry or porphyrite occur near the eastern edge of a narrow band (½-mile wide) of schists. In this disturbed

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[a] 18th Ann. Rep. U.S. Geol. Surv., Pt. 3, 1898, p. 87.

area are situated auriferous veins carrying tellurides of gold and silver (sylvanite and hessite).[a]

GOLD PRODUCTION OF YUKON TERRITORY.

Year.	Fine Ounces.	Dollars.	Sterling.	Year.	Fine Ounces.	Dollars.	Sterling.
1885–6	4,838	$100,000	£20,563	1897	120,948	$2,500,000	£513,929
1887	3,387	70,000	14,394	1898	483,793	10,000,000	2,056,120
1888	1,935	40,000	8,223	1899	774,069	16,000,000	3,289,793
1889	8,466	175,000	35,980	1900	1,077,649	22,275,000	4,580,008
1890	8,466	175,000	35,980	1901	870,827	18,000,000	3,701,014
1891	1,935	40,000	8,223	1902	701,500	14,500,000	2,981,375
1892	4,233	87,500	17,990	1903	592,646	12,250,000	2,518,745
1893	8,515	176,000	36,188	1904	507,983	10,500,000	2,158,927
1894	6,047	125,000	25,699	1905	402,864	7,000,000	1,435,000
1895	12,095	250,000	51,403	1906	270,882	5,994,600	1,228,893
1896	14,514	300,000	61,684	1907	....	3,15[illegible],000	645,750
						$123.708,100	£25,425,881

UNITED STATES OF AMERICA.

The United States had been for long the greatest gold-producing country of the world. It now, however, occupies second position, being surpassed in yield by the enormously rich Witwatersrand field of the Transvaal. For a few years its position was challenged by Australasia, whose gold output was then being augmented by the rich mines of Kalgoorlie, but owing to the decline of the Western Australian fields and the discovery of the rich propylitic veins of Nevada, the United States has of late easily outdistanced its southern rival.

Gold-mining in the United States may be said to have commenced only with the fourth decade of the nineteenth century, and its enormous gold yield of £639,263,726 ($3,118,798,216) is therefore the produce of only some 77 years of mining and washing. From 1830 to 1850 the veins and gravels of the Southern Appalachian States supplied much of the gold required for coinage, but Marshall's discovery in California in 1849 speedily shifted the centre of North American gold-production to the west of the Rocky Mountains, where new discoveries, often of apparently fabulous richness, have from time to time supplied the place of those exhausted and abandoned.

[a] Cairnes, Jour. Can. Min. Inst., Toronto, 1907; quoted Can. Min. Jour., April 15, 1907, p. 211.

As pointed out by Lindgren[a] the auriferous vein deposits of the United States may be grouped in three divisions, each division forming a more or less meridional band. These divisions are well separated, both geologically and geographically. The Appalachian belt is the oldest. It lies between the Atlantic coast and the higher ranges of the Appalachian Chain, and may be said to extend from the province of Quebec in the north to the State of Alabama in the south. To be associated in age with the deposits of the Appalachian belt are the minor occurrences in the Lake of the Woods region in Minnesota, and also some of those of the Black Hills, South Dakota, and of the State of Wyoming. The auriferous veins of this age lie mainly in schists, and show often two periods of auriferous deposition. Their placers, especially in Georgia and in the Carolinas, have been fairly productive. The general age of these beds is pre-Cambrian or Algonkian.

Next in age but separated by the Palæozoic and Mesozoic eras in time and by the width of North America in position, comes the great Pacific belt of Cretaceous veins, extending from Alaska to Lower California. The time-gap is not partially bridged in the United States, as it is in Australia and to a minor degree in Western Europe, by Permo-Carboniferous or later auriferous deposits, probably owing to the general absence of volcanic activity in North America during Palæozoic and Mesozoic times. The Pacific, or Sierra Nevada belt of veins lies on the western flanks of the Sierra Nevada range and shows in general an association with the great granodioritic and dioritic intrusions that form the core of the Pacific littoral uplift. Veins in this belt are normally fissures filled with quartz. Their denudation, though they are themselves often low in grade, has furnished the extremely rich Pliocene and recent placers of California.

The third belt, and at the present time the most productive by reason of its bonanzas, is that in the later Tertiary propylitic deposits of Nevada, Utah, Colorado, and New Mexico. It has a great development to the south in Mexico and reaches as far north as the Owyhee range, in Southern Idaho. Deposits, generally containing auriferous veins, of the same nature are sporadic along the Cordilleran uplift in Oregon and Washington, and after a great interval on Unga Island, in the Aleutian Group, Alaska. The later Tertiary propylitic deposits are characterised by a general preponderance of silver in their bullion, and by the presence of great bonanzas (*e.g.*, Cripple Creek and Comstock). The placers from these veins are of little importance owing to a variety of causes, of which the

[a] Trans. Amer. Inst. M.E., XXXIII, 1903, p. 790.

small degree of denudation the veins have suffered, the comparative aridity of the Rocky Mountain region, and the fineness of the gold and its association with sulphides and tellurides tending to continuous secondary enrichment of the outcrop of the zone-vein, are the chief. The propylitic vein outcrops indeed represent the original upper portions of the fissures, while the veins of the Pacific and Appalachian belts are but the roots of original veins that have been denuded to depths of many thousands of feet.

The general direction of the three belts is due to the axes of regional folding and of mountain building being more or less meridional. In the case of the Appalachian uplift, simple erosion, aided perhaps by faulting, has brought the Archæan rocks to the surface. Folding along the Cordilleran uplift has resulted in the formation of meridional planes of crustal weakness along which igneous magmas have intruded and have welled forth to the surface.

The total gold yield of the United States cannot be stated with any degree of accuracy owing to the fact that only since 1877 have statistics been systematically collected. Previous yields have been estimated by various authorities with widely varying results. In the following compilation, for the gold yields prior to 1901, the estimates of Lindgren[a] have been followed, and for those subsequent to 1901, the figures published by the Geological Survey[b] and by the Director of the United States Mint.[c]

TOTAL GOLD YIELD OF UNITED STATES, 1792–1907.

State.	Value, Dollars.	Value, Sterling.
Alaska	$121,348,200	£24,896,880
Appalachian States	49,020,906	10,049,286
Arizona	66,226,931	13,576,519
California	1,503,447,536	308,206,642
Colorado	424,066,234	86,833,576
Idaho	122,736,655	25,161,014
Montana	234,861,321	48,146,569
Nevada	294,842,056	60,442,619
New Mexico	20,254,318	4,152,134
Oregon	64,628,974	13,248,937
South Dakota	135,476,392	27,762,659
Utah	57,185,608	11,723,047
Washington	23,593,599	4,836,806
Wyoming	1,107,486	227,038
Total United States	$3,118,798,216*	£639,263,726*

* Including estimated figures for 1907.

[a] Trans. Amer, Inst. M.E., XXXIII, 1903, p. 808.

[b] Min. Res., U.S. Geol. Surv., 1901-1906.

[c] Prelim. Rep., Jan., 1908.

ALASKA.

The earliest discovery of gold in Alaska appears to have been made by the Russian engineer, Doroshin, as long ago as 1849. Doroshin was unsuccessful in his attempt to obtain payable results from the auriferous alluvial deposits of the shores of Cook Inlet, and no further search for gold was made for many years. Mining was indeed actively discouraged by the Russian fur-trading companies, then holding possession of the Alaskan coast. In 1866 Alaska was sold to the United States for a little less than a million and a half sterling ($7,200,000), but the change of ownership was not productive of any immediate result. In 1879 gold-quartz veins were found near Sitka, and gold-placers in the Juneau region in 1880. The working of the latter led to the discovery of the famous Alaska-Treadwell lodes, and with this gold-mining in Alaska may be said to have commenced.

The first discovered of the rich gold-placers of the Yukon valley within Alaskan territory was the Fortymile (so called from a stream 40 miles below old Fort Reliance). The field was worked with some vigour from 1886, the year of its discovery, until 1897, when the reports of the gold of Klondike drew most of its miners across the international boundary. The geological conditions prevailing on the Fortymile stream[a] are very similar to those of the Klondike and need no further description here. Unlike the Klondike, however, the Fortymile region is still being worked by small parties and by individual miners. Near Eagle, 25 miles below the boundary, is a small placer area of no great present importance. Circle City, 175 miles further down the Yukon, is the centre of the Birch Creek region, for long and perhaps still the most important of the placer districts of the interior Yukon. It was discovered in 1893, and its annual yield in 1904 was estimated at from £30,000 to £35,000 ($150,000 to $175,000).

The town of Rampart is 575 miles below the boundary and is the river port for the Rampart auriferous region. The creeks of this district all lie within 30 miles of the Yukon river, but the most southerly flow south into the Tanana, its chief Alaskan tributary. On the northern or Yukon slope the richer creeks are the Minook and the Troublesome. These, for the most part, flow in narrow valleys, with well-developed "benches," or old high-level gravels, on the valley sides. From the benches much of the gold has been obtained. On the southern slope the valleys, especially in their lower courses, are broader and more open. Baker Creek is the best known. The oldest rocks of the Rampart region are garneti-

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[a] Spurr, 18th Ann. Rep. U.S. Geol. Surv., Pt. III, 1898, p. 155.

ferous quartz-mica-schists with calcareous members, but the greater part of the bed-rock of the country is formed by the constantly associated shales, cherts, conglomerates, limestones, tuffs, and diabases of Devonian age that have collectively been termed the Rampart series.[a] Granitic, monzonitic, and diabasic intrusions and masses are numerous. Both gravels and "muck" (peaty overburden) are, on the whole, of much less thickness than at Klondike. An interesting occurrence of silver nuggets from Ruby Creek and Slate Creek is recorded.[b] One from the latter stream weighed 8 ounces.

A hundred miles east of Rampart lies the Fairbanks region, one of the latest discovered and most active of interior Alaskan fields. Its yield in 1904 was some £100,000 ($400,000). The chief producing creeks in 1903 were Pedro, Clery, and Fairbanks. There are here no high-level gravels, but the conditions are otherwise similar to the majority of Yukon districts.

The placer districts high up the Koyukuk, a northern tributary of the Yukon, and more than 50 miles within the Arctic Circle, are the most northerly goldfields in the world. The principal mining centres are Bettles, Peavy, and Cold Foot. Little is known about this region, since it is, naturally, difficult of access. The placers of the Kobuk river, which flows into Behring Straits, are also well within the Arctic Circle.

Seward Peninsula.—By far the richest placers of Alaska, are, however, those of the Seward Peninsula. They occur along many streams from Kotzebue Sound on the north to Golofnin Sound on the south, and in streams to the west of a line joining these Sounds. The Nome placers are the best known and at the present time the most productive. The first discovery in the immediate neighbourhood of Nome was made on Anvil Creek in 1898, and was followed in the succeeding year by that of the Nome beaches. The latter, for three miles east and west of Nome, have yielded a rich harvest and have been worked over by hand twice and three times. They are now to be dredged. At Nome, coastal uplift has produced three main lines of beach gravel. The first and lowest is the present beach, the second is 37 feet higher and three-quarters of a mile inland, while the third is 79 feet above sea-level and five miles from the present shore.[c] The present beach is made up of sand, fine and coarse shingle, angular and sub-angular gravel, and a few large boulders. The last were probably

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[a] Spurr, loc. cit. sup.

[b] Prindle and Hess, Bull. U.S. Geol. Surv., No. 259, 1905, p. 114.

[c] Hutchins, Eng. Min. Jour., Nov. 23, 1907.

brought to their present position by floating ice, since they are generally found on or near the surface. Strata of clay sometimes occur forming "false bottoms." The gold occurs irregularly through the deposit, but none is found in the overlying "tundra" or muck—vegetable soil, sand, moss, grass, and ice. At Nome both gravel and overlying "tundra" are generally frozen, though unfrozen areas, due perhaps to springs and often indicated by willows, are met with. As a rule the beds of the large streams are not frozen.[a] Only the richest of the frozen ground may be worked. Numerous dredges have been placed in commission in Alaska, but the majority have failed owing to weak or faulty construction. One of first-class design, placed on the Solomon river (east of Nome) has proved successful. Its working costs running full time and treating 3,000 cubic yards per day are estimated at 6 grains ($0.20) per cubic yard. The conditions for hydraulic sluicing methods being generally favourable in the Seward Peninsula, considerable use is made of giants or monitors. In 1904 it was estimated that there were no less than 275 miles of water-races constructed or under construction. During that year the peninsula produced about £900,000 ($4,500,000) gold. Some of the low-lying gravels have been very rich. In October, 1904, a single rocker working near the head of Little Creek recovered in 7 hours 200 pounds weight of gold![b]

Other important placer regions in the Seward Peninsula are Solomon river, Bluff district, Casadepaga river, Council district, Kongarok river, and Fairhaven district.

In southern and south-eastern Alaska placer deposits are not of great importance. Those of Turnagain Arm, Cook Inlet, are worked by hydraulic methods. They were the first discovered in Alaska and are interesting as yielding nuggets of native silver. As might be expected, the bullion is low-grade, ranging from 62s. 6d. to 66s. 8d. ($15 to $16) per ounce. The gold nuggets from this region are flat and smooth with occasional glacial striae.[c] Near Cape Yagtag, 400 miles north-west of Sitka, are small beach placers that have been worked intermittently and yield from £2,000 to £3,000 ($10,000 to $15,000) per annum. The best returns are always after the heavy winter storms. The sands are garnetiferous and the gold is very fine.[d] Further south-east, placers of economic interest are those of Porcupine Creek near Dyea, Skaguay district, and of Gold Creek, Juneau. Owing to the comparatively recent

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[a] Schrader and Brooks, Rep. U.S. Geol. Surv., Washington, 1900

[b] Brooks, Bull. U.S. Geol. Surv., No. 259, 1905, p. 20.

[c] Moffitt, Ib., p. 98.

[d] Martin, Ib., p. 89.

intense glaciation of this region the south-eastern placers are of no great extent and the majority are now exhausted.

Up to the present, valuable quartz veins are unknown on the northern Alaskan mainland. On the Seward Peninsula a quartz mine has been opened up on the Big Hurrah tributary of the Solomon river, to the east of Nome. Spurr[a] records recent propylitic mineralisation from the Tordrillo mountains and from the Skwentna and Kuskokwim rivers, where the gold deposits are apparently connected with Eocene dykes, generally acidic in character.

Aleutian Islands.—The islands of the Aleutian Chain furnish two gold-quartz mines in andesites. The better known is the Apollo Consolidated on Unga Island, one of the Shumagin group. The mine lies on the south side of the island, and has, since 1891, yielded between £400,000 and £600,000 ($2,000,000 and $3,000,000).[b] The lode is essentially a zone of closely reticulated veins in a large mass of Tertiary andesite or dacite. The gangue is quartz with subordinate amounts of calcite and orthoclase. Much of the gold is free, and associated minerals are galena, pyrite, blende, chalcopyrite, and native copper. Minor parallel ore-bodies occur and are worked on either side of the main body. Ore-shoots occur where two diagonal sets of fractures intersect. The ore varies considerably in value, averaging perhaps 33s. 4d. ($8.00) per ton. A small beach placer, the gold of which is derived from similar andesites, is worked on the neighbouring Popoff Island. The dark-grey Tertiary andesites of Unalaska Island, where volcanic activity is still persistent, also carry low-grade pyritous lodes. Workings on these have not proved profitable.

South-Eastern Alaska.—The auriferous veins of south-eastern Alaska occur along a belt extending from Berners Bay in the north to Ketchikan in the south. The outcrops of the various geological formations along this belt are disposed in bands parallel to the general strike of the strata and to the north-west trend of the coast. The axial rocks of the great Coast range are intrusive diorites and granodiorites, which are themselves occasionally intruded by later basic rocks. There are also contained within the diorites bands of metamorphic rocks similar to and probably of the same age as those on the outer flanks of the range. The diorites are of various types, ranging from hornblende- and mica-diorite to quartz-diorite and granodiorite.

[a] 20th Ann. Rep. U.S. Geol. Surv., Pt. 7, 1900, p. 259.

[b] Becker, 18th Ann. Rep. U.S. Geol. Surv., Pt. III, 1898, p. 83; Martin, Bull. U.S. Geol. Surv., No. 259, 1905, p. 100.

The albite-diorite of Becker[a] probably represents an extreme phase of differentiation in the main underlying diorite-magma. True granite is associated with the diorite in the north of the belt near Skaguay.

Eastward and seaward of the dioritic mass is a series of crystalline schists derived from sedimentary rocks. This series, along a section line from the sea across Douglas Island to the main range, is about three miles wide, giving an apparent thickness of strata of about 15,000 feet. Its rocks are mainly mica-, hornblende-, and garnet-schists, such as might result from the metamorphism of felspathic and calcareous sandstones. Associated with the schists are limestones and quartzites. The next series to the eastward is composed of interbedded slates and greenstones. It has been divided by Spencer[b] into three principal lithological groups, with the outermost and most westerly of which we are chiefly concerned. It is this group—made up of alternating bands of greenstone, greenstone-breccias, and black calcareous and carbonaceous slate—that forms the auriferous horizon of the Treadwell deposits. The whole series near Douglas Island has a width of outcrop of some seven miles. It is considerably metamorphosed, the black slates often becoming graphitic. By Spencer the stratified rocks of the series are referred to the Carboniferous period.

While the lode-deposits of south-eastern Alaska follow, as a rule, fairly well-defined geological horizons, they nevertheless vary greatly in character. At Berners Bay, Sitka, and Snettisham, the auriferous lodes are large quartz veins of only moderate grade. At Sheep Creek and Funter Bay, rich gold-quartz stringers occur in slates and schists. In the Silver Bow basin, behind Juneau, gold-quartz veins follow wide basic dykes. In many places quartz veins are not developed, and the lodes are then heavily mineralised belts of slate and schist. In the Treadwell district, as will be seen more fully in later pages, the lodes are shattered albite-diorite dykes.

The ore for which the lodes of the Ketchikan area, in the extreme south of the Alaskan coastal region, are worked, is mainly chalcopyrite, containing from 1½ to 2 dwts. ($1.50 to $2.00) gold per ton. Gold-quartz veins also occur and are being actively prospected. In the Dolomi area, Johnson Inlet, 36 miles west of Ketchikan, numerous gold-quartz veins occur in limestone and in calcareous schists. Similar deposits in limestone have been found on Dall Island. At the Golden Fleece mine, Dolomi, the dolomitic limestone in the neighbourhood of the auriferous quartz vein is traversed by diabase dykes. At the Valparaiso mine in the same

[a] 18th Ann. Rep. U.S. Geol. Surv., Pt. III, 1898, p. 64, *et seq.*

[b] Spencer, A. C., loc. cit. inf.

district a quartz-calcite vein, 6 to 8 feet wide, in crystalline limestone is worked. With the free gold of the Valparaiso vein are associated both tetrahedrite and pyrite.[a]

Spencer[b] calls attention to the marked resemblance of the Juneau gold-belt of south-eastern Alaska to the Californian gold belt: "The rocks of both regions are in part of identical character, and some of them correspond in age and in the nature of their metamorphism. There is also a marked similarity in the occurrence of the gold veins and in the general effects of mineralisation; and some of the broader facts suggest that the dates of vein and ore-deposition correspond closely, though more definite proof of this is required." The Coast Range diorites are compared with those of the Sierra Nevada in California; the Carboniferous slates of Alaska with the Calaveras formation of California; and the greenstones with the amphibolites in the vicinity of the Mother Lode.

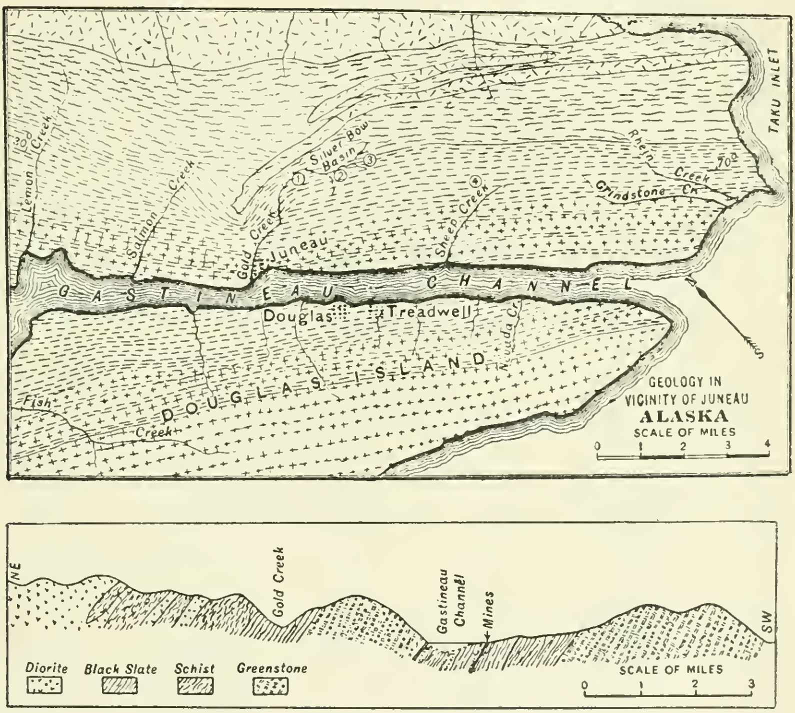
The famous Alaska-Treadwell mines are situated on the shore of Gastineau Channel, which separates Douglas Island from the mainland. Juneau, about three miles north-east of the mines and across Gastineau Channel, is the chief township of the district. The Treadwell deposits were first worked as placer diggings about the year 1881. The placers were rich, but small and shallow. In the same year a small mill of five stamps was erected. The ore even then was low-grade, being worth only from 32s. to 40s. ($8.00 to $10.00) per ton. There is thus evidence of the absence from the Treadwell lodes of notable secondary surface-enrichment. The extent and tenor of the ore-bodies was soon recognised. A mill of 120 stamps was put in operation in 1885 and the stamping power has gradually been increased until in 1906 there were no less than 880 stamps engaged in crushing the ore of the four Douglas Island mines, that, under one management, constitute the Treadwell group. These mines have, from 1882 to 1905 inclusive, produced £5,087,485 ($24,817,000) gold. Yet the ore crushed has always been of exceedingly low grade, that mined during 1903-4 being valued at only a little more than $2.00 per ton. The working costs in 1907 were 5s. 6d. ($1.33) per ton.

It has already been said that the Treadwell ore-bodies are shattered albite-diorite dykes in a country of alternating carbonaceous and calcareous slates interbedded with greenstones. The dykes lie in a zone that extends for three miles along the strike of the enclosing rocks and possess a width of some 3,000 feet. The hanging-wall of the zone is sharply defined by a band of

[a] Brooks, Prof. Paper, U.S. Geol. Surv., No. 1, 1902, p. 79.

[b] Trans. Amer. Inst. M.E., XXXV, 1905, p. 479.

greenstone 300 feet thick, dipping with the country to the north-east, and therefore towards Gastineau Channel. The strike of the greenstone is slightly oblique to the shore, and towards the south-east the greenstone outcrop disappears beneath the channel waters. The greenstone, according to Spencer, is almost certainly interbedded with the slates, and is not intrusive into them. To the north-west it appears as a fine-grained diabase but, near its point of disappearance beneath Gastineau Channel, it becomes coarser and more granular, with coarsely crystallized hornblende and some pyrite. The albite-diorites are much younger than and are intrusive through the greenstone. While the diorite dykes far away from the hanging-wall greenstone have been heavily mineralised, it is only when they



Figs. 158 and 159. Geological Plan and Section of Neighbourhood of Juneau, Alaska (*Spencer*).

lie immediately under the hanging-wall that they become sufficiently valuable to be worked. The original albite-diorite of the lodes is now much altered. The primary felspars were albite-oligoclase with microperthite. Secondary felspars are pure albite. Few traces of original ferro-magnesian silicates remain. Thin basaltic dykes are the youngest rocks of the district. These are believed to have no genetic connection with the ore-deposits.

The lodes vary in width from a few inches to 200 feet. The ore consists essentially of albite-diorite rock impregnated with pyrite and other sulphides, and reticulated with pyritous quartz and calcite veinlets. The sulphides present are pyrite, stibnite, and pyrrhotite, with rarer chalcopyrite, galena, blende, and molybdenite. Magnetite occurs in some quantity. Arsenic, realgar, and orpiment have been detected. The presence of molybdenite is said to indicate higher-grade ore. From 60 to 75 per cent. of the gold is free milling. The concentrates, constituting 2 per cent. of the ore crushed, are worth from £6 to £10 ($30 to $50) per ton. Gold is very rarely visible. The ore-dykes have already been mined to depths of more than 1,000 feet.

The sulphide-filling of the cross veinlets within the dykes appears to be due to metasomatic replacement, the original hornblende and mica having completely disappeared and the secondary albite being largely replaced by sulphides. Further evidenee of metasomatic replaeement may be derived from the fact that the ore-filling of the cross veinlets does not pass beyond the foot and hanging-walls of the diorite dykes, though the fissures themselves may be traced into the adjoining slates.

The following table shows the annual value of the gold production of Alaska since the year 1880:—[a]

Year.	Value, Dollars.	Value, Sterling.	Year.	Value, Dollars.	Value, Sterling.
1880	$20,000	£4,100	1894	$1,282,000	£262,810
1881	40,000	8,200	1895	2,328,000	477,342
1882	150,000	30,750	1896	2,861,000	586,505
1883	301,000	61,705	1897	2,439,500	499,995
1884	201,000	41,205	1898	2,517,000	515,985
1885	300,000	61,500	1899	5,602,000	1,148,410
1886	446,000	91,430	1900	8,166,000	1,674,030
1887	675,000	138,375	1901	6,932,700	1,421,203
1888	850,000	174,250	1902	8,283,400	1,698,097
1889	900,000	184,500	1903	8,683,600	1,780,138
1890	762,000	156,210	1904	9,160,000	1,877,800
1891	900,000	184,500	1905	15,630,000	3,204,150
1892	1,080,000	221,400	1906	21,800,000	4,469,000
1893	1,038,000	212,790	1907	18,000,000†	3,690,000†
Total				$121,348,200	£24,896,880

† Estimated.

[a] Brooks, Rep. Min. Res. Alaska, 1907, Bull. No. 314, U.S. Geol. Surv., p. 21.

WASHINGTON.

Two main auriferous belts are found in this State: a central belt extending along the trend of the Cascade Mountains, and an eastern belt, the southern continuation in Ferry and Stevens counties of the already described regions of Rossland and Slocan in British Columbia. In the former region the Cascade Mountains, which reach their highest altitude in Mount Tacoma or Rainier (14,530 feet), are made up of Palæozoic and Mesozoic sedimentary rocks, intruded and often covered by granodiorite and diorite of Mesozoic and Tertiary age. The geological features are therefore closely akin to those of the Coast range in British Columbia in the north, and to those of the Sierra Nevada in California in the south. On the Cascade belt the principal mining field is at Monte Cristo, 40 miles west of Everett and of Puget Sound. The rocks of Monte Cristo are entirely Tertiary.[a] The oldest are arkoses and conglomerates derived from neighbouring Mesozoic granodiorites. These are overlain by andesite, tonalite (ranging to dacite), rhyolite, and basalt, of Miocene age, through which is intruded late Pliocene pyroxene-hornblende-andesite. The period of ore-deposition is apparently Pleistocene. The minerals associated with the silver-gold of the veins are pyrite, pyrrhotite, arsenopyrite, blende, galena, and chalcopyrite, with rare chalcocite, bornite, molybdenite, and stibnite. Metallic arsenic has been found in the neighbourhood. The average content per ton of the Monte Cristo ores is 0·6 ounce gold and 7 ounces silver per ton. The gangue is quartz with occasional calcite. The veins are, on the whole, characterised by a remarkable persistency and regularity in extension. The milling ore, however, occurs in irregular pay-shoots.

In the Mount Baker district further north and near the international boundary the veins are also associated with late igneous rocks. They are copper-gold lodes and carry undetermined gold tellurides.[b]

South of Monte Cristo lie the Peshastin and Sauk districts, best known for their alluvial gold. The country of the gold-quartz veins of the former is altered Mesozoic peridotite or serpentine, and of the latter, the Sauk (Eocene) sandstones and shales. In many cases a diabase dyke intrusive through the sedimentary rocks forms one wall of the quartz vein. In other cases the quartz veins lie wholly within the diabase dykes. In a specimen from the Gold Leaf mine in this district perfect octahedral crystals of gold lie on the ends of the quartz crystals.[c] From the foregoing illustration

[a] Spurr, 22nd Ann. Rep. U.S. Geol. Surv., 1901, Pt. II, p. 788.

[b] Landes, Rep. Wash. Geol. Surv., Olympia, 1902, p. 40.

[c] Smith, G. O., Bull. U.S. Geol. Surv., No. 213, 1903, p. 80.

of vein occurrences in the Cascade Mountains it will be clear that while the geological relations of the enclosing rocks are similar to those of the Sierra Nevada in California, the gold-quartz veins are themselves much younger than those of California, and are, indeed, probably no older than late Tertiary.

The mines of Stevens and Ferry counties in the north-eastern corner of the State present considerable resemblances to those of the Rossland district. The oldest rocks of the Republic district in Ferry county are granite, gneiss, crystalline schist, and limestone. Through these, granites have been intruded. In early Tertiary times there occurred extensive porphyritic andesite flows, in which the principal veins of the district were formed. The gangue is clean quartz without sulphides, and the gold is ordinarily so fine that it cannot, even in rich specimens, be detected with a lens. Nevertheless, the values of different portions of the same veins may vary considerably. In Stevens county, the Pierre Lake is the principal district. Its rocks are also gneisses and crystalline schists.

Nearly all the terraces and bars of the upper Columbia river in Washington State carry fine gold. Most of the richer spots have been discovered and worked by Chinese, but it is considered that there may yet remain limited areas sufficiently rich to warrant the use of dredges.[a]

Beach-placer mining has been intermittently conducted since 1864 on the Pacific Coast on beaches lying from 10 to 25 miles south of Cape Flattery. The yield has never been large and is estimated at a total of £3,000 ($15,000).[b] The gold is concentrated by wave-action from cliffs and terraces of Pleistocene sands and gravels. Small quantities of platinum and iridosmine occur with the gold.

The total yield of Washington State since the discovery of gold to 1900 inclusive is estimated at £4,387,000 ($21,400,000).

The yield for recent years is :—

Year.	Value, Dollars.	Value, Sterling.
1901	$580,500	£119,002
1902	272,200	55,801
1903	279,900	57,380
1904	314,463	64,465
1905	370,000	75,850
1906	221,648	45,438
1907	154,888	31,870
Grand Total to end of 1907.	$23,593,599	£4,836,806

[a] Collier, Bull. U.S. Geol. Surv., No. 315, 1907, p. 70.
[b] Arnold, Ib., No. 260, 1905, p. 155.

OREGON.

Two distinct and well-separated auriferous areas are found in the State of Oregon, one in the Blue Mountains in the north-east, the other in the south-west, where it forms the northern prolongation of the auriferous belt of California. The first is the more important. It covers a considerable area, extending the length of the Blue Mountains, with a width westward from the Snake river of some 130 miles. Its placers were known first in 1862. For several years, and especially in the neighbourhood of Auburn, they yielded handsome profits, notwithstanding the fact that the early miners had each to recover at least $8.00 gold per diem to cover bare living expenses. By 1870 the richest placers were exhausted and a gradual decline in placer-mining has continued to the present day. In 1885 a railroad was constructed through the region, and the active development of the gold-quartz veins dates from that year.

The Blue Mountains may be regarded as the western portion of the great central mountain mass of Idaho. They are made up of cores of Palæozoic rocks partly surrounded by later Tertiary lavas—rhyolites, andesites, and basalts.[a] The oldest rocks are siliceous argillites of possibly Carboniferous age. Overlying them come Triassic shales and limestones. In many places the sedimentary rocks are disrupted and folded by intrusive masses of granite, granodiorite, diorite, gabbro, and serpentine. The area is considered by Lindgren to resemble closely in its general geological features the auriferous belt of the Sierra Nevada in California. The gold-silver veins of the Blue Mountains occur within a belt 100 miles in length and 30 to 40 miles in breadth, and from this restricted area the placer-deposits ramify through the lower country. The principal veins lie in Baker and Grant counties. Their country is either the granodiorite, an associated igneous rock (diorite or tufaceous greenstone), or the argillite. Most of the larger and richer mines are in the latter. It would therefore appear that here, as in California, the enclosing country exercises no potent influence on the richness or otherwise of the vein. But there is nevertheless a genetic connection between the intrusive rocks and the gold-quartz since the veins are, speaking broadly, grouped on one or other side, or on both sides, of the contacts of the intrusive rock (which ranges from granite to serpentine) with the sedimentary members of the complex. In age the veins are probably Cretaceous. Their gangue is quartz with occasional calcite or dolomite. Gold occurs both free and with sulphides.

The placer-deposits of north-eastern Oregon are at the present day comparatively unimportant. The bars of the Snake river, which

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[a] Lindgren, 22nd Ann. Rep. U.S. Geol. Surv., Pt. II, 1902, p. 576.

forms the boundary between Oregon and Idaho, carry fine gold, and small gulch deposits are being worked in the head-waters of the tributaries of the Grande Ronde, Powder, Burnt, and Malheur rivers, all flowing east to join the Snake, and in the upper tributaries of the John Day river, flowing west from the Blue Mountains and falling into the Columbia river. The placer-deposits are of widely differing ages. Early Miocene, or possibly even Pliocene, gravels have been covered up by the great flows of later, mainly Miocene, lavas. For the most part these ancient auriferous channels lie below the present drainage level of the country and are inaccessible. Similar gravels have, however, been worked at Winterville and Parkerville at the head of Burnt river. Gravels of intervolcanic (later Miocene) age are found as benches or high-level gravels at Sumpter, Canyon, and elsewhere. Pleistocene gravels occur as low benches or occupy the present drainage channels. On the whole the gold is coarse, but exceedingly fine gold is found when the distance from its original source becomes considerable. The quality of the placer-gold varies from 680 to 990, the percentage of silver naturally decreasing with the size of the gold grains. The largest nugget found in the area is said to have come from McNamee Gulch, near Robinsonville. It is reported to have been worth £2,800 ($14,000), and its weight was therefore at least 700 ounces. Working costs show that in this area hydraulic sluicing requires at least 1¼ grains, and dredging at least 5 to 6 grains gold per cubic yard to cover expenses.

In south-western Oregon gold-quartz veins are found in Lane, Douglas, Curry, Josephine, and Jackson counties. The Bohemia mining district described by Diller[a] is apparently typical of these occurrences. The district lies on the Calapooya Mountain, a western spur of the Cascades. The mountain mass is made up of Eocene and Miocene lavas, such as are common through the whole Cascade chain, and, indeed, form its highest mountains [Rainier (Tacoma) and Shasta]. The lavas are dacite-porphyry, andesite, and basalt. They are now considerably propylitised. The veins lie in narrow, irregular, crushed and mineralised zones. Pyritous impregnation often extends 6 feet and more on each side of the original fissure. The gangue is mainly quartz with kaolinic and sericitic matter. The gold is free or is associated with pyrite, blende, galena, and chalcopyrite.

Fifty miles north of the Bohemia district is the Blue River goldfield. Its rocks are more acid than those of Bohemia, rhyolite being abundant. Andesites and basalts, however, occur.

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[a] 20th Ann. Rep. U.S. Geol. Surv., Pt. III, 1900, p. 11.

Most of the placer gold of Oregon is obtained in Josephine county, and is derived from veins similar to those just described. The largest alluvial gold mine at present working in south-eastern Oregon is the Greenback, in Josephine county. Beach placers, arising from the action of waves on gravel cliffs, have been worked near Cape Blanco and Port Orford. Their yield is small.

The total production of gold of the State of Oregon from the year of its discovery to 1900 is estimated at £11,172,500 ($54,500,000). Subsequent annual yields have been :—

Year.	Value, Dollars.	Value, Sterling.
1901	$1,818,100	£372,710
1902	1,816,700	372,421
1903	1,290,200	264,491
1904	1,412,186	289,498
1905	1,244,900	255,204
1906	1,366,900	280,216
1907	1,179,988*	241,897
Grand Total.	$64,628,974	£13,248,937

* Estimated.

CALIFORNIA.

The gold belt of California extends along the western foothills of the Sierra Nevada and for some distance beyond them to the south. It may be described as commencing in Mexico 100 miles south of the State boundary line and passing up, by way of San Diego, San Bernardino, and Kern counties, to the foot of the Sierra Nevada, where it develops breadth and richness, forming, along the western flanks of the Sierra Nevada to Tehama county, the main central portion of the gold belt. In Tehama county it disappears beneath the great lava fields of Northern California. The general width of the belt is from 20 to 60 miles ; the greatest width is attained in and to the north of Mariposa county. The belt is probably continued by the gold occurrences of the northern counties of Shasta, Trinity, and Siskiyou, and further north, as has already been indicated, by some of the gold veins of Southern Oregon.

A second and very dissimilar belt, orographically and geologically belonging to Nevada rather than to California, occurs on the eastern flank of the Sierra Nevada in Tertiary andesitic regions. It passes from south-east to north-west through San Bernardino, Inyo, Mono, and Alpine counties.

The rock-core of the Sierra Nevada and of its geological extension into Lower California is a granodiorite (quartz-mica-diorite containing a little orthoclase) which is intrusive into the great complex termed the "metamorphic series" or "auriferous slate," though the latter is well developed only in the north of the auriferous area. The metamorphic series consists largely of more or less altered, highly compressed and folded sediments ranging in age from early Palæozoic to late Jurassic. Through these are intruded igneous masses also of varying ages from Palæozoic to Mesozoic, but mainly of late Jurassic or early Cretaceous time. In the intrusive rocks augite-porphyrite, diabase, and serpentine all find representatives. The older rocks have shared in the orogenic movements that initiated mountain building and are therefore largely converted into crystalline schists.[a] The sedimentary rocks occur mainly in the eastern or higher portion of the metamorphic belt, the igneous in the western or lower portion. The last intrusions through the metamorphic series are apparently apophyses from the great granodioritic central core.

The auriferous area is closely connected with the metamorphic series, their respective boundaries being practically coincident. Even in the far south, where the granodiorite is widely developed, the scattered gold deposits are usually found to be connected with small schistose areas. Gold-quartz veins are uncommon in the granodiorite, and when they do occur, they are generally near a contact with the metamorphic series. Within the latter, however, they may and do occur in any given member of the complex, whether metamorphic, sedimentary, or igneous. While no increase in the number or in richness of the veins is noticeable near the main line of contact of the granodiorite and metamorphic series, yet, within the latter, gold-quartz veins are very often found clustered along the granodiorite dyke contacts. Lindgren[b] at first insisted that the California gold-quartz veins showed no remarkable dependence on acid igneous rocks, but in 1903 a general genetic relation was admitted, although few, including the great Mother Lode, for example, can be shown to be directly dependent on these granodioritic apophyses. Gold-quartz veins are also known to occur in areas of diabase and of augite-porphyrite far removed from other rocks.

The period of filling of the gold-quartz veins of California is believed to be late Jurassic or early Cretaceous. The filling itself is probably due to thermal or solfataric action, consequent on granodioritic or magmatically connected intrusions. According to Lindgren some deposits are perhaps even earlier, since in the uppermost member of the series certain Jurassic conglomerates carry gold believed to be placer in origin.[c]

[a] Lindgren, Bull. Geol. Soc. Amer., VI, 1895, p. 224.
[b] Loc. cit., p. 225.
[c] Lindgren, Amer. Jour. Sci., XLVIII, 1894, p. 275.

The normal gold-quartz veins of California are fissure veins that are subsequent in age to the metamorphism of the slates, &c. Unlike the normal lenticular bedded veins of schistose rocks, the typical gold-quartz veins of California run indifferently across or with the strike or dip of the slates and schists. In the massive rocks (diabase, granodiorite, or gabbro) no rule is observable. The great Mother Lode itself is parallel with the strike of the enclosing rocks but cuts across the dip.

The quartz veins have been formed by simple filling of fractures and fissures, wall-replacement having apparently played no part in their development. The quartz is white and milky. Calcite, mariposite (green chromium-potash-mica), roscoelite (vanadium-potash-mica), rhodonite, and albite occasionally occur in the gangue. Free native gold is irregularly distributed in the matrix, and in vughs is often crystallized. Pyrite, chalcopyrite, blende, galena, and arsenopyrite are common associates of the gold, while pyrrhotite, molybdenite, tetrahedrite, cinnabar, and various tellurides occur more rarely. It appears to be the rule that veins in granodiorites contain more sulphides than those in other rocks, and pyrrhotite is found only in these rocks. The pay-ore is ordinarily contained in shoots following an empirical law which is nevertheless of very wide application, viz., that the shoots pitch to the left when the observer is looking down the dip of the vein. Rich pockets or bonanzas are often met with at the intersection of two veins.

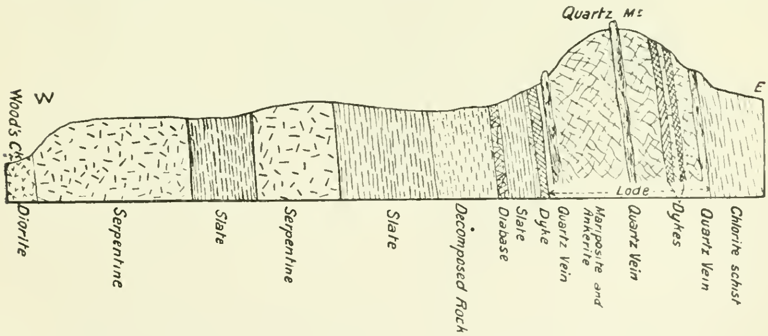


FIG. 160. SECTION ACROSS MOTHER LODE AT QUARTZ MOUNT (*Fairbanks*).

In addition to the normal type of simple gold-quartz vein, low-grade auriferous zones of pyritous impregnations are found in amphibolitic schists. Quartz veins passing through these may be strongly enriched. These deposits are distinctly older than the principal quartz veins and are contemporaneous with the metamorphism of the diabase to schists. Later impregnations of the schists and massive rocks with auriferous pyrite have also been noted.

The Mother Lode.—The most remarkable auriferous lode in California and, indeed, in some respects, in the world, is the famous Mother Lode, that extends northward from Mount Ophir in Mariposa county to beyond Calaveras county, a total distance of more than a hundred miles. Properly speaking, it is not a true lode, but rather a sheared and fissured zone in which numerous quartz veins and stringers are developed. Its strike, as already noted, is north-west and south-east, *i.e.*, with the country. In many places it forms a single lode varying in width from a few feet to more than 100 feet. The maximum width of the formation is about a mile. Owing to the greater resistance to erosion of the quartz it often stands out above

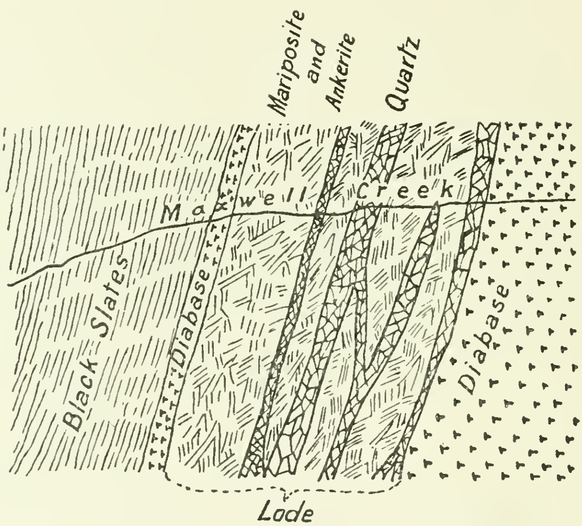


FIG. 161. PLAN OF MOTHER LODE, NEAR COULTERVILLE (*Storms*).

the level of the county as a great white wall. When followed in depth it shows neither diminution in size nor decrease in value.[a] The Mother Lode is associated with a narrow and almost continuous belt of black slate, called the Mariposa beds. The contained veins occur either in the slate or on the contact between it and the greenstone (diabase) dykes. The regularity and continuity of the lode are due largely to the geological structure. At Quartz Mount, Calaveras county, the lode is 600 feet wide. Here, however, and for some distance north and south, there are really two principal veins with intervening country. In Amador and Eldorado counties, the lode splits into a series of parallel veins. The Mother Lode is undoubtedly due to major

[a] Fairbanks, 10th Ann. Rep. State. Min., Cal., 1890, p. 23; Id. ib., 1896, p. 666.

faulting developed along a line parallel with the axis of the Sierras during the uplift of those mountains. The whole length of the lode cannot be worked at a profit, but the erosion of even the poorer parts has nevertheless resulted in rich placer-deposits. Some zones have been particularly rich, as at Grass Valley and Nevada, and in that portion of the Mother Lode belt in Tuolumne county. The quartz-bodies forming the ore-shoots occur in lenticular masses that range from a few inches to 50 feet in thickness, and extend for over 1,000 feet along the strike. The lenses are irregularly

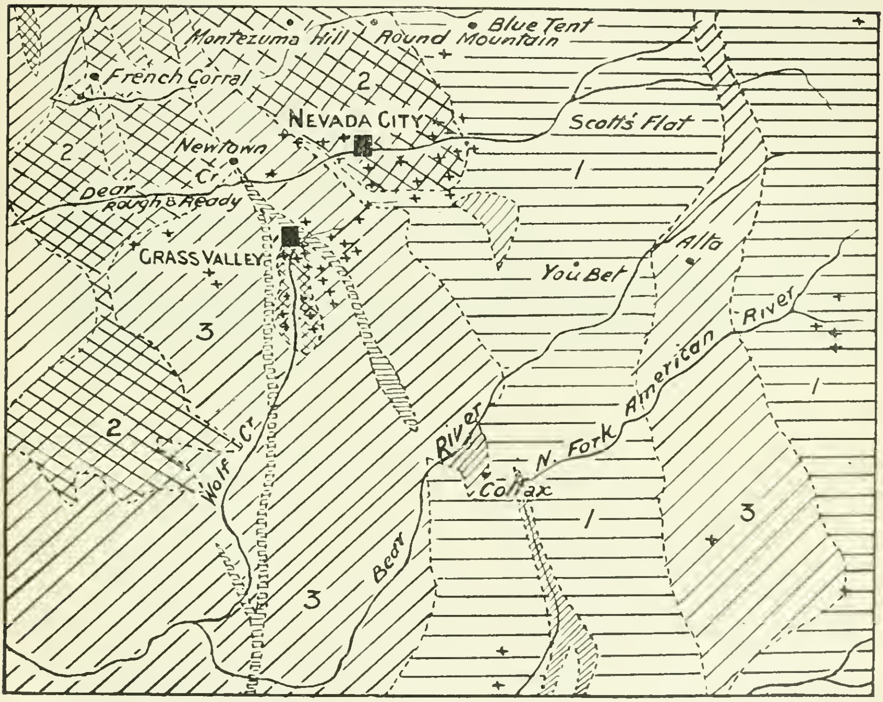


FIG. 162. GEOLOGICAL MAP OF NEIGHBOURHOOD OF GRASS VALLEY AND NEVADA CITY, CALIFORNIA (*Lindgren*).

1. Mesozoic and Upper Palæozoic sedimentary beds. 2. Granodiorite.
3. Diabase, porphyrite, gabbro, diorite, serpentine, and amphibolite. + Gold-quartz mines.

distributed along the fissure zones. The vein usually contains much gouge matter and also much mariposite. The quartz is characteristically ribboned and banded, a structure due to black slaty seams disposed parallel to the walls. The lode or the parallel series of veins that may represent it occurs either in the Mariposa beds or on the contact between it and the diabasic dykes ("greenstone" of the miners). In its course it passes through a great variety of rocks, but it nevertheless varies but little in size or richness. The movements that have resulted in the formation of clay and "pug" in the lode have at times been immense, since the gouge in places is 30 feet in thickness.

Grass Valley.—The Nevada City and Grass Valley regions in Nevada county may be taken as furnishing fairly typical Californian vein occurrences. They were first worked for their placer gold, but as early as January, 1851, a stamp-mill had been erected. The districts are estimated to have produced to the end of 1896 no less than £23,165,000 ($113,000,000) gold, both from quartz veins and from alluvial deposits. The quartz veins lie along the contact between the foothills, composed of igneous rocks, and the middle slopes of the Sierra Nevada, formed of sedimentary rocks—siliceous argillite, slate, sandstone, and schist—partly of Jurassic, partly of Carboniferous

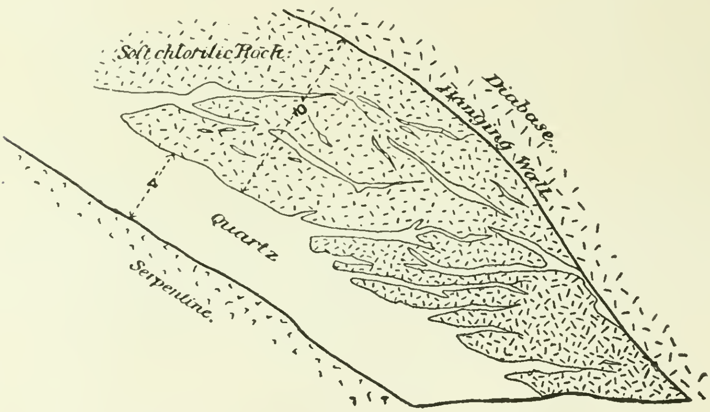
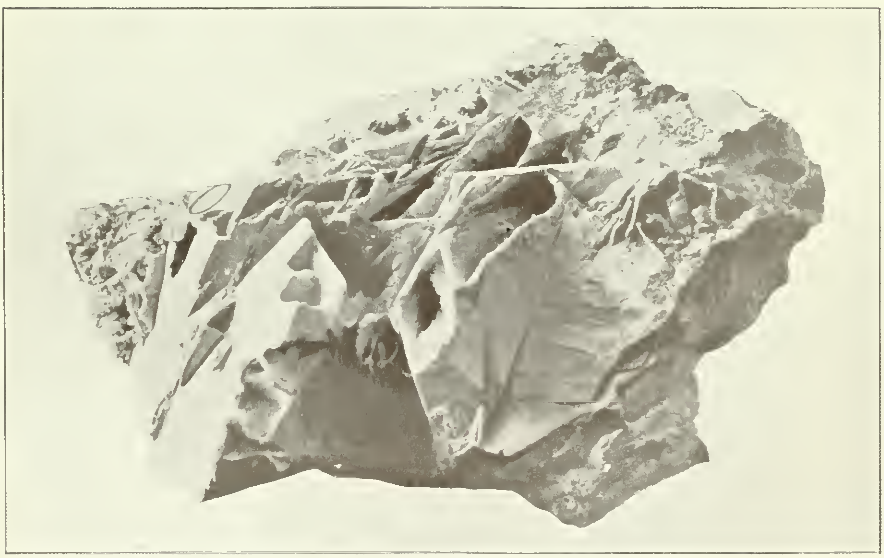


Fig. 163. Cross-section of Maryland Vein above 1,500ft. level (*Lindgren*).

age. The igneous rocks are granodiorite, diorite, gabbro, and diabase, together with porphyrite, pyroxenite, and peridotite. Amphibolites have been formed from the four first-named rocks, and serpentines from the two last. The igneous rocks are Jura-Trias[a] or later, and the eruptive sequence was apparently closed by the early Cretaceous granodioritic intrusions. Fissures were induced by folding and by intrusions, and these are now filled with vein matter. The principal vein-stone is quartz with native gold and metallic sulphides, all having been deposited in open spaces along fissures. A remarkable analogy in the general character of vein formation may be traced between Grass Valley and Gympie, Queensland, though in the latter case auriferous deposition is

[a] Lindgren, 17th Ann. Rep. U.S. Geol. Surv., Pt. II, 1896, p. 258.

Stope above 1,500 feet level, Maryland Vein, Grass Valley, California.



Cavernous Quartz Pseudomorphic after Original Barytes or Calcite, De Lamar Mine, Idaho (*Lindgren*).

obviously dependent on the presence or absence of carbonaceous matter. In this respect it may be noted that Prichard[a] attributes the origin of auriferous solutions to the intrusion of the granodioritic dykes and the actual precipitation of the gold of the Mother Lode to the carbonaceous matter of the slates of the Mariposa Formation.

From Trinity county in the north of California, Hershey[b] describes pockets of gold occurring mainly in a dirt seam at the contact plane between a massive diabase and an overlying Jurassic slate. The diabase is believed by him to be the matrix of the gold. since portions of the rock on assay have yielded tenors of $2.00 to $3.00 per ton. It would, however, seem more probable that the gold had been deposited along the plane of contact. The gold grains of the pockets are curiously rounded, as if water-worn. They moreover occur near quartz veins that pass down from the slates into the diabase.

Bodie.—The Bodie camp, Mono county, 8,200 feet above sea-level, is typical of the mining fields situated in andesitic rocks on the Nevada border. In 1875 it was the scene of a great but disappointing rush from Virginia City, then past the zenith of its glory. The Bodie country is a hornblende-andesite, probably overlying slates that are, however, not exposed within some miles of the field. The mines have yielded several million dollars in dividends. The gold-bearing quartz veins are confined to a single ridge or zone of country about a mile long and a quarter of a mile wide. The veins carry equal amounts of gold and silver. Almost without exception the lodes have failed to carry pay-ore to greater depths than 500 feet, but a great number of veins occur and some of these have been of large size. Most of them show a banded structure. Manganese oxides occur largely as a filling in vughs.[c] The bullion is 675 fine in gold, the remainder being silver. The ores average about 33 dwts. gold and 63 dwts. silver per ton.[d] The veins have produced from 1877 to 1907 about £2,972,500 ($14,500,000). They are usually termed gash veins, since their ores disappear at comparatively shallow depths.

A field apparently somewhat similar to Bodie is the newly-discovered Hart region, in San Bernardino county.

Placer Deposits.—The general characters of the placer deposits of California have already been indicated. Among older placers, Lindgren[e] describes an auriferous conglomerate of Jurassic

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[a] Trans. Amer. Inst. M.E., XXXIV, 1904, p. 454.
[b] Amer. Geol., 1899, XXIV, p. 40.
[c] McLaughlin, Min. Sci. Press, June 22, 1907, p. 795.
[d] 8th Ann. Rep. State Min. Cal., 1888, p. 382.
[e] Amer. Jour. Sci., XLVIII, 1894, p. 275.

age, but his evidence for the contemporaneous deposition of gold and pebble is not convincing. R. L. Dunn also describes an auriferous conglomerate lying at the base of the Chico (Cretaceous) beds on the Klamath river, Siskiyou county. It has an average thickness of 100 feet, the pay-gravel being the lowest stratum. It contains marine shells and is a marine gravel, though Dunn at first believed it to be of fluviatile origin.[a] The actual amount recovered from the Cretaceous auriferous conglomerate was about 2s. 6d. ($0.60) per square foot of bed-rock over 31,000 square feet, while the total value contained was estimated at 16s. 8d. ($4.00) a ton, or 4s. 2d. ($1) a square foot. There seems to be no

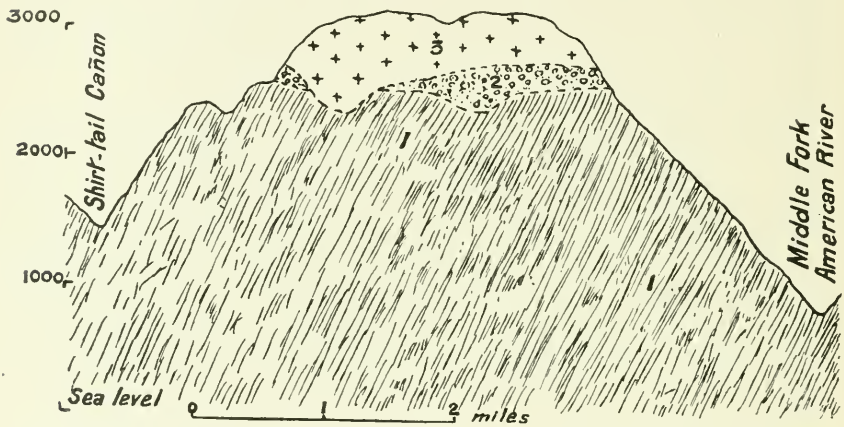

FIG. 164. AURIFEROUS GRAVEL BURIED BENEATH LAVA, FOREST HILL DIVIDE, AMERICAN RIVER (*Browne*).
1. Bed rock (metamorphic slate). 2. Auriferous gravel. 3. Basaltic lava cap.

reason to doubt Dunn's determination of the source of the contained gold, though at the same time he gives no absolute details of the condition of the gold, &c., merely remarking that it is not waterworn. In this connection it must not be forgotten that if pyrite may be deposited, as it frequently is in alluvial gravels, gold may, on decomposition of the pyrite, be left behind, and it is to be noted that the Siskiyou deposit in particular, though very red when oxidised, is blue at depth, denoting possibly an impregnation with pyrite.

The Neocene (Pliocene and Miocene) auriferous gravels of California may be divided into two main groups : (*a*) an older and more important, composed chiefly of white quartz pebbles and light-coloured clays and sands together with interbedded minor flows of rhyolite, and (*b*) later gravels interbedded with andesitic

[a] 12th Ann. Rep. State Min. Cal., 1894, p. 459.

tuffs and containing numerous volcanic rock pebbles. From the flora of the former they are considered to be Upper Miocene in age.

Lindgren[a] has described fully the Neocene rivers and the conditions antecedent to their formation. The duration of the volcanic period separating the two gravels is estimated at one-twentieth of the period of subsequent denudation. The Sierra Nevada in Neocene times is considered to have formed a mountain range as well developed as that of to-day, and moreover one situated in the same position. The slope of the Sierra Nevada has, however, been considerably increased, and greater cutting power

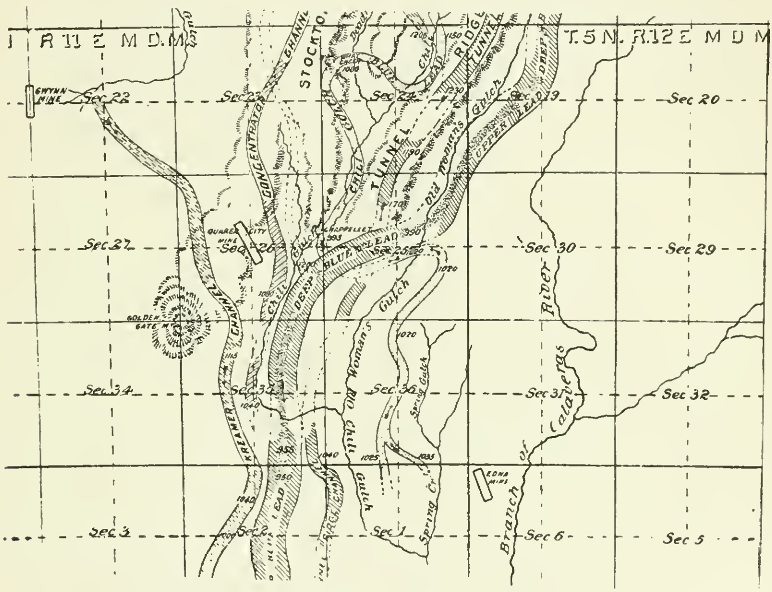

Fig. 165. Plan of Blue Lead, near Mokelumne Hill (*Storms*).

has thus been given to its streams since the deposition of the older gravels, causing the latter to be left as high-level gravels and terraces.

There are thus developed in California two systems of auriferous river gravels, the courses of which differ considerably. The modern river system follows the courses of existing streams; the ancient river system followed a general direction almost at right-angles to that of the present streams. The older formed gravels that are now partly eroded and partly covered by later débris or by thick lava flows, and as a natural result of stream erosion and base-levelling the remnants of the old valley gravels now occupy

[a] Amer. Geol., 1895, XV, p. 371; Bull. Geol. Soc. Amer., IV, 1893, p. 257.

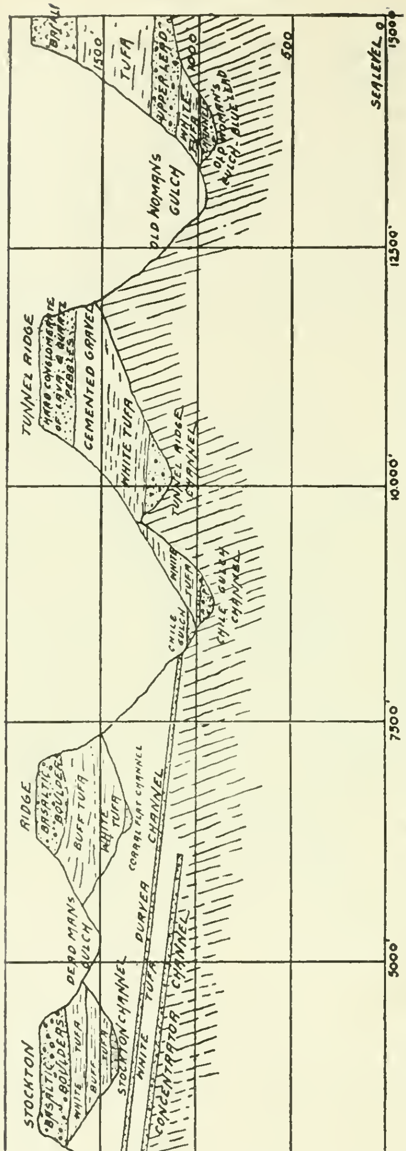

Fig. 166. Cross-section East from Mokelumne River, showing ancient River-channels (*Storms*).

a much more elevated position than the beds of modern streams. The bed-rock of an ancient valley has, at North Bloomfield, an elevation of 2,650 feet above sea-level. At Yankerville, near Forest Hill, placers are worked at an elevation of 2,000 feet. The gravels contain fragments of nearly every rock known in the Sierras. The chief auriferous streams of California are the Sacramento and San Juan with their numerous westward-flowing tributaries that fall from the slopes of the Sierra Nevada. In the old gravels the upper portion is often red, due to the oxidation of the iron content; the lower is blue and unoxidised. The blue gravels are largely cemented with iron pyrites. They often contain silicified wood. The values lie on the old bed-rock. The lava-capped gravels, as in Victoria, are mined by shafts, drifts, and levels. The North Bloomfield mine, near Nevada City, is believed to have been one of the largest of individual placer mines, covering 1,535 acres. The mine was among the many closed by the operations of the Caminetti Law of 1893. It had produced £1,230,000 ($6,000,000) gold.

Oroville.—At Oroville, Butte county, a camp that may be considered fairly typical of Californian dredging areas, profitable dredging operations are being carried on along and beside the Feather river over an area of some 9 miles long by 2 miles wide. The dredging ground appears to be worth 8½d. to 9½d. per cubic yard with an average depth of 33 feet and a maximum of some 60 feet, at which depth a "false bottom" is reached. The average cost of dredging is about 3d. per cubic yard. It is said that £16,810,000 ($82,000,000) alluvial gold has been obtained within a radius of 8 miles of Oroville.[a] The deposits are obviously the débris from an ancient river that flowed westward from the Sierra Nevada. The gravel is rarely cemented, is fairly coarse, and contains no very large boulders. The gold occurs in thin streaks through the gravel. It is finely divided and nuggets are rare. On an average the bullion contains 922 parts fine gold. Electric power is used and furnishes cheap motive power. Oroville presents in every respect most favourable conditions for dredging, and to this somewhat rare combination is entirely due the success of the industry, since it is a form of mining that is peculiarly sensitive to local conditions.

The first discovery of alluvial gold in California is credited to J. A. Marshall, who, on January 19th, 1848, found numerous small grains of gold in a mill-race at Coloma, Eldorado county. The history of the great gold rush that followed in the succeeding year has often been told and need not be recapitulated in this place.

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[a] Knox, Trans. Inst. Min. Met., XII. 1903, p. 452.

Turning to the modern placer industry, the last available returns show that in 1906 Californian placers yielded £1,512,064 ($7.375,925) and deep quartz-mines £2,328,089 ($11,356,527) or 64·3 per cent. of the whole. Placer operations are carried on both by hydraulic mines and by dredging. The former method is largely practised in the northern counties and more especially in Siskiyou and Trinity, where there are no restrictions as to the disposal of the débris. Gold-sluicing was formerly a flourishing industry throughout the foothills of California, but owing to the stringent restrictions placed on the escape of débris under the Caminetti Act of 1893, the industry has been almost completely destroyed. Trinity county is the most productive in hydraulicing, Siskiyou county being second in importance. Drift-mining is not progressing in California, but dredging is largely practised and is highly profitable. Butte county is the largest gold producer in this respect, yielding in 1906 nearly 55 per cent. of the total amount recovered by dredging.

Butte county again, by virtue of its dredges, is the largest gold producer in the State, yielding £6,184,331 ($29.684,788) in 1906. In 1907 dredges were producing one-fourth of the gold yield of the State. Of the total gold production of California, estimated at £282,900,000 ($1,380,000,000), not more than $30,000,000 is the yield of the eastern Tertiary propylite fields.[a] By far the greater proportion of California's yield is due to placers, which, to 1900, furnished perhaps as much as 94 per cent. of the whole.

Marine Placers.—Sea-beach placers are worked in California in a few places in Humboldt and Del Norte counties. Gold Bluff in the former county is perhaps the best known. None have proved of great economic value.

The total gold yield of California from 1849 to 1907 is estimated at :—

Year.	Value, Dollars.	Value, Sterling.
1849–1900	$1.380.000,000	£282.900.000
1901	16,891,400	3,462.737
1902	16,792,100	3.442,380
1903	16,104,500	3,301,422
1904	18,633,676	3.819.903
1905	18.898.545	3.874.201
1906	18.732.452	3.840,152
1907	17,394,863*	3.565,847*
	$1,503,447,536	£308,206,642

* Estimated ; Prel. Rep. Director U.S. Mint, Jan., 1908.

[a] Lindgren, Trans. Amer. Inst. M.E., XXXIII, 1903, p. 818.

IDAHO.

The auriferous region of Idaho lies in the central and south-western portion of the State. It extends southward from 45° 45′ north latitude to near the Nevada frontier, and from the Oregon boundary line to the 114th meridian of west longitude. It may be conveniently subdivided into two districts, lying north and south respectively of the Snake river. In the former district are the Cretaceous veins and the Tertiary placers of Oro-Fino, Florence, Warren, Pierce, Gibbonsville, Elk City, Idaho Basin, and Hailey. South of the Snake river the gold occurrences are restricted to Owyhee county, and are found in, or arise from, veins of post-Miocene age. Vein occurrences are of much greater importance here than in the northern area, where the greater proportion of the gold obtained has been recovered from placers.

The general geology of the Idaho area is well known. The oldest rocks are limestones, quartzites, shales, and schists, of possible Carboniferous age.[a] These lie as a broad belt along the east of the region, and reach nearly as far south as the Snake river. They also occur as a comparatively small area in the north-west. Between the Carboniferous exposures there has been intruded a great central belt of post-Palæozoic and pre-Miocene granite that apparently corresponds very closely in age and general relations to the great granitic batholiths of California. To the west and south are the widespread Columbia (Miocene) basaltic lava flows, that in places attain a thickness of 2,000 feet. They are associated with overlying subordinate rhyolitic lava-flows. The extensive effusions of lava considerably modified the drainage of the country, damming back streams and forming lakes. Deposits formed in such lakes have a considerable development in the south-west, along the present course of the Snake river. The Columbia lavas vary in character from diabase to glassy basalt. Numerous dykes of Tertiary age ramify through the granite. They range from pegmatite and aplite through diorite-porphyry to basic minettes and lamprophyres.

Nearly all the veins north of the Snake river are in the granite. They show a remarkable general uniformity in possessing a strike that is either due east and west or very near to that direction. There is thus a considerable similarity to the veins of the Butte, Montana, and to those of the Blue Mountains in Oregon. In the latter region, however, the general strike is rather north-east and south-west, but the fissures of all three regions nevertheless appear to have arisen from the same compressive forces. Veins are also found north of the Snake in granite-porphyry and diorite-porphyry intrusive through the granite. Silver-lead veins are

[a] Lindgren, 20th Ann. Rep. U.S. Geol. Surv., Pt. III, 1900, p. 75.

not uncommon in the sedimentary rocks, but gold-quartz veins are rare and unimportant. The gangue of the veins in the granite is ordinarily quartz and valencianite (orthoclase).

One of the first placer districts discovered in Idaho, and, moreover, one of the richest, was the Florence, north of the Salmon river. Its yield of alluvial gold from 1861 to 1868 is estimated at from £3,000,000 to £6,000,000 ($15,000,000 to $30,000,000). The veins of the district are low-grade, with a quartz gangue free from sulphides. The fineness of the vein gold is only 650. The country is biotite-granite. The Warren placers were also derived from veins in biotite-granite and proved, like those of Florence, exceedingly rich for a few years after their discovery.

The most noteworthy districts north of the Snake river lie in the counties of Idaho, Basin, and Boise, north and north-east of Boise City. Their veins are either in the post-Palæozoic granites, or in or with associated hornblende-porphyrite and minette dykes.[a] The granite country in the immediate vicinity of the vein fissure suffers a marked change due to the passage of underground water. Biotite and hornblende are bleached and disappear while the felspars are sericitised. Alteration is accompanied or followed by pyritous impregnation. Both bench and recent gravels have derived their gold from these veins. The gravels, as, for example, those of the Salmon river, were most productive from 1861 to 1870.

The Wood River district (Hailey) is mainly a silver-lead region, but a few gold-quartz veins are being worked. Of these, the Croesus, Hope, and Camas are the richest. The first lies entirely in quartz-diorite, the last in the normal granite of Idaho.[b]

De Lamar.—South of the Snake river, in the Owyhee range in south-west Idaho, is the important Silver City and De Lamar gold region. These camps are some 5 miles apart, and the principal veins are grouped between them, and in their immediate vicinity. As with most other gold-quartz fields attention was first attracted to the district by the discovery of placer gold. From 1863 to 1869 the alluvial gravels gave handsome returns. The first gold-quartz veins worked were those of Poorman, Oro Fino, and War Eagle, in the granite east of Silver City. It was not till 1871 that the present Black Jack and Trade Dollar veins were opened up in rhyolite on Florida Mountain. In 1875 the De Lamar veins were known, but early workings on them were unprofitable, and it was only in 1889 that the famous De Lamar ore-shoots were exposed. From 1889 to 1898 the ore-shoots yielded £1,183,954 ($5,861,160), of which about £500,000

[a] Lindgren, 18th Ann. Rep. U.S. Geol. Surv., Pt. III, 1898, p. 638.

[b] Lakes, Mines, and Minerals, Dec., 1901, p. 205.

($2,500,000) was for silver value, while the total production of gold from Owyhee county, almost entirely derived from the restricted area near De Lamar and Silver City, from 1880 to 1898 inclusive, was 313,448 ounces, valued at £1,327,798 ($6,477,065).[a]

The geology of the Owyhee range closely resembles that of the northern area. A granite core is almost completely covered by Miocene basaltic and rhyolitic flows, and forms an igneous peninsula, round which thick Miocene and Pliocene lacustrine deposits are wrapped. The granite is of the normal post-Palæozoic type. The basalt is often diabasic in character. It lies directly on the granite. The rhyolite is of later date and probably at one time covered the whole area, the subsequent exposure of the older rocks being due to denudation. On Florida Mountain, west of Silver City, the

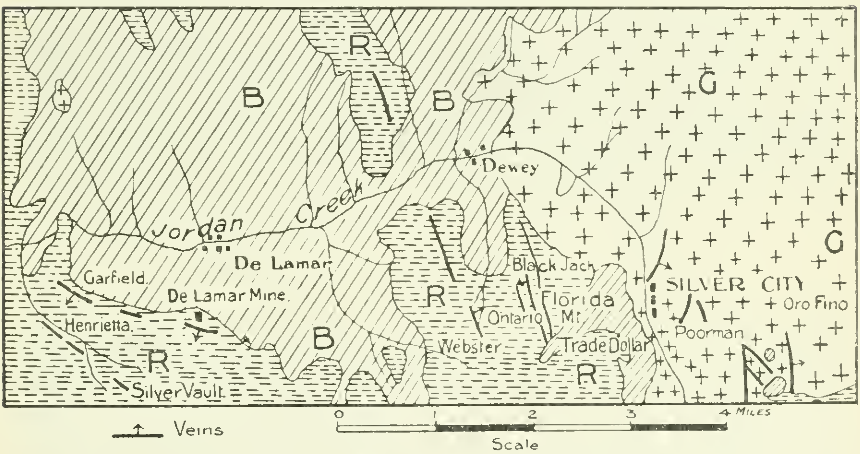


FIG. 167. GEOLOGY OF DE LAMAR MINE AND VICINITY, IDAHO (*Schrader and Lindgren*). *B.* Basalt. *R.* Rhyolite. *G.* Granite.

thickness of the rhyolite flow is 1,200 feet, while on Cinnabar Mountain it reaches 2,000 feet. The rhyolite is of the normal type and was apparently extruded in thick, viscous flows. Its colour is grey to light-brown. The phenocrysts are quartz and sanidine (orthoclase), with rare oligoclase. The ground mass often shows flow-structure. Rhyolite dykes penetrating through the granite and basalt, and indicating the original fissure vents, are common. The final phase of igneous activity in the area is represented by glassy basaltic dykes ramifying through the older basalts and rhyolites. The acid flows are here described with some particularity, since the gold-quartz veins of De Lamar and Florida Mountain

[a] Lindgren, 20th Ann. Rep. U.S. Geol. Surv., Pt. III, 1900, p. 110.

are by far the most important known in rhyolite. It will, however, be apparent from a eonsideration of the features of the Trade Dollar veins on Florida Mountain that there is probably no genetie conneetion between the rhyolite and the gold-quartz veins, and that the oeeurrence of the latter in the former is purely adventitious.

The De Lamar veins lie entirely in decomposed rhyolite, near its eontaet with basalt. The rhyolite is on the whole greatly kaolinised or silieified, and, espeeially near the lode fissures, is highly impregnated with pyrite and mareasite. The salient feature in the De Lamar mines is the presenee of the so-ealled "iron dyke," merely an intensely erushed and altered rhyolite, highly impregnated with pyrite. The ehief mineral-bearing zone lies in the immediate vicinity of the "iron dyke." The veins abut against it and are apparently eut off by it. The De Lamar vein

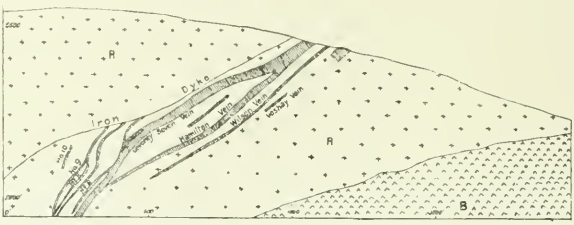
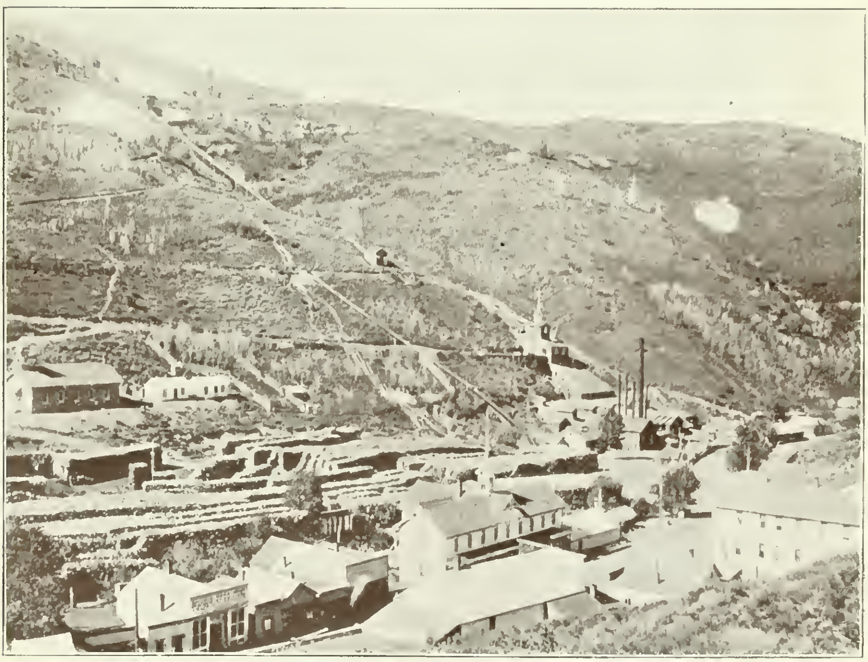


Fig. 168. Section through De Lamar Vein System (*Lindgren*).
R. Rhyolite. *B*. Basalt.

system eomprises 10 veins lying from 20 to 80 feet apart. Of these, the Hamilton and the Seventy Seven are the richest. The width of the veins varies from 1 to 6 feet, and will average perhaps 3½ feet. The rich ore of the De Lamar is eontained in ore-shoots that follow approximately the dip of the "iron dyke." The shoots are some 200 feet in length, from 1 to 30 feet in thiekness, and extend in depth from near the surface to the tenth level. The gangue is a cavernous quartz, largely made up of thin interseeting quartz-lamellae enerusted with very fine quartz erystals. The whole is obviously pseudomorphie after original barytes or ealeite. The gold is free, but is very finely divided. The quartz earries 0·75 per eent. of sulphides (pyrite and argentite). The impregnated eountry is often rieh in silver, but contains little gold. The proportion of gold to silver varies eonsiderably, and is diffieult to estimate. Judging, however, from the total output, the proportion of the former to the latter is perhaps 1 to 6. The average value of the ore treated at De Lamar and Florida Mountain is between £4 and £4. 10s. ($16.00 and $18.00) per ton.[a]

[a] Min. Res. U.S. Geol. Surv., 1905, p. 237.

Trade Dollar Mine and Mill on Florida Mountain, looking North-west.
(U.S. Geological Survey.)



De Lamar Mine and Mill, looking South.
(U.S. Geological Survey.)

On Florida Mountain the Trade Dollar is the principal vein. The value of the ore lies at the present time mainly in silver, which occurs with gold in the proportion of 60 to 1. In the early days of the mine gold predominated near the surface. The Trade Dollar vein was opened up in rhyolite, and has been followed in depth through the basalt into the underlying granite. On the whole, it would appear to be richer in the last than in the rhyolite or basalt. The gangue filling is quartz and valencianite (orthoclase), and is the same in all three rocks.

The veins east of Silver City (Poorman, Oro Fino, War Eagle, &c.) are in granite. They are in most cases closely connected with intrusive dykes, which may be either acidic or basic. There is obviously a very close genetic connection between the veins of De Lamar, Florida Mountain, and War Eagle. They are probably all to be relegated to the same period, which is apparently post-Miocene.

At De Lamar a recent siliceous spring-deposit containing vegetable remains has been found to yield small quantities of gold and silver, one assay giving as much as 0·1 ounce gold and 0·25 ounce silver.[a]

As in Oregon, the Snake river in Idaho contains exceedingly fine flour gold (4,000 " colours " to the grain). Its quality is high (990 fine), as indeed would follow from its state of fine division. A suction dredge to raise the gravels and fine gold was successfully worked on this river south of Shoshone. It treated 3,000 cubic yards of gravel per day, and saved, perhaps, 50 per cent. of the gold. The average value recovered was less than 5d. (10 cents) per cubic yard.[b]

The total gold yield of Idaho is shown below :—

Year.	Value, Dollars.	Value, Sterling.
To 1900 inclusive	$112,800,000	£23,124,000
1901	1,869,300	383,206
1902	1,475,000	302,375
1903	1,570,000	321,850
1904	1,710,000	350,550
1905	1,075,600	220,498
1906	1,149,100	235,566
1907	1,087,655*	222,969
Grand total to end of 1907 ..	$122,736,655	£25,161,014

* Estimated; Prel. Rep. Dir. U.S. Mint, Jan., 1908.

[a] Lindgren, loc. cit. sup., p. 187.

[b] Schultz, Bull. U.S. Geol. Surv., No. 315, 1907, p. 81.

NEVADA.

The older rocks of Nevada are pre-Cambrian schists and Palæozoic and Mesozoic sediments. These are intruded by porphyry dykes and are often buried deep beneath Tertiary andesitic, rhyolitic, and basaltic flows. Intrusive granitic batholiths and simple gold-quartz veins of the Californian type are rare. Argentiferous lead ores with minor quantities of gold are not uncommon in limestones near igneous contacts. The deposits of the Eureka district furnish the best-known example of this type. The most productive gold veins in Nevada are, however, those in later Tertiary propylitic rocks, in which the gold is generally subordinate in quantity to silver. Of this type the famous Comstock lode is an excellent example. Of recent years numerous veins of similar character have been found extending from the Comstock south-east along the Californian boundary to the far south of the State. This chain of propylitic goldfields includes Tonopah, Klondike, Goldfield, Rhyolite, Bullfrog, and several others of present minor importance.

The placer industry in Nevada is insignificant, and is dwindling to the vanishing point. The total yield for the State for the year 1905 was only some 400 ounces, of which three-fourths came from Elko county. In 1906 the alluvial gold recovered was greater, reaching 2,556 ounces. Lack of water is largely responsible, but it is also a fact, as pointed out for this particular region by Lindgren,[a] that rich propylitic veins rarely produce important placer deposits.

After the partial exhaustion of the Comstock and Eureka deposits in the early 'eighties the veins of Nevada were for long neglected, and gold-mining in that State may be said to have revived only with the discovery of the rich outcrops of Tonopah in 1900, a discovery that led to wide-spread prospecting and to the formation of the numerous camps of the south-west desert. The ore from some of these camps has been phenomenally rich, assaying often hundreds of pounds in gold and silver values per ton. The principal gold-producing counties of Nevada are, in order, Esmeralda, Nye, Lincoln, and Storey.

Comstock.—The Comstock lode is perhaps the most widely known, as it has been the richest, of the silver-gold veins of modern times. Its lustre has, however, been dimmed for the last 25 years, and though persistent efforts have been made, especially during the last decade, to discover new bonanzas in the lode, these efforts have as yet been unsuccessful. Placer gold had been known in and had been washed from the various canyons leading up to the

[a] Trans. Amer. Inst. M.E., XXXIII, 1903, p. 840.

great lode as early as 1851, but the lode itself was not demarcated until the spring of 1859. The term "gold" in connection with these placer deposits is somewhat of a misnomer, since the bullion recovered in sluicing in Six Mile canyon was worth no more than 29s. ($7.00) per ounce. In the immediate vicinity of the outcrop it fell in value to 21s. ($5.00), being then rather alluvial silver than

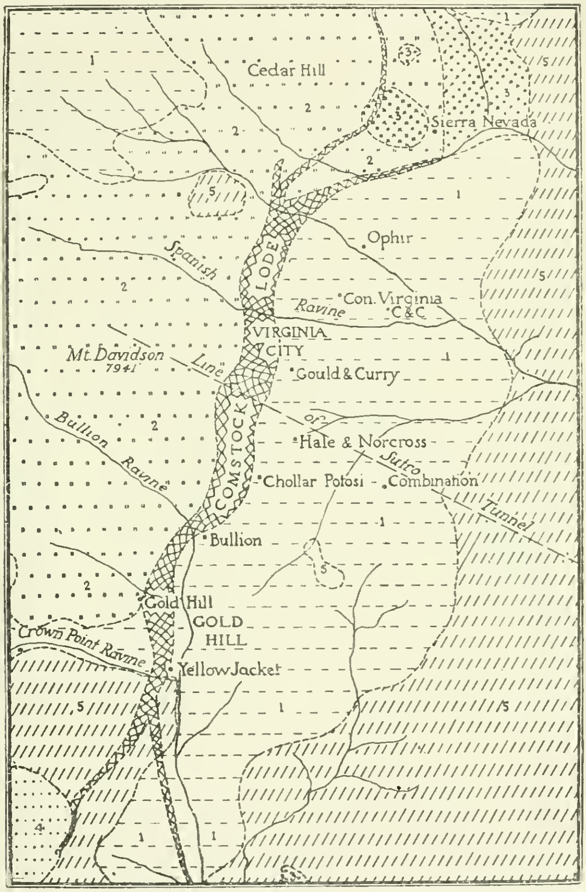


FIG. 169. GEOLOGICAL MAP OF THE NEIGHBOURHOOD OF THE COMSTOCK LODE (Modified from *Becker*).
1. Hornblende-andesite. 2. Diorite, diabase, and hornblende-andesite. 3. Hornblende-mica-andesite. 4. Rhyolite and dacite. 5. Pyroxene-andesite and diabase.

alluvial gold. When the outcrop of the lode was first worked, gold alone was sought, and the presence of silver compounds in quantity was not suspected. Outcrop specimens, however, came into the possession of Melville Atwood, a Californian assayer, who determined a hitherto neglected black mineral staining the outcrop to be a sulphide of silver, and to be present in quantities denoting a value of from £1,000 to £2,500 per ton of ore, thus making the Comstock the greatest silver deposit that had been known since the days of Potosi. The famous "Washoe rush" was immediately precipitated, and the towns of Virginia City, Gold Hill, and Silver City sprang up with mushroom-like growth along the line of the lode. The first-named city had, at one time, a population of 35,000 inhabitants. For the next decade, despite the terrible stress of the intervening years of the Civil War, the Comstock was the most prosperous mining field in the world. Before 1880 no less than £23,753,500 ($115,871,000) had been paid in dividends. From the year of its discovery to the end of 1906 its total production may be estimated at £76,731,295 ($374,299,000), of which the value of the gold produced is responsible for £30,750,000 ($150,000,000). The difficulties encountered, both in metallurgical and mining practice, were enormous. The former were surmounted by the evolution of the Washoe process of hot-pan amalgamation. The latter were more serious, and have not yet been completely overcome. The roofs and walls of the large cavities made in mining required adequate support, a difficulty solved by the adoption of the then novel method of "square-set" timbering. Enormous quantities of water had to be pumped to the surface, necessitating costly pumping machinery. The heat encountered in the deeper levels proved a most serious and, finally, an insurmountable obstacle. The great streams of water gushing from the fissures in the rock possessed a temperature generally over 110° Fahr. In the case of the Yellow Jacket shaft, a stream was encountered with a temperature of 170° Fahr. The heat is probably to be attributed to expiring vulcanicity, since the well-known solfataric Steamboat Springs lie only some 10 miles to the north-north-west. Even at so shallow a depth as 1,500 feet it was necessary to pump cold water into the working faces in the endeavour to reduce the temperature. The miners, stripped to the waist, could work only 15-minute spells, and the effective working time of each miner during a nominal shift of eight hours was only two hours. Mining costs were therefore enormous. To secure better ventilation, and to reduce the great expense of pumping water to the surface at the outcrop of the lode, the Sutro adit level, 20,000 feet long, was driven to strike the lode 1,600 feet below the average level of its outcrop. Its progress was unfortunately so slow that many of the bonanzas above the tunnel level had been worked out before the tunnel reached the lode. The Sutro adit nevertheless proved of vital importance during later operations. The fight against heat and water was vigorously continued until 1883, when the great depth, considering the conditions, of 3,300 feet from the surface had been reached. By 1887 most of the mines had been shut down. The field remained almost deserted until an association of the 28 existing mines was formed in 1898 to unwater the old workings. This end has partly been effected, though the water being pumped has a temperature of 160° Fahr., and is slightly acid. No new bonanzas have as yet been discovered, and the work is being carried on entirely by contributed

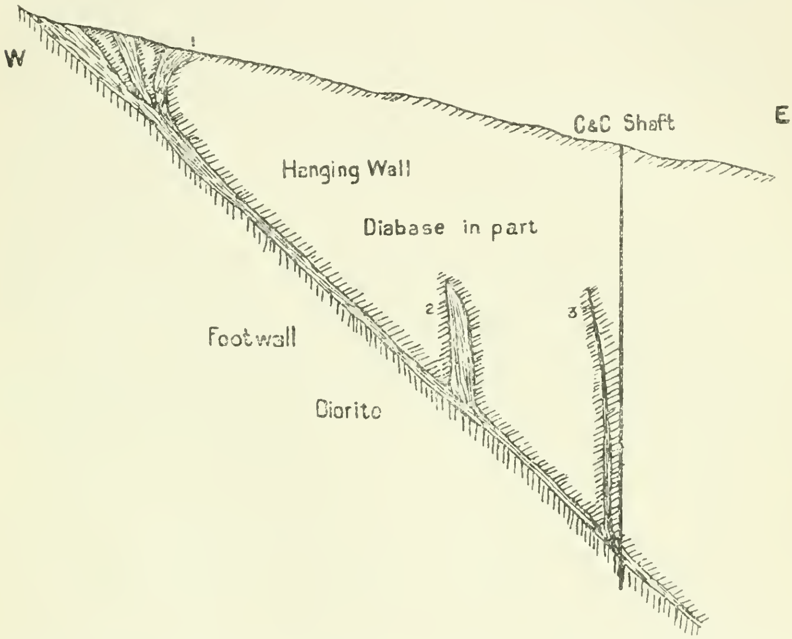


Fig. 170. Showing formation of Bonanzas in Hanging-wall of Comstock Lode (*Reid*).

capital. Pumping, mining, and milling operations are performed by electricity generated at the Truckee river, 33 miles from Virginia City.[a]

The Comstock lode lies on the east flank of Mount Davidson (7,941 feet), an elevation on a spur of the Sierra Nevada. The strike of the lode is nearly north and south, and it has a total length of some 2½ miles. At both the northern and southern ends it forks into two small branches which soon thin away in the country. The thickness of the lode varies from 100 to 1,400 feet. The footwall is always distinct and well-defined, while the hanging-wall is rarely clearly marked, the ore blending with the country. The true dip of the lode is to the east. The vein matter is quartz, but brecciated

[a] Ross, Min. Sci. Press, Oct. 12, 1907, p. 468.

masses of country, often of high grade, are scattered through the lode. The ores are silver sulphides (argentite, stephanite, polybasite) with occasional galena and zinc. The bullion derived from the ores contained half its value, or 6 to 7 per cent. by weight, in gold. The ore occurs entirely in shoots or bonanzas separated by wide barren stretches. Recent work outlined by Reid[a] has thrown considerable light on the origin of the bonanzas of the central and northern Comstock. Near Virginia City the bonanza-ore occurs not in the main fissure but in nearly vertical fissure planes in the hanging-wall. These vertical veins, since they pinch out in *height*, are believed to arise from relief from tension in the hanging-wall, the tension being due to a differential movement (amounting to 3,000 feet) of the walls of the main fissure. The apparent splitting of the lode at the surface is explained in the same way, the rich east vein found there being a vertical that had reached the surface, probably merely by the erosion of the overlying rock. As will readily be seen on reference to the accompanying sketch, the east vein (1), the great bonanza (2), and the lowest vein (3) now being worked, have all therefore a common origin. On the other hand, the bonanzas of Gold Hill further south are of an entirely different character, and lie within the main fissure itself. Assays of the waters of the Comstock lode gave the following remarkable results :—[b]

	Vadose Waters.	Deep Waters.
Gold ...	4·1528	·298 mgm. per ton of solution.
Silver ...	188·0912	2·920 ,, ,, ,,

The waters carry alkaline sulphates and carbonates. Sulphates (mainly ferrous) are now being plentifully deposited in unused levels. Numerous faults occur in the region and these are shown by Reid to have vitally affected the length of the main fissure, and to be responsible for many of the orographic features of the district. Cedar Ravine, Ophir Ravine, and Bullion Ravine are thus the physiographic expressions of fault-planes. The Comstock lode itself lies along a great fault, the eastern member of the block-faulting system of Mount Davidson.

The petrological nomenclature of the rocks adjacent to the Comstock lode raises a much-vexed question. The monumental work of Dr. Becker in 1882 gave rise to a vigorous controversy that has done much to advance petrological science. Lapse of time and

[a] Bull. Geol. Univ. California, IV, 1905, p. 178.

[b] Reid, loc. cit. sup.

the progress of petrology have served to diminish rather than to accentuate the differences between Dr. Becker's nomenclature and that proposed by Messrs. Hague and Iddings. It will serve no useful purpose to recapitulate in this place the points at issue. They may be followed by reference to the literature.[a]

The oldest igneous rocks of the district may be regarded as pyroxenic (augite-hypersthene) and hornblendic andesites. The former are probably the older and shade away by differences of crystallization to diabase and augite-diorite. In places the hornblende-andesite is known to be intrusive into the pyroxenic forms, but the general relations are not at all clear. After a temporary cessation of volcanic activity the older andesites were intruded by hornblende-mica-andesites, dacites, rhyolites, and basalts. Glassy forms are found only on or near the surface, while rocks from depths are generally holocrystalline. All are probably Tertiary in age. The Comstock lode therefore lies wholly within a rock that may shade from the augite-diorite of Mount Davidson on the west to undoubted andesite on the east. A remarkable rock is the "black dyke," a diabase dyke on the footwall of the lode.

The pyrite and also the augite of the country adjacent to the lode was found, on assay by J. H. Curtis, to be slightly auriferous, the pyrite yielding as much as ·30 gramme gold per metric ton.

Fairview and Wonder.—South-east of Carson Sink, in Churchill county, are the newly established camps of Wonder and Fairview. The principal rock of the latter field is andesite, which is intruded by later andesitic and rhyolitic dykes. In the main ore-zones the gangue is quartz, but the country adjacent to fissure zones has also been extensively silicified. The valuable minerals are free gold, cerargyrite, and argentite. Ruby silver and silver bromide are also found. About one-fifth of the value of the ore is due to gold.[b] Wonder is 18 miles north of Fairview. Here also are two generations of andesite, in the older of which, as at Tonopah, a field to be described later, the ore-bodies have been deposited. Later rhyolite dykes cut through the andesite, and it is along contacts of the latter with rhyolite hanging-walls that the richer ore-shoots lie. Gold may also be found in silicified zones in andesite. The proportion in value of gold to silver in the ore is from 1 : 4 to 1 : 8. Silver sulphides, taken often from the outcrop itself, furnish the bulk of the rich ore.[c]

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[a] King, U.S. Geol. Surv., Expl. 40th Parallel, III, "Mining Industry," 1870; Church, "The Comstock Lode," New York, 1879; Becker, Mon. U.S. Geol. Surv., III, 1882; Hague and Iddings, Bull. U.S. Geol. Surv., No. 17, 1885; Becker, Bull. Cal. Acad. Sci., No. 6, 1886; Id., Amer. Jour. Sci., II, XXXIII, 1887, p. 50; Reid, loc. cit. sup.

[b] Zalinski, Eng. Min. Jour., April 13, 1907.

[c] Id., ib., April 20, 1907.

Manhattan.—Manhattan is likewise a new camp, its existence dating back no further than April, 1905. It lies 30 miles north-north-east of Tonopah at an elevation of some 7,250 feet above sea-level. The sedimentary rocks of the region are highly metamorphosed (presumably Palæozoic) slates, limestones, and quartzites. The predominant members were originally slates that now appear as glossy phyllites or as biotite-schists. The schistosity is parallel with the bedding planes. Granite is found intrusive in the neighbourhood, and is probably partly responsible for the metamorphism noted. Diorite-porphyry of unknown relations also occurs. Tertiary rhyolite covers much of the sedimentary strata, through which it is also found intrusive. The rhyolitic flows are in places hundreds of feet in thickness. Ore-deposits at Manhattan are confined entirely to the metamorphosed sedimentaries.[a] The ore-bodies are: (*a*) narrow, tabular veins crossing the bedding and schistosity of the metamorphic rocks; (*b*) deposits interlaminated with the schistosity; and (*c*) deposits parallel to the bedding planes and forming siliceous replacements in limestones and other calcareous beds. The principal gangue materials are quartz and calcite, but barytes and fluorite are sometimes present. The value of the lode lies almost entirely in its gold, which is finely disseminated through the quartz. Low-grade ore occurs in brecciated zones cemented by quartz. Outcrop ores are rich, ranging in value from £14 ($70.00) to £60 ($300.00) per ton, with an average value of £25 ($125).

Rawhide.—One of the most recently discovered of the new gold camps of Nevada is Rawhide, in Esmeralda county. It was located early in 1907 and was the objective of a vigorous rush towards the end of that year. The country appears to show considerable geological affinity with Tonopah. It is a brecciated quartz-porphyry, originally, perhaps, an andesite-breccia, which has been so altered as now to be difficult of identification.[b] The ore may be quartz, quartz-porphyry, silicified rhyolite, or kaolinised porphyry.

Tonopah.—The mining field of Tonopah lies in the west of Nevada and of the Great Basin region, near the boundary of Esmeralda and Nye counties. Its lodes were discovered only in 1900, as a result of assays of outcrop specimens collected by a wandering prospector. Outside a limited area in the immediate vicinity of the claims marked off by the original discoverer no further valuable lodes have been found. The geology of the dis-

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[a] Emmons, W. H., and Garrey, Bull. U.S. Geol. Surv., No. 303. 1907, p. 84.

[b] Del Mar, Algernon, Eng. Min. Jour., April 25, 1908, p. 853.

trict has been fully described by Spurr in a monograph[a] that may well serve as a model for future descriptions of andesitic goldfields.

No ancient sedimentary rocks occur nearer Tonopah than some eight miles to the south, where limestone of probable Cambrian

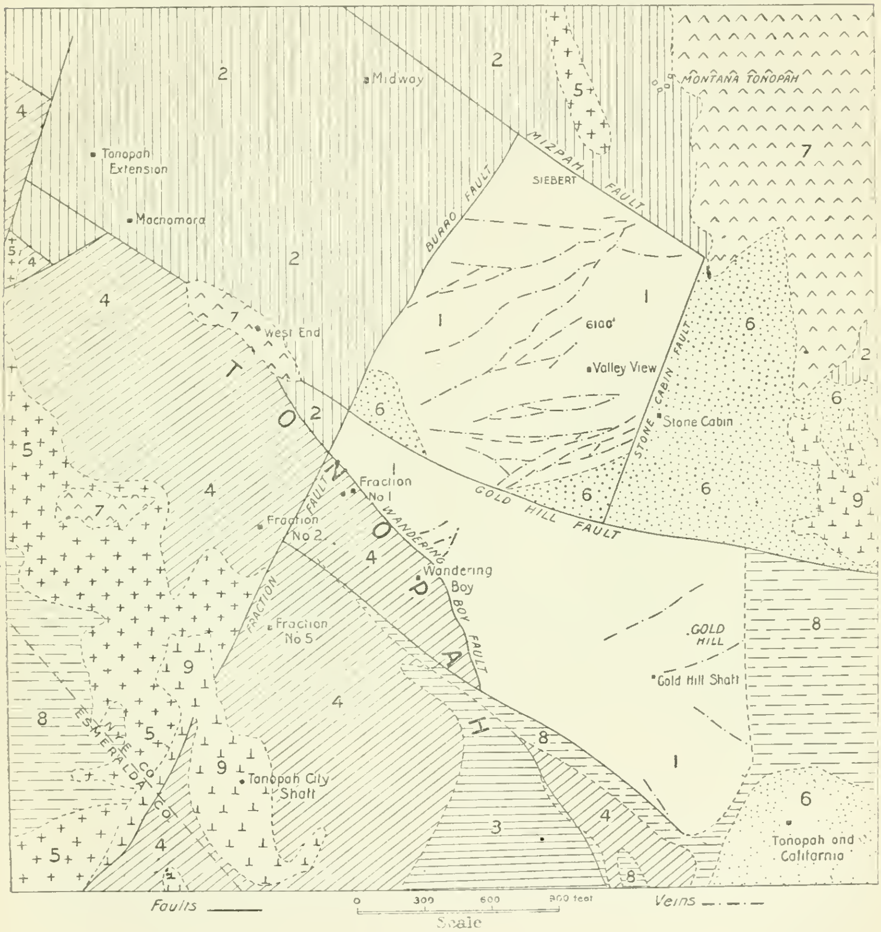

FIG. 171. GEOLOGICAL MAP OF TONOPAH GOLDFIELD (*Spurr*).

1. Earlier Andesite. 2. Later Andesite. 3. Heller Dacite. 4. Fraction Dacite-breccia. 5. Tonopah rhyolite-dacite. 6. Siebert tuffs (lake beds). 7. Oddie rhyolite. 8. Brougher dacite. 9. Latest rhyolite or dacite.

or Silurian age is found. The volcanic breccias of Tonopah, nevertheless, contain occasional fragments of limestone, quartzite, and granite, that have probably been derived from underlying rocks.

[a] Prof. Paper, U.S. Geol. Surv., No. 42, 1905.

The oldest igneous rock is a somewhat porphyritic, always decomposed andesite, that is assumed to have been, when fresh, a hornblende-biotite-andesite. In this rock all the important silver-gold veins are found. Its surface area is small, but it has been proved to occur extensively under later lavas. A second period of volcanic activity produced also an andesite (biotite-augite-), but one much less siliceous and normally much less decomposed

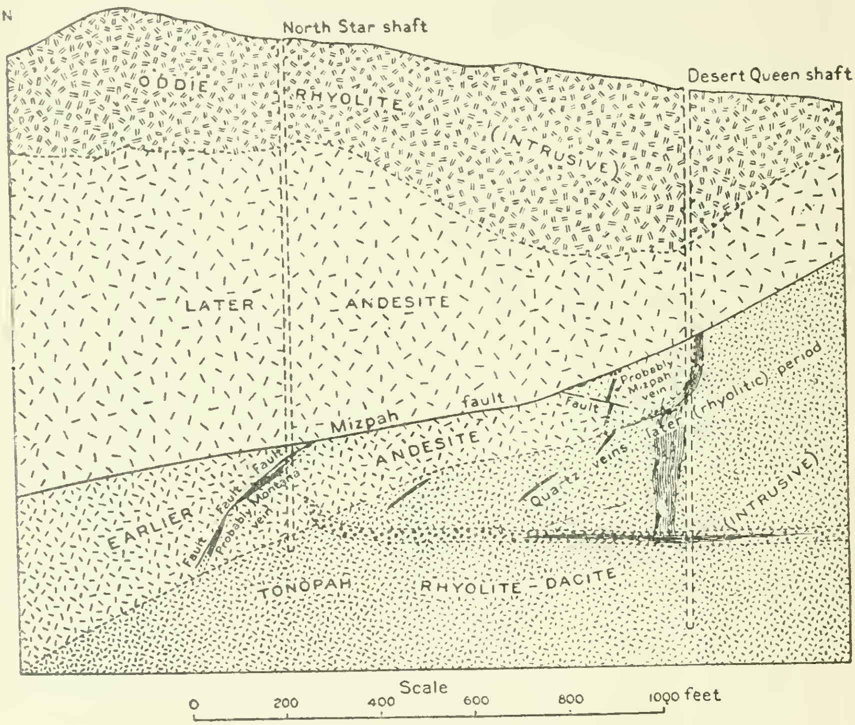

FIG. 172. SECTION SHOWING MASKING OF AURIFEROUS VEINS, TONOPAH (*Spurr*).

than the first-described. Possessing more iron it is usually darker, and when decomposed, more highly coloured than the underlying andesite.

Rhyolite and dacite flows, genetically very closely connected, succeeded the andesites. The dacite is highly siliceous and might well be classed as a rhyolite. The term, however, serves to clearly distinguish it from an exceedingly acid rhyolite found elsewhere in the district. These rhyolite-dacites have been subdivided and locally named according to character and to relative position. They were poured out as flows, between the periods of the extrusion of which were periods of explosive eruption now represented by interbedded tuff. The Brougher dacite, resisting well the somewhat weak weathering agents of the region, forms most of the hills of the district. The highly siliceous (Oddie) rhyolite, above mentioned, lies to the north of Tonopah and makes up the bulk of Mount Oddie. The contemporaneous Siebert tuffs are stratified and are obviously of lacustrine origin. The last lava flows of the region appear to have been basaltic in character, though certain rhyolite and dacite volcanic necks indicate craters and vent-filling somewhat later in age.

Owing to extensive faulting the structure of the district is extremely complicated. As already observed, the most important mineral veins are restricted to the earlier andesite. They were

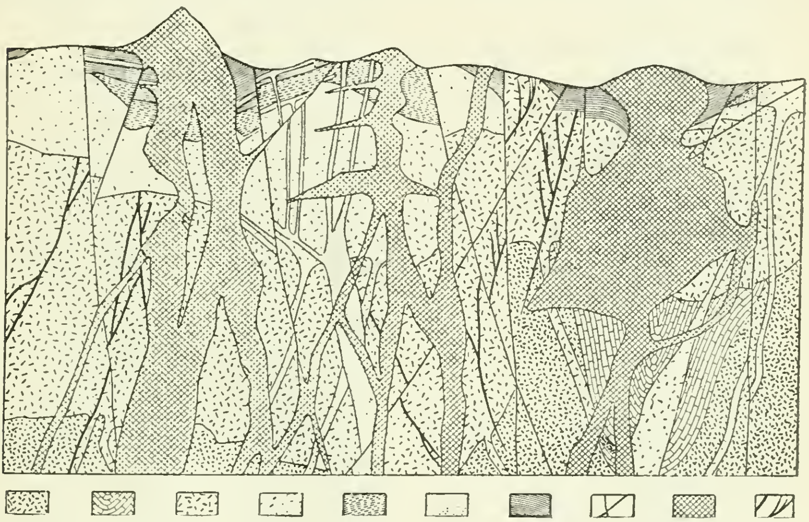

FIG. 173. IDEAL SECTION ACROSS TONOPAH ROCKS *(Spurr).*

formed prior to the deposition of the later rocks, and are due to replacement and silicification of the andesite along fractures. The direction and position of the ore-shoots within the fissure-zones is largely affected by the cross-fractures, since the latter have determined, during the period of active ore-deposition, the local direction of the flow of the hot, ascending, ore-bearing solutions. The gangue of the primary ores is quartz intercrystallized with adularia (orthoclase), together with minor sericite and carbonates. Both quartz and adularia have obviously been deposited from solution. The ores are silver sulphides (polybasite, argentite, and stephanite), selenide of silver (?), chalcopyrite, pyrite, galena, and blende. In an average ore, gold is present in the proportion by weight of 1 to

100. Free gold has never been detected in the sulphide ores but naturally it occurs to some extent in the upper oxidised zones. In some places the oxidised ores are found as deep as 700 feet, a feature perhaps not remarkable in view of the aridity of the region, and of the fact that certain shafts are dry at depths of over 1,000 feet. Water, though in no great quantity, has, however, been struck in other shafts at much less depth. Where the old vein-outcrops lie buried beneath later lavas their zones of oxidation may be comparatively shallow (200 feet). Silver chloride is abundant in the oxidised ores. The presence of selenium, which is revealed only by analysis, furnishes an interesting analogy with the geologically somewhat similar fields of Waihi, New Zealand, and of Redjang Lebong, Sumatra.

Numerous poor or almost barren silver-gold quartz veins occur in the Tonopah rhyolite-dacite, and also in calcitic gangue in siliceous rhyolites, as at Mount Ararat. The ores contained in these veins probably arise from the solution and re-deposition of the ores of the earlier andesites. Spurr draws attention to the analogies presented by this field in respect of its geology and ore-deposition with those of Washoe and Eureka, Nevada, and of De Lamar and Silver City, Idaho.

The Tonopah veins vary in width from a few feet to 40 feet. In some mines ore-shoots have been developed for 1,000 feet along the strike. In 1906 working costs were so high that nothing below £6 ($30.00) per ton was treated. To that year the total output of the Tonopah camp had been £2,665,000 ($13,000,000). The yield for the year 1906 was £267,458 ($1,304,677) in gold and £782,610 ($3,817,612) in silver.

Ten miles south of Tonopah is the Southern Klondike district. As at Manhattan, Palæozoic sedimentary rock (in this case, limestone) intruded by a granitic dyke, is surrounded at the surface by Tertiary lava flows. The main ore-body is, however, somewhat remarkably situated. It is a quartz vein carrying silver and gold, and lies in the limestone parallel to the granitic dyke mentioned above and 75 feet to the south-east of it. The occurrence is described by Spurr,[a] who compares the acid intrusion with the beresite of Berezovsk in the Urals. With the silver and gold are associated galena and pyrite and possibly stetfeldtite (copper-antimony-silver sulphide). The outcrop ores were very rich.

Goldfield.—By far the most important camp in south-western Nevada at the present time is Goldfield. Active mining operations on this camp were commenced only in 1903, though the

[a] Econ. Geol., I, 1906, p. 382.

Tonopah Hills from the North-east.

Tonopah and Neighbourhood, Looking West from Mount Oddie.
(U.S. Geological Survey.)

field had been prospected in the previous year. So rich was some of the surface ore that it was found necessary when blasting to cover the hillside with bullhides to prevent unnecessary loss.[a] For 1906 the yield of Goldfield was £1,440,361 ($7,026,154) in gold, and

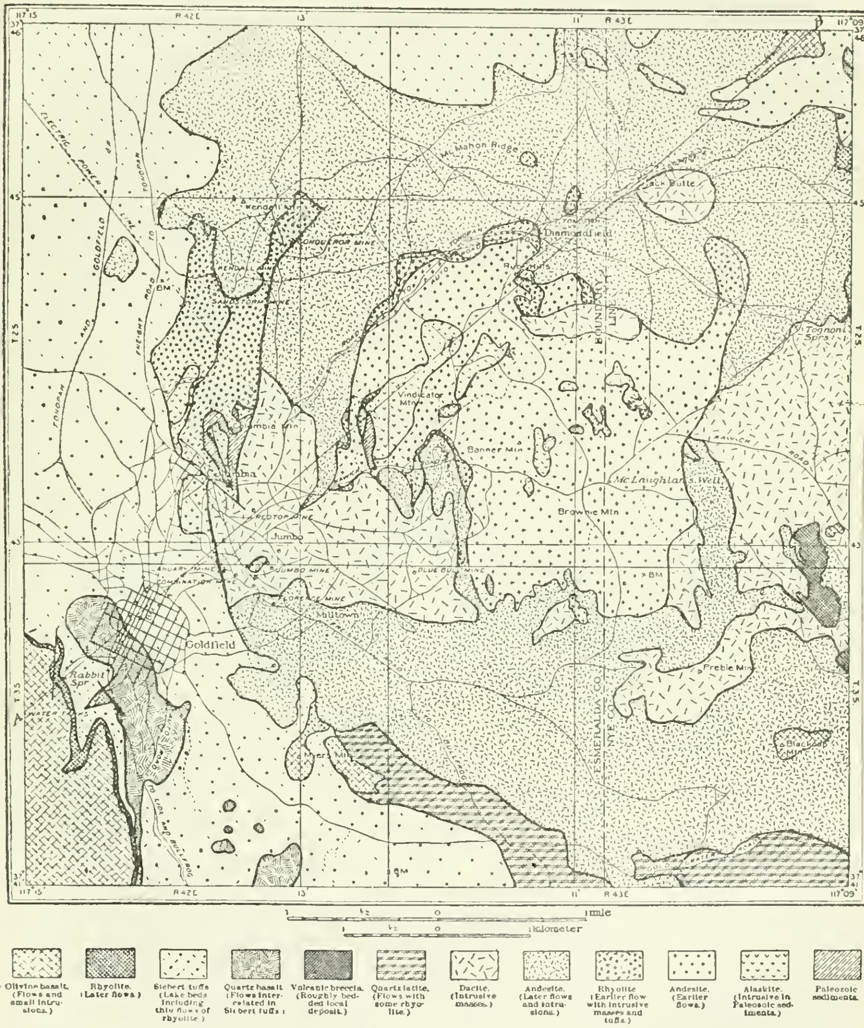

FIG. 174. GEOLOGICAL MAP OF GOLDFIELD, NEVADA (*Ransome*).

only £2,149 ($10,484) in silver. Owing to the importance of the camp its geological literature is already extensive.[b]

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[a] Min. Sci. Press, June 8, 1907.

[b] Spurr, Bull. U.S. Geol. Surv., No. 225, 1904, p. 118; Id., ib., No. 260, 1905, p. 132; Hastings and Berkey, Bull. Amer. Inst. M.E., No. 8, March, 1906; Ransome, Bull. U.S. Geol. Surv., No. 303, 1907, p. 7; Rickard, T. A., Min. Sci. Press, May 30, 1908.

Goldfield lies on an elevated plateau, 5,700 feet above sea-level, and near the so-called river Amargosa, the only running water within 40 miles of the town. The Palæozoic basement rocks of the district have been exposed by denudation in a few places, as on Columbia and Vindicator Mountains. Where exposed, they are contorted and metamorphosed jasperoid and vitreous quartzites, representing original calcareous shales, limestones, and quartzites, the carbonate of lime of the former being now largely replaced by silica. Metamorphism is apparently due to post-Jurassic acid intrusions of the rock type termed by Spurr[a] "alaskite" (a dyke-rock composed of quartz and minor orthoclase). Most of the alaskite in the Goldfield area contains in addition to quartz and orthoclase a little biotite and plagioclase. These older rocks are covered by thick Tertiary volcanic deposits of varying type and composition. Their sequence may be succinctly shown by the following table,[b] in which the older rocks are shown at the bottom :—

12. Olivine basalt ; flow and small intrusive bodies.
11. Breccia and conglomerate.
10. Rhyolite ; flow.
9. Lake beds ; tuffs.
8. Quartz-bearing basalt ; flow intercalated in lake sediments.
7. Lake beds ; tuffs, possibly corresponding to Siebert tuffs, Tonopah.
6. Latite and rhyolite ; flows.
5. Dacite ; sheet-like and irregular intrusion, possibly in part a flow.
4. Andesite ; flows with some tuffs and small intrusive bodies.
3. Rhyolite ; intrusive masses.
2. Rhyolite ; flows and tuffs.
1. Andesite ; flow.

The most important rock of the district, from an economic point of view, is a dacite, No. 5 in the above list, and the country of all the richer veins. It resembles the underlying andesites in appearance, but is perhaps somewhat more porphyritic. Unlike them, however, it contains phenocrysts of quartz, and the rock is, as a whole, made up of labradorite, augite, hornblende, biotite, and quartz, with the usual andesitic ground mass. Chemical analysis shows it to contain 60 per cent. of silica. The Tertiary lavas, when considered broadly, have a gentle quaquaversal dip, and the general structure of the district is that of a geological dome in which the younger formations dip away from a pre-Tertiary core exposed by denudation.

The valuable portion of the Goldfield deposits is an oxidised gold-ore, derived from original sulphide ores containing, in addition

[a] Amer. Geol., XXV, 1900, p. 229.

[b] Ransome, loc. cit. sup., p. 14.

to gold, unimportant quantities of silver, copper, antimony, arsenic, bismuth, and tellurium. The deposits have been formed along fissure zones, and their formation has been attended by much silicification and impregnation of the vein-walls. The ore-zones, though not necessarily their richer portions, often, therefore, stand well above the level of the adjacent, more easily eroded rock. The ore-zones of Goldfield are extremely irregular in form and are equalled in this respect only by the irregularity of the pay-shoots or richer bonanzas occurring within them. The gangue is ordinarily a dense flinty quartz resulting from silicification along shattered fracture-zones in the dacite. The unoxidised ore of the district consists of pyrite, bismuthinite, and probable tetrahedrite. Free gold is often seen with the sulphides. The latter occur as crusts, and also in a finely divided state well disseminated through the gangue. Concentric shells of sulphides about silicified rock fragments are common in the richer shoots, quartz with free gold often forming the innermost shell, thus recalling the method of ore-deposition in the Bassick volcanic vent, Custer county, Colorado. The order of deposition may, however, vary, and the gold may be deposited on the outside of the sulphides. Minute quantities of tellurium have been detected on analysis. The ore treated has hitherto been of very high grade, often averaging £100 ($500) per ton over many thousands of tons. Though much of the very rich ore has been oxidised, yet some, at least, of the sulphide-ore has exceeded in value anything found in the upper zone.

The field is much better situated with respect to a water supply than Tonopah, since most shafts are wet at depths below 200 to 250 feet. Power for the mines is obtained from electricity generated at Bishop's Creek, California, 98 miles to the south-west. Goldfield is at the present time the richest camp in Nevada, having in 1906 produced 45 per cent. of the total gold yield of the State, and a similarly high percentage in 1907.

Rhyolite.—The Rhyolite or Bullfrog district is situated about 60 miles south-east of Goldfield. The two main camps, Rhyolite and Bullfrog, were formed about 1904. On this field the basement rocks are pre-Silurian quartz-, quartz-muscovite-, and amphibole-schist, gneiss, and crystalline limestone. Through the metamorphic rocks numerous pegmatitic veins are intruded. The whole series is overlain by Silurian limestones. None of these are however of economic importance, since the ore-deposits are restricted to the Tertiary rhyolite that covers so large a part of the district. The total thickness of the various rhyolite flows thus poured out on the surface approximates closely to 7,500 feet. A few thin floors of basalt are interbedded with the rhyolite, and a single dacite flow occurs near the top of the volcanic series. Dark olivine-basalt dykes are numerous, but appear to have exercised no influence on ore-deposition.[a] The rhyolite rocks of the mining district proper are traversed by numerous intersecting faults, forming in plan a close network. The ore-zones lie for the most part in nearly vertical faults, along which run numerous thin quartz stringers. The zones vary in width from 10 to 100 feet, while the quartz and calcite stringers within them are generally a few inches wide. Gold with

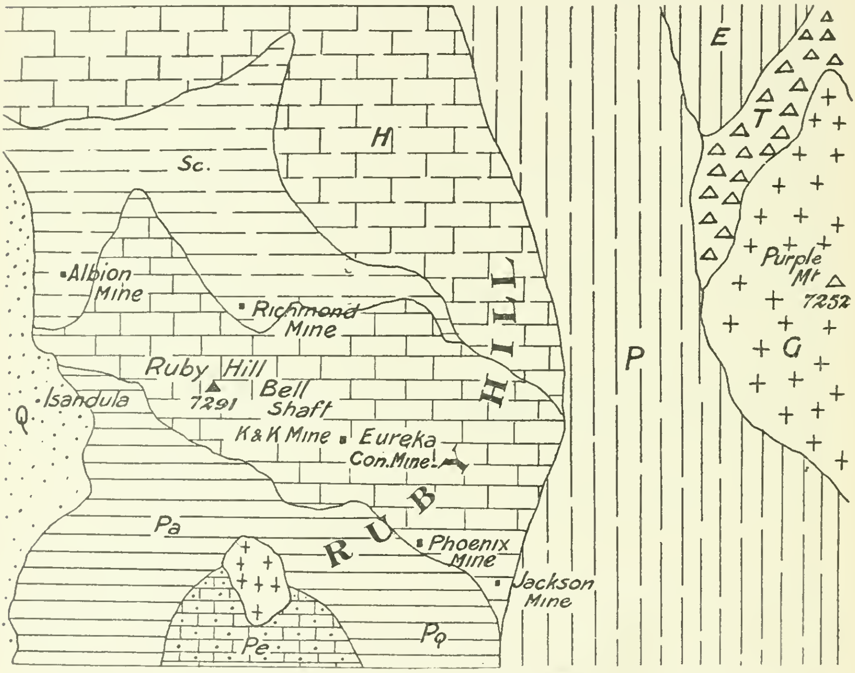

FIG. 175. GEOLOGICAL MAP OF RUBY HILL, EUREKA MINING DISTRICT (*Hague*).
G. Granite. *T.* Rhyolite Pumice. *Cambrian:* *Pq.* Prospect Mountain quartzite. *Pl.* Prospect Mountain limestone. *Sc.* Secret Cañyon shale. *H.* Hamburg limestone. *Silurian:* *P.* Pogonip limestone. *E.* Eureka limestone. *Q.* Quarternary. Scale: 1,600 feet to one inch.

auriferous pyrite is finely disseminated through the quartz gangue. As might naturally be expected from the more siliceous nature of the enclosing rock, siliceous replacement of vein-walls is not so common as at Goldfield.

Lincoln County.—Lincoln county is the most southerly in Nevada. Its principal camps are Crescent, Searchlight, Eagle Valley, Ferguson, and Pioche. The Searchlight field is in hornblende-andesite, but some of its veins, as the Quartette, pass into an adjacent ancient gneiss with which is associated quartz-monzonite.

[a] Emmons, W. H., and Garrey. Bull. U.S. Geol. Surv., No. 303, 1907, p. 43.

The Quartette lode is a soft mass of shattered country carrying quartz, galena, chalcocite, wulfenite, chrysocolla, azurite, and their normal oxidised products. Eldorado Canyon lies 20 miles further north and at the northern end of the gneiss and quartz-monzonite belt mentioned above. Here the auriferous lodes are in the gneissic rocks, but at no great distance from their contact with basalts and rhyolitic flow breccias. The veins of Crescent, west of Searchlight, are also in gneissic rock.[a] The richest mine in Lincoln County in 1906 was the Bamberger Delamar, Ferguson County, which was surpassed in yield for Nevada only by the leading mine at Goldfield and at Tonopah respectively. In 1906, Searchlight field produced £106,556 ($519,785) in gold.

Eureka.—In northern Nevada goldfields are few and scattered. The Tuscarora camp was for long an important centre, but is now almost deserted. Its produce was mainly silver, derived from

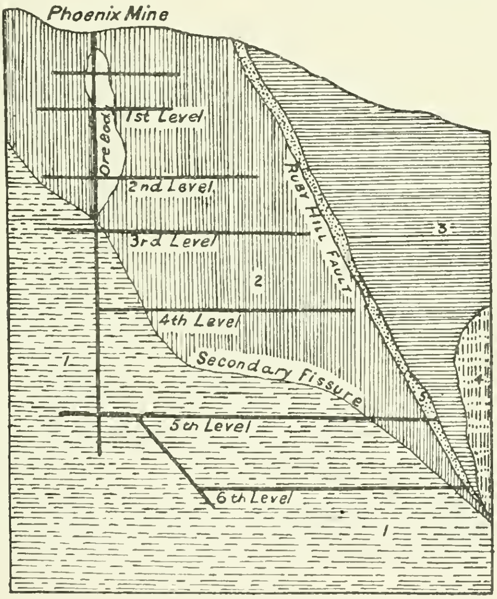

FIG. 176. CROSS-SECTION IN PHŒNIX MINE, EUREKA (*Hague*).
1. Quartzite. 2. Crushed Limestone. 3. Limestone. 4. Shale. 5. Rhyolite.

lodes in a decomposed hornblende-andesite. By far the most important of the north-eastern fields is Eureka, in Eureka County, famed in the 'seventies for its extraordinary silver-lead production. The development of the field was long hindered by smelting difficulties. In its early years its ores carried on an average 45 per cent. lead, £12 to £16 ($60 to $80) silver, and £3 to £4 ($15 to $20)

[a] Ransome, Bull. U.S. Geol. Surv., No. 303, 1907, p. 68.

gold per ton, while the pig lead thus produced contained £16 ($80) gold per ton. After 1884 the production decreased rapidly, but to the year 1882 there had been obtained 225,000 tons lead, £8,000,000 ($40,000,000) silver, and £4,000,000 ($20,000,000) gold, nearly all derived from pockets in the limestone of Ruby Hill.[a]

The rocks of Eureka are Palæozoic quartzites, limestones, and shales, much faulted and displaced, and intruded and covered by igneous rocks (andesites and rhyolites). Ore-deposition has taken place through a vertical thickness of 17,000 feet of strata: from Cambrian limestone through Silurian limestone and quartzite to Devonian limestone. The most productive mines are, however, in the Cambrian rock, a feature arising merely from the ease with which that limestone was affected by orographic and structural agencies. Ore-deposition took place after the extrusion of the igneous rocks, and, according to Hague,[b] is to be associated with rhyolitic rather than with andesitic rocks. The ores were originally deposited as sulphides and in depth are found as such.

The total gold production of Nevada to 1900 inclusive is estimated[c] at some $250,000,000 or £51,250,000.

Later yields are:—

Year.	Value, Dollars.	Value, Sterling.
1901	$2,963,800	£607,579
1902	2,895,300	593,536
1903	3,388,000	694,540
1904	5,060,494	1,037,401
1905	5,359,100	1,098,615
1906	10,470,704	2,146,494
1907	14,704,658*	3,014,454
Grand total..	$294,842,056	£60,442,619

* Estimated; Prel. Rep. Dir. U.S. Mint, Jan., 1908.

ARIZONA.

Little is known of the details of the geology of the auriferous occurrences of Arizona, except indeed where the gold-quartz veins are associated with the great copper deposits of the south-eastern portion of the territory. The gold-producing counties of Arizona are Yavapai, Mohave, Cochise, and Yuma, the first-named in 1905 furnishing 50 per cent. of the total yield for that year. The general

[a] Ingalls, Eng. Min. Jour., Dec. 7, 1907, p. 1051.

[b] Mon. XX, U.S. Geol. Surv., 1892, p. 294.

[c] Lindgren, loc. cit., p. 839.

geology of the metalliferous regions is simple. Short desert ranges occur with cores of pre-Cambrian schists, granites, and gneisses overlain by Palæozoic limestones and quartzites, all being intruded by numerous porphyry dykes of late Cretaceous or early Tertiary age. Wide areas are covered with later Tertiary lavas of the same age and type as those described from the Nevada goldfields. Four principal auriferous areas may be distinguished in Arizona: (1) the vicinity of Tombstone, Cochise County; (2) north and south of Tucson for some 30 miles; (3) the Weaver mountains south of Prescott; and (4) the Harqua Halla mountains 40 miles to the south-west of the last preceding.[a]

The rocks of the Tombstone district are limestones and quartzites in alternating order but with shale as the uppermost member. These are folded into anticlines and synclines. Dykes of granophyric character are intrusive through and into the sedimentary series. The most productive mines lie within the sedimentary rocks, at some distance from the contact with the main granitoid mass. The ore-deposits are essentially replacements along fissures in the sedimentary rocks. Most of the rich ore has been found along anticlinal axes. About one-half of the gold and silver produced in Tombstone has been derived from deposits in the upper shales, and most of the remainder from limestones, very little being furnished by quartzites. The sedimentary rocks are covered near the mineral area by rhyolite, in which rock is developed the vein of the well-known Commonwealth mine, 18 miles north-east of Tombstone. In the Tombstone district two important veins, Lucky Cuss and Knoxville, occur near a granodiorite contact. There is, nevertheless, no apparent connection between ore deposition and igneous rock, whether granodiorite or granophyre. The principal vein of the district—one that has yielded ore to the value of nearly £2,500,000—is 4,000 feet away from the eruptive mass. The entire gold yield of Tombstone to 1902 is estimated at 163,000 ounces. During the same period its silver yield was 21,500,000 ounces.[b]

The Mammoth veins, north-east of Florence, in Pinal County, and in former years notably rich in gold, are associated with a rhyolite dyke in granite country. South of Prescott, Yavapai County, numerous veins are found in the pre-Cambrian rocks. The Congress is the best-known mine in this area. Its veins are pyritous and are within granitic rocks.[c] The Socorro, Gold King,

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[a] Pratt. Eng. Min. Jour., June 7, 1902, p. 795.

[b] Church, Trans. Amer. Inst. M.E., XXXIII, 1903, p. 3.

[c] Lindgren, Ib., p. 814.

and Fortuna mines, further west, are also in similar country. Reid[a] describes the mines of the Cherry Creek district in Central Arizona as occurring in broken and sheeted zones in granite-porphyry dykes in the main mass of Algonkian biotite-granite. The latter shows the same relations to the overlying limestone as in the magnificent and often-described Grand Canyon of the Colorado river further north. The surface ores of Cherry Creek are free-milling. The much better-known United Verde mine at Jerome, 16 miles north of Cherry Creek, was first worked as a gold mine and showed no copper in the outcrop. In depth, however, the latter metal became predominant, and is now almost the sole product.

The total gold production of Arizona to 1900 is estimated at £8,610,000 ($42,000,000). Later returns are :—

Year.	Value, Dollars.	Value, Sterling.
1901	$4,083,000	£837,015
1902	4,112,300	843,021
1903	4,357,600	893,308
1904	3,478,532	713,099
1905	2,691,300	551,716
1906	2,964,683	607,760
1907	2,539,516*	520,600
Grand total ..	$66,226,931	£13,576,519

* Estimated.

COLORADO.

Colorado has been for many years the leading State of the Union in respect of its gold production. Its pre-eminence has, however, been seriously challenged during 1906 and 1907 by the territory of Alaska, but as the latter region is dependent entirely on its readily exhaustible alluvial gold, serious rivalry will, in all likelihood, not long be maintained. The commanding position of Colorado is due principally to the well-sustained production of the famous Cripple Creek district, on the western slopes of Pike's Peak. This field, discovered in 1892, reached its maximum production eight years later with an output for 1900 of £3,705,077 ($18,073,539), the greatest gold production for a single year of any field in the United States. The equally celebrated Comstock mines, even in 1877, when in the heyday of their prosperity, produced about £700,000 ($3,500,000) less. Ninety-seven per cent. of the gold of Colorado comes from quartzose

[a] Econ. Geol., I, 1906, p. 428.

ores, the remainder (45,000 ounces for the year 1906) being derived as a by-product from the smelting of lead, zinc, and copper ores.

The metalliferous wealth of Colorado may be attributed to the folding and extensive orogenic movements to which the rocks of the western portion of the State have been subjected, accompanied as they were in Tertiary times by volcanic intrusions and eruptions that were attended or followed by the widespread percolation of ore-bearing solutions. While deposition may have and did take place in the Palæozoic and Mesozoic sedimentary rocks, the valuable deposits of Colorado nevertheless lie in the Tertiary propylitic rocks. Moreover, even in the former case, the ore-deposition is generally ascribed to the influence of an adjacent Tertiary intrusive rock. Deposits in the older rocks are more abundant in the northern counties of Boulder, Clear Creek, and Gilpin, while those in the younger rocks prevail in the Cripple Creek district and also in the rich San Juan region in the south-west. The leading counties with their principal fields, in order of gold production, are Teller (Cripple Creek) Ouray (Camp Bird), San Miguel (Telluride), Gilpin, Lake (Leadville), and San Juan (Silverton). Each of these counties produces more than a million dollars annually.

Boulder County.—The mines of Boulder County lie on the foothills of the Rocky Mountains, some 30 to 35 miles north-west of Denver. Their elevation above sea-level is from 6,500 to 8,500 feet. The fundamental rocks of the eastern foothills are granite, gneiss, and mica-schist, through which there have been extruded andesite, trachyte, rhyolite, and phonolite. The ore-deposits normally occur in fissure lodes in the older rocks, or at contacts of sedimentary and igneous rocks. The high-grade ore occurs in irregular shoots, and may be free-milling gold-ore, changing in depth to sulphide-ore ; or the values may be in tellurides of gold and silver (petzite, calaverite, sylvanite). The first discovery of gold-telluride (petzite) in Colorado was made by Dr. Anton Eilers in 1871, when examining ore from the Red Cloud mine.[a] An example of normal gold-occurrence is the Golden Age vein, near Jamestown, at the contact of a quartz-porphyry dyke with granite and gneiss. The gangue is the bluish horn-quartz of the telluride ores of Boulder County. Free-gold ores also occur in close proximity. The values are distributed in irregular shoots, and the veins on the whole are rich but uncertain.[b] The Smuggler mine in the same county has been worked since 1880, and had produced to 1891 more than £400,000 ($2,000,000) gold. Its lode is a fissure vein in mica-schist and carries its value in high-grade tellurides, mainly sylvanite.[c]

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[a] Genth, Amer. Jour. Sci., 2, XLV, p. 305.
[b] Owen, Trans. Inst. M.E., XIX, 1900, p. 325.
[c] Farish, Trans. Amer. Inst. M.E., XIX, 1891, p. 547.

Gilpin County.—In Gilpin County, the next to the south, gold-quartz veins are found in rocks similar to those of Boulder County. The ores are free gold, with highly auriferous pyrite and chalcopyrite. Attention was first directed to the district by the rich placers of the streams. The mining area is extremely small, covering only about 16 square miles in the immediate neighbourhood of Central City. It has, nevertheless, been exceedingly productive in the past.

Clear Creek County.—Considerable geological work has been done in the mining areas of Clear Creek County, and the geological relations of the various rocks have therefore been made fairly evident.[a] The older rocks of the Idaho Springs and Georgetown districts form the presumably pre-Cambrian complex of the Front Range of the Rocky Mountains. They are biotite- or quartz-gneisses and schists, granites, pegmatites, and basic igneous rocks resembling diorites and amphibolites. These rocks are intruded by numerous felsitic and granitic porphyries, that are clearly older than the period of the prevalent ore-deposition. The ores are pyrite, galena, blende, and chalcopyrite. The gold is occasionally free, but is more often combined with the sulphides. The chief gangue mineral is quartz, with which is associated subordinate siderite, barytes, calcite, rhodochrosite, and magnesite. Many veins are connected with the porphyry dykes, but apparently merely because the dyke intrusion has formed parallel fissures or planes of weakness in the country along which the veins have been deposited. Pay-shoots are met with most often at the intersections of the larger veins or of feeders with the main veins, where ore-bearing solutions have been mingled, with consequent precipitation of their burden. From the foregoing it will thus be apparent that the counties of Boulder, Gilpin, and Clear Creek form a single mining field contained within Archæan rocks, but with a mineralisation to be ascribed to a much later date.

Summit County.—The next county to the south-west is Summit. Its principal camps are Breckenridge and the Ten-mile district, both in the south of the county. Placer-mining and dredging are being carried on near the former place, but its deep mines are much more important, producing silver-gold-lead ores to the value of £50,000 per annum. Breckenridge is almost unique among North American goldfields, inasmuch as its veins furnish remarkably well-crystallized gold from pockets in narrow

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[a] Spurr and Garrey, Bull. U.S. Geol. Surv., No. 260, 1905, p. 99; Id., ib., No. 285, 1906, p. 35.

lenticular veinlets lying in uptilted black marine Cretaceous slates or shales that are traversed by porphyry dykes. One such pocket is said to have yielded nearly £6,000 ($29,000), mostly obtained by simply scraping out the contents of a vugh.[a] The Ten-mile or Kokomo district is mainly a silver-lead-zinc field, but gold is also produced. The ore-deposits occur as veins or "blankets" in a series of Carboniferous limestones and sandstones intruded by sheets of diorite-porphyry. The sulphides are pyrite, marcasite, galena, and zinc blende.[b] Similar ores, also in Carboniferous limestones intruded by diorite-porphyry are worked near Alma, London, &c., a few miles to the south of the Ten-mile district, but in Park County.

Leadville.—The Leadville mines of Lake County produce, in order of decreasing value, zinc, silver, lead, gold, and copper. Its gold production for 1905 is estimated[c] at £241,982 ($1,180,401).

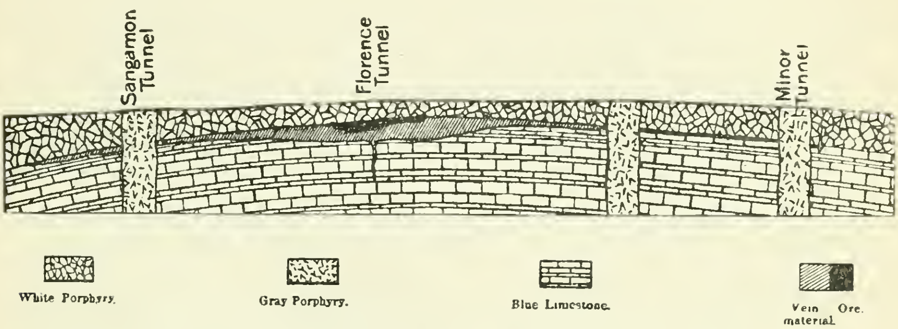

FIG. 177. SECTION THROUGH FLORENCE MINE, PRINTER BOY HILL, LEADVILLE (*Emmons*).

The ores, being sulphides, are generally treated by concentration and subsequent smelting. Mining commenced in this district with the discovery in 1859 of the rich placers of California Gulch, from which large quantities of alluvial gold were won for three or four years. With their exhaustion the field was practically deserted, for the rich silver-lead deposits that have since made Leadville famous were not discovered until 1875. By 1880, however, most of the richer mines were yielding enormous quantities of silver and lead. The economic geology of the district is described in one of the classic monographs of the United States Geological Survey.[d] The basement rocks are crystalline Archæan gneiss, granite, and amphibolite. These are overlain by several thousand feet of sedimentary strata, including

[a] Lakes, Mines and Minerals, Dec., 1900, p. 222.

[b] Emmons, S. F., Atlas U.S. Geol. Surv., Fol. 48, 1896, p. 5.

[c] Lindgren, Min. Res. U.S., 1906, p. 204.

[d] Emmons, S. F., Mon. U.S. Geol. Surv., XII, 1886.

Cambrian quartzite, Silurian blue or dark limestone (the chief ore-horizon), Lower Carboniferous grits, Upper Carboniferous blue limestone, and Quaternary lacustrine deposits.

All the Palæozoic strata were caught up in the early Tertiary uplift of the Rocky Mountain zone, were folded and crushed, and were intruded by porphyry dykes and sheets. To the influence of the intrusive igneous rocks the ore-deposits are probably to be ascribed. The ore-bodies are generally situated beneath the contact

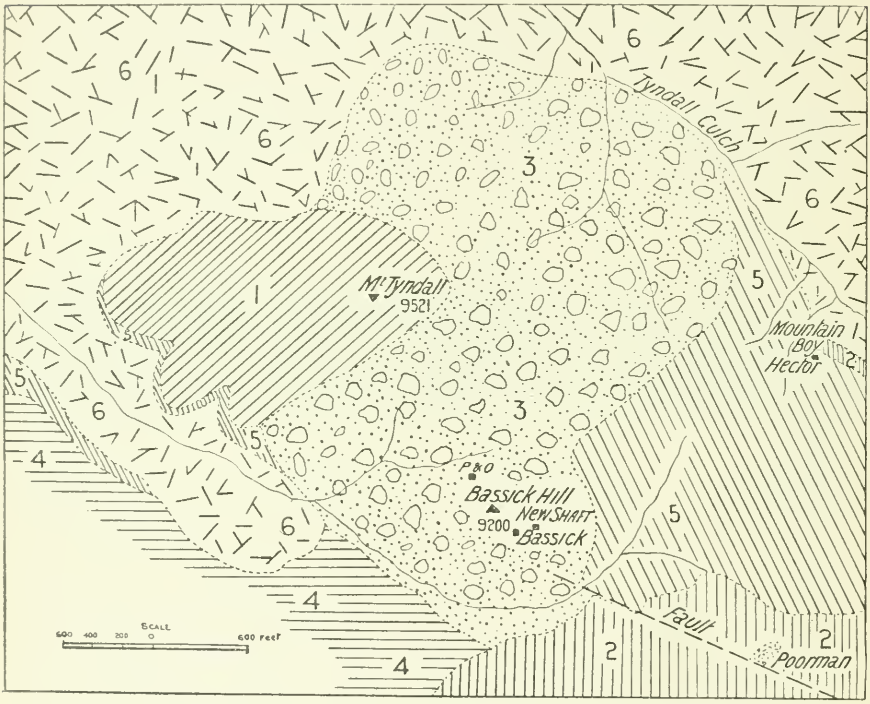

Fig. 178. Geological Map of Bassick Hill, Colorado (*Cross*).
1. Rhyolite. 2. Trachyte. 3. Bassick andesitic agglomerate. 4. Bunker andesite. 5. Rosita andesitic tuff and breccia. 6. Granite and gneiss.

of the porphyry sheet with the underlying blue limestone. The free-gold lodes of Leadville are best exemplified on Printer Boy Hill, where they occur in connection with a body of porphyry not identical with any other found in the district. The Printer Boy vein was discovered as early as 1866. It lies within the porphyry in a vertical fissure plane, and varies in width from a few inches to 3 feet. Similar veins, also in the porphyry, are found in the vicinity. In 1907 important gold discoveries were made in the Breece Hill district.[a]

[a] Rickard, F., Min. Sci. Press, Jan. 11, 1908, p. 70.

Chaffee County.—Auriferous veins occur near Granite and Buena Vista in the north of Chaffee County, where a few small placers are also worked. Little is known of the geology of the district. In Saguache County, a little gold is being obtained near Crestone in the western foothills of the Sangre de Cristo range.

Custer County.—The Rosita and Silver Cliff districts, Custer County, lying 40 miles south of Cripple Creek, and on the western foot-hills of the Wet Mountain range, present many analogies with the more famous Cripple Creek occurrences. The conditions under which the ores occur are sufficiently remarkable to merit a slight amount of detail. The peculiar features of occurrence, features that are indeed repeated several times in the district, are perhaps best shown in the Bassick mine,[a] which worked on two chimney-like

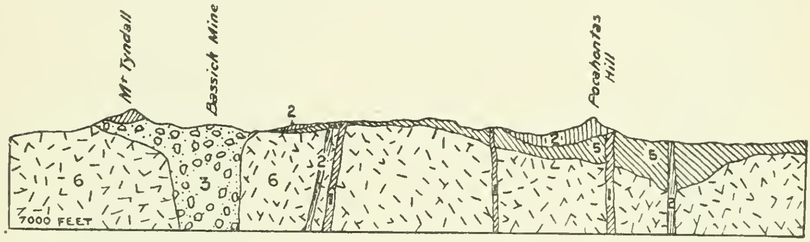

FIG. 179. GEOLOGICAL SECTION THROUGH BASSICK MINE AND NEIGHBOURHOOD (*Cross*).
1. Rhyolite. 2. Trachyte. 3. Bassick andesitic agglomerate. 4. Bunker andesite. 5. Rosita andesitic tuff and breccia. 6. Granite and gneiss.

ore-deposits. The basement rock of the district is granite and gneiss. Through these Archæan rocks, and possibly along a vertical line of weakness resulting from the intersection of two faults or fissures, an Eocene volcano burst forth with eruptive violence, making for itself an elliptical conduit in the metamorphic rock. Through the rent lavas welled and ashes were thrown to the surface. The lavas varied in character ; the order of the succession from the oldest to the youngest appears to have been andesite, diorite (dykes), dacite, rhyolite, andesite, trachyte, and andesitic agglomerate. Part of the fragmental material is well stratified, and was apparently deposited on lake-beds. The Bassick mine itself lies on the slope of Mount Tyndall, its andesitic agglomerate being partially protected from erosion by a rhyolite flow that forms the cap of the mountain. The fragments of the agglomerate range in size up to 3 feet. Two nearly vertical agglomerate chimneys, formed as above described, lie within a short distance of each other in the gneiss ; both have been worked. The larger is rudely elliptical in horizontal section, with major and minor axes of 75 and 25 feet long

[a] Cross, 17th Ann. Rep. U.S. Geol. Surv., II, 1896, p. 263 ; Emmons, S. F., ib., p. 411 ; Welles and Lakes, Mines and Minerals, June, 1903, p. 487.

respectively. Towards the walls of the vent a considerable admixture of gneissic fragments has taken place. The ore-body itself lies within the agglomerate, filling the throat, and with its richest ore near the centre, where also are disposed the larger fragments of andesite.

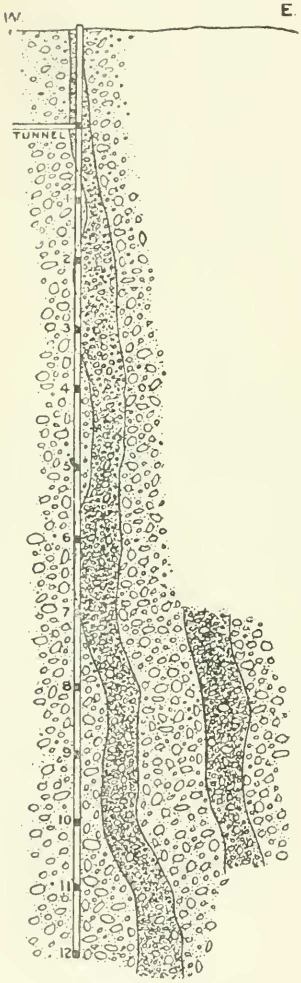

FIG. 180. CROSS-SECTION THROUGH ORE-BODY OF BASSICK MINE (*Emmons*).

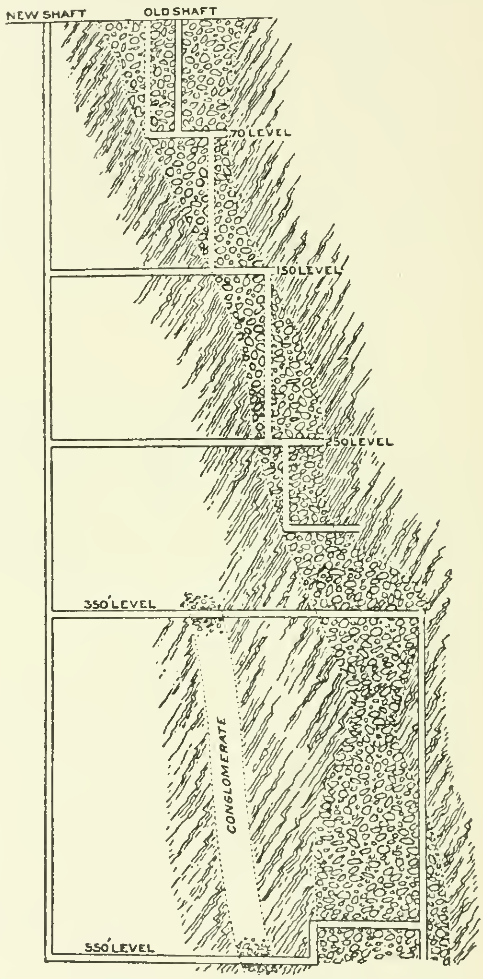

FIG. 181. CROSS-SECTION OF BULL-DOMINGO CHIMNEY CUSTER CO., COLORADO (*Emmons*).

These last are well-rounded and bear every indication of having undergone considerable attrition within the vent. The walls of the ore-body are by no means distinct, and its general downward course, which is not always exactly in the centre of the chimney, is believed by Emmons to have been determined by the intersection of fracture planes. The ores found in the vent are blende, galena, jamesonite, tetrahedrite, smithsonite, calamine, and free gold, with relatively insignificant quantities of quartz and calcite. The disposition of the ore is remarkable. The sulphides are arranged in concentric shells of constant local thickness (from one-fourth inch and less to 2 inches) of different sulphides that are always disposed in the same order around the more or less rounded agglomerate fragments. The innermost shell is composed of sulphides of zinc, antimony, and lead, containing on an average 60 ounces silver and 1 to 3 ounces gold. It is succeeded by a second layer with more gold, silver, and lead, often as much as 100 ounces of the first and 200 ounces of the second per ton. A third layer or shell of crystalline blende with some iron and copper sulphide forms the most valuable ore in the mine, having an average tenor of 15 to 20 ounces gold and 60 to 120 ounces silver per ton. This is generally the outermost shell, but there may also occur further successive shells of chalcopyrite and of pyrite respectively. The interstitial matter connecting the agglomerate fragments is mainly kaolin, through which is loosely disseminated tetrahedrite (grey copper) and tellurides of gold and silver, obviously the last products of the solfataric action that had deposited the ores. The Bassick ore-body has been followed in depth within the chimney to nearly 2,000 feet. Carbonised and partly silicified wood has been found at a depth of 765 feet from the present surface. The Bull-Domingo mine, at Silver Cliff, is working on a similar volcanic-throat agglomerate. Its ores show the same characteristic disposition in concentric shells of different sulphides round andesitic fragments. The ores of the Bull-Domingo are, however, mainly argentiferous and contain little gold. The Bassick mine was opened in 1877. Since then it has yielded more than £512,500 ($2,500,000) in gold and silver.

Costilla County.—In Costilla County an auriferous area occurs at Plomo on the Rito Seco, north-east of San-Luis, and on the western slope of the southern Sangre de Cristo range. Here the ore-bodies occur in granite-gneiss along zones of siliceous and pyritous replacement. The ores are low-grade, ranging in value from 10s. ($2.50) to 30s. ($7.50) per ton.[a]

Cripple Creek.—The Cripple Creek district, from 1893 to 1908 the leading gold camp in the United States, lies on the western slopes of Pike's Peak at a general elevation of some 10,000 feet above sea-level. It may be reached by several railway routes, of which the Cripple Creek Short Line from Colorado Springs is perhaps the most convenient, and is certainly the most picturesque.

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[a] Gunther, Econ. Geol., I, 1906, p. 151.

The earliest report of the gold in this region induced a celebrated rush to Pike's Peak as long ago as 1859, a rush that ended in failure and even in disaster. The district was practically abandoned by miners until 1891, when various Colorado Springs prospectors discovered gold and gold-tellurides and marked out claims that have since proved of extraordinary value.[a] From that time onward the development of the district was exceedingly rapid and

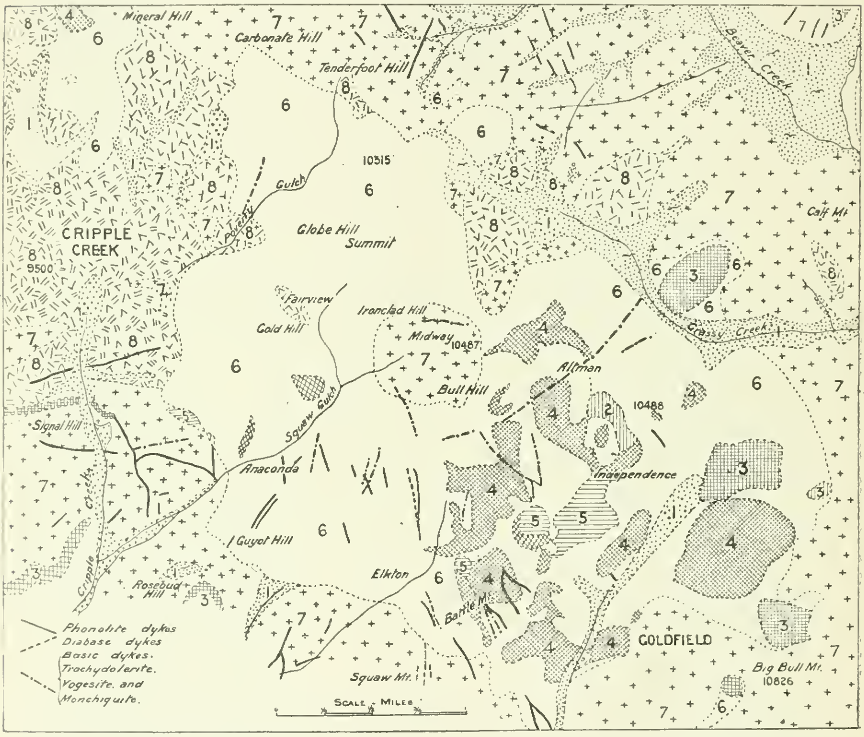


Fig. 182. Geological Map of the Cripple Creek Goldfield, Colorado (*Ransome and Graton*)
1. Alluvium. 2. Trachydolerite. 3. Phonolite. 4. Latite-phonolite. 5. Syenite. 6. Phonolite-breccia. 7. Granite. 8. Gneiss and schist.

its yield increased, as has already been noted, until 1900, when the annual output reached £3,705,075 ($18,073,539). The general progress of the field has at times been somewhat retarded by labour troubles. These became especially serious in 1894 and again in 1903. The amount of the total dividends paid by the various mines is not ascertainable with accuracy, but to the end of 1903 is believed to have been £6,714,160 ($32,752,000). The goldfield is a small one, being comprised entirely within a circle with a radius of three miles from Gold Hill.

[a] Rickard, T. A., Trans. Inst. Min. Met., VIII, 1899, p. 49.

The oldest rocks in the district are fibrolite-muscovite schists and fine-grained granitic gneisses. On these the greater portion of the town of Cripple Creek is built. Associated with the older rocks and intrusive into them are granites of three types : Pike's Peak, Cripple Creek, and Spring Creek, differing mainly in texture. These have not been differentiated on the accompanying geological sketch map, and the older rocks generally are of interest only in so far that they form the basement rocks of the district through which the Tertiary eruptives have broken. At the time of eruption the country appears to have been a granitic plateau similar in most respects to that existing at the present day. The Tertiary eruptive magmas broke with explosive violence through a narrow short vent, shattering to fragments the overlying granites and brecciating those in the immediate vicinity, much of the débris falling back into the vent. Following the first explosions came eruptions of phonolite, latite-phonolite, and syenite, the products of which were subsequently shattered and comminuted in the vent by later eruptive paroxysms. The materials in the throat, at least, were therefore thoroughly mingled. At the same time a volcanic cone was built up on the surface. Of this cone but little trace now remains, nearly all of it having disappeared before the agencies of erosion. Thus the accompanying geological map shows rather the plan of the original throat than the wider extent of the now vanished cone. The volcanic breccia forming the principal portion of the throat-filling is generally a structureless agglomeration of ash and larger fragments. Banding, however, occurs in places, as at the 220-foot level of the Portland mine. Carbonaceous and silicified material representing original tree trunks have been found at depths of from 500 to 800 feet below the present surface, and show that a forest grew on the site of the crater or that it flourished on the crater slopes between eruptions.

In addition to the breccia, intrusive masses of latite-phonolite and syenite are found in the throat. The former occurs mainly as irregular stock-like bodies or in thick sheets. The syenite is genetically connected with the latite-phonolite and is merely a different facies of the same intrusive mass. Though differentiated on the map, they are therefore closely related masses and shade the one into the other in position, texture, and composition.

The dense black aphanitic, typical trachy-dolerite found on Bull Hill is apparently younger than the latite-phonolite. Nearly all the large intrusive masses composing the throat-breccia are latite-phonolite, occurring, as on Beacon Hill, as plugs in elliptical chimneys in the granite. The breccia, the latite-phonolite, and the surrounding pre-Cambrian rocks are all cut by exceedingly numerous thin phonolitic dykes of different ages, that have had a considerable economic effect on ore-deposition. The last eruptions from the Cripple Creek vent were basic dykes showing, like the phonolite dykes, a tendency to radiate from a centre. They may be trachydolerite, vogesite, or monchiquite. These basic dykes (termed by Stevens[a] nepheline-basalt, limburgite, felspar-basalt, and tephrite) are considered by him to have also exercised a most important influence on ore-deposition. A rhyolite occurs in small scattered patches in the south of the district some distance from the auriferous areas, and represents perhaps a portion of an original surface flow of probable Miocene age and therefore practically contemporaneous with the later activity of the Cripple Creek volcano.

Petrologically considered, the phonolite is a fine-grained, fairly dark, often porphyritic, but generally aphanitic rock. Its felspar is soda-orthoclase. The distinctive mineral is of course nepheline, which occurs in large quantity. Nosean and sodalite are also present, as also is analcite, which is here regarded as a primary constituent of the rock.[b] The ferro-magnesian silicates are aegerine and

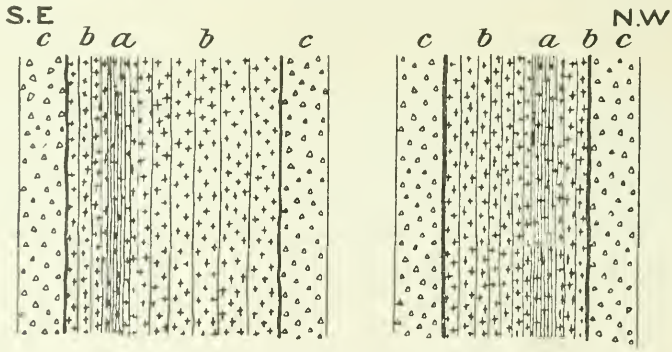


FIG. 183. SECTION IN NORTH STAR MINE, CRIPPLE CREEK (*Penrose*).
a. Veins. *b.* Dykes. *c.* Country. Scale: 1 inch = 4 feet.

aegerine-augite, together with an undetermined blue amphibole. The term latite-phonolite is proposed for certain Cripple Creek volcanic rocks, to denote a type intermediate between phonolite and latite, the latter term itself denoting a form intermediate between andesite and trachyte and therefore the volcanic equivalent of monzonite. The latite-phonolites contain therefore orthoclase, soda-plagioclase, a soda felspathoid (including analcite) and some mineral of the pyroxene, amphibole, or mica-groups.[c] The syenites are granular rocks closely resembling the latite-phonolite. They are medium to

[a] Loc. cit. inf., p. 698.

[b] Lindgren, 16th Ann. Rep. U.S. Geol. Surv., 1895, Pt. II, p. 36; Graton, Prof. Paper No. 54, U.S. Geol. Surv., 1906, p. 62.

[c] Graton, loc. cit., p. 69.

South slope of Bull Hill, from Squaw Mount, Cripple Creek.

Cripple Creek, looking West from Gold Hill.
Mount Pisgah in the background. (U.S. Geological Survey.)

dark-grey rocks with prominent prismatic crystals of pyroxene in a felspathic matrix. The last basic intrusions through the rocks of the Cripple Creek vent strongly resemble basalts in outward appearance, and are divided by Graton, because of their high alkali content, into trachydolerite, vogesite, and monchiquite, the last possessing phenocrysts of pyroxene and olivine embedded in a matrix of analcite.

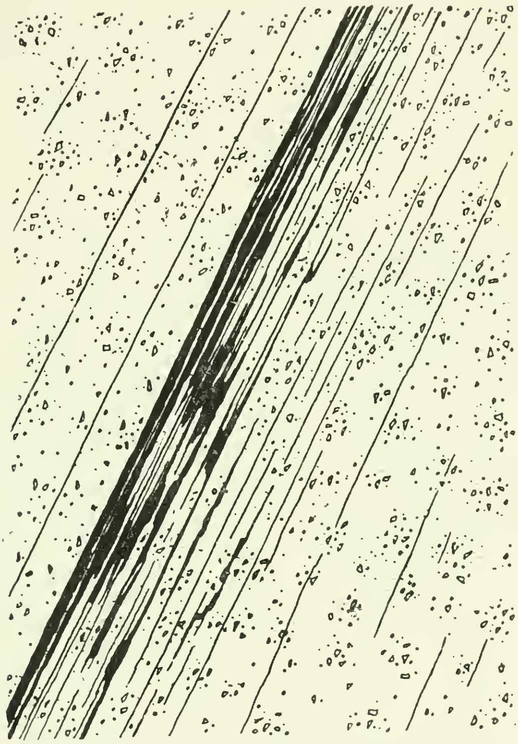


Fig. 184. Ore-streaks (black) in Andesite-breccia, Cripple Creek (*Rickard*).

The prevalent breccia is wholly fragmental and may vary in fineness from a tuff to an agglomerate, the general tendency being toward the finer-grained rock. The breccia is largely made up of phonolite and latite-phonolite, but numerous granite fragments also occur. Granite brecciated *in situ* is also found on the walls of the original vent. The activity of the volcano seems to have been greatest in Miocene times.

On the whole, the Tertiary volcanic rocks of the Cripple Creek metalliferous area may be regarded as having been differentiated from a single originally homogeneous magma.

The auriferous ore-bodies of the district may be divided into two classes: (*a*) those tabular in form and strictly following simple fissures or sheeted zones in the volcanic breccia, and (*b*) irregular bodies adjacent to fissures and formed by replacement and recrystallization of the country rock, which is, in this case, usually granite. The groups are not sharply defined and may shade into one another. Cripple Creek fissures are always narrow and are not always filled with the usual quartz or fluorite gangue. Wide lodes are indeed worked, but these are essentially zones of thoroughly shattered country along which run numerous narrow parallel fissures thinning away to mere cracks in which the rich tellurides are deposited. The country in the vicinity of the fissures is often replaced by dolomite, pyrite, and a little fluorite. The fissures often remain unfilled and exhibit a characteristic "vuggy" structure. The rich tellurides, being the last deposited,

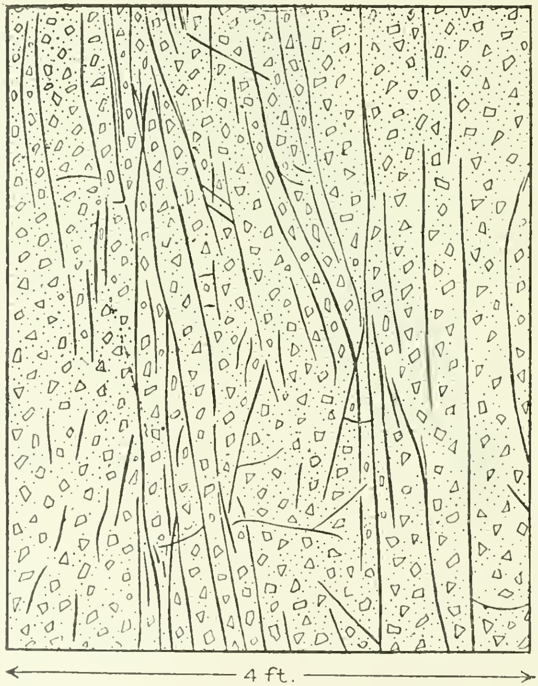


Fig. 185. Sheeting in Breccia, Captain Vein, Portland Mine, Cripple Creek (*Lindgren*).

are generally found on the walls of the "vughs" or fissures. Sheeted zones and single fissures are also well developed and are profitably worked in the surrounding granite, as in the El Paso, C. K. & N., and Gold Coin mines. They often follow phonolite dykes that, by their intrusion, have induced parallel fracturing in the country. In the sheeted zones, the ore may occur in pay-shoots

2,000 feet long and 1,000 feet deep, but is ordinarily contained in very much smaller ore-bodies.

Replacement deposits in granite occur near the breccia contacts and are extensively worked in the Elkton, Ajax, Independence, and Portland mines. In these cases the ore occurs both in the fissures and in the adjacent country.

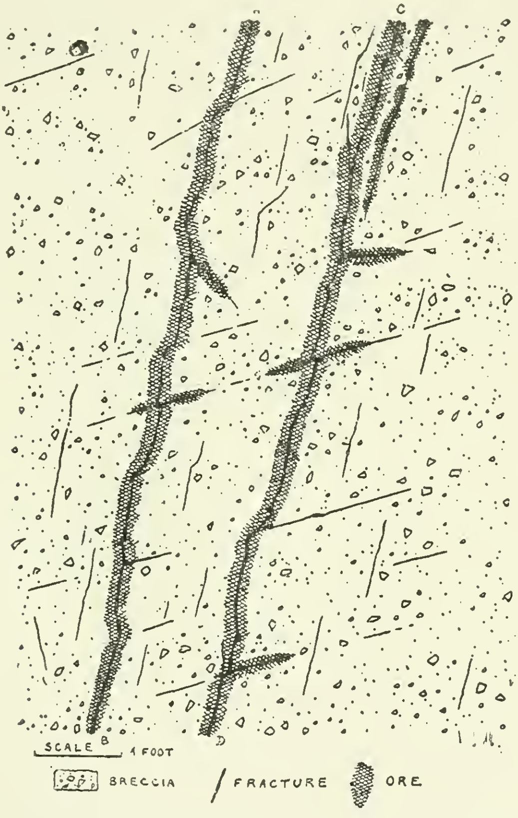


FIG. 186. IMPREGNATIONS ALONG PARALLEL FRACTURES, CRIPPLE CREEK (*Rickard*).

The gold-ores of Cripple Creek are tellurides, viz., sylvanite, krennerite, and calaverite, with which are associated free gold derived from the foregoing tellurides, pyrite (the most common sulphide in the district), molybdenite, stibnite (usually associated with very rich ores), blende, and tetrahedrite. Molybdenite, stibnite, and tetrahedrite are occasionally very rich, but it appears probable from analyses that their gold content is due to mechanically admixed calaverite.

Quartz is the most important vein-forming mineral, and occurs as crusts and combs. It is frequently intergrown with calaverite.

Fluorite, ordinarily purple in colour, is abundant in all veins. Dolomite is also common. Roscoelite, rhodochrosite, and celestite are among the most interesting of the numcrous vein minerals found. Valencianite (potash-felspar) is common as a secondary product in the ores enclosed in the granite. The oxidised zone is from 200 to 400 feet in depth. The normal ores of the district contain 1 ounce silver to 10 ounces gold. Where galena and tetrahedrite are abundant the proportion of silver rises considerably. The average value of Cripple Creek ore, as mined, is some £6 to £8 ($30 to $40) per ton, though small lots may reach £600 to £800 ($3,000 to $4,000), or even more, per ton.

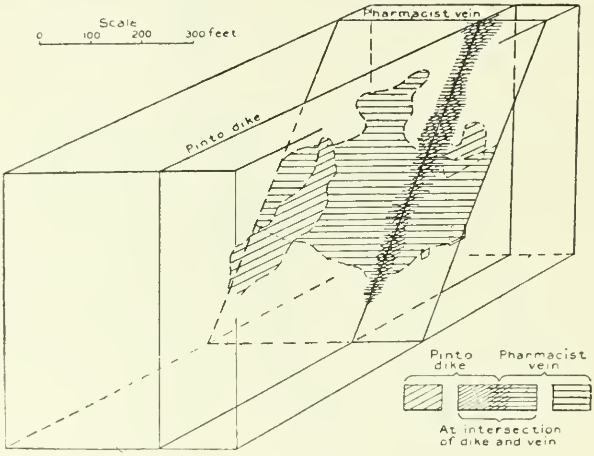


Fig. 187. Stereogram of Ore-shoot on the Pinto Dyke and Pharmacist Vein, Cripple Creek (*Lindgren* .

The values occur in irregular ore-shoots within the fissures. The shoots have generally a greater extension vertically than laterally. They are ordinarily either vertical or pitch steeply northward. Few ore-bodies exceed 1,000 feet in length or depth. The principal productive zone extends to the 1,000-foot level. Below that depth the ore is decidedly less in quantity rather than lower in grade. Little evidence of secondary enrichment was found by Lindgren and Ransome either in the sulphide zone by downward solutions or of absolute enrichment in the oxidised zone by upward-moving solutions, the final conclusion being that in both zones secondary enrichment was practically absent.

The principal mines of the district are the C. O. D. and Gold King in Poverty Gulch ; Anchoria-Leland, Moon-Anchor, Anaconda, on Gold Hill ; Doctor Jackpot, Work, Mary McKinney, and Elkton, in Raven and Guyot Hills ; El Paso, C. K. & N., on Beacon Hill ; Lost Dollar, Modoc, and Union, on Bull Hill ; Victor and Isabella, between Altman and Goldfield; Pinto and Pharmacist, near Altman; Findley and Shurtoff, Hull City, Vindicator, and Golden Cycle, all in the neighbourhood of Bull Cliff on the Vindicator lode system; Portland and Stratton's Independence to the east of

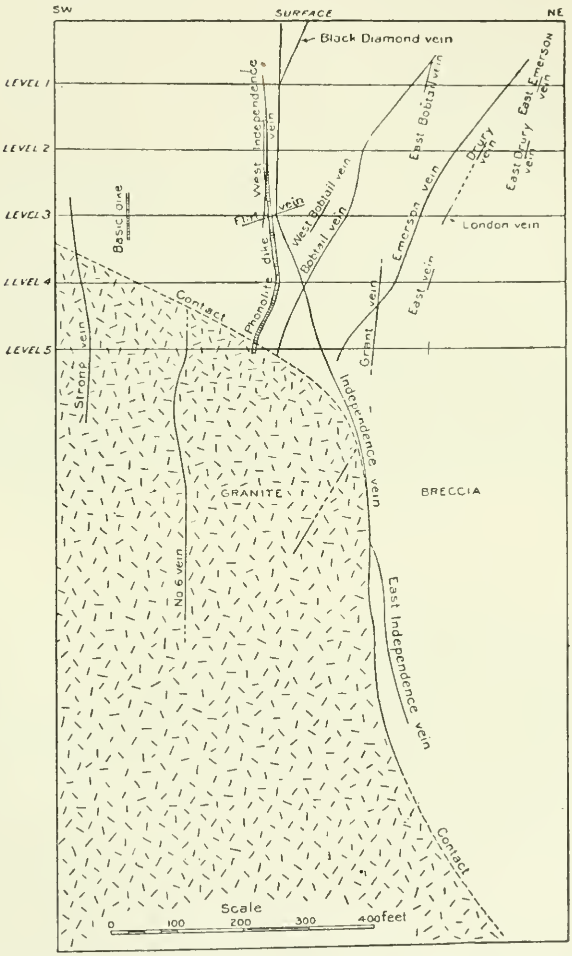


Fig. 188. Section through Stratton's Independence Mine, showing relation of veins to zone of granite-breccia contact (*Lindgren*).

Battle Mount; and finally, Strong, Granite, Ajax, and Gold Coin, on Battle Mount (western portion).

It is clear from a consideration of the distribution of the richer mines that the richest part of the field lies in the neighbourhood of Bull Cliff and Independence, or in other words, well to the south-east side of the ancient vent. The ores of the district have in the past nearly all been carried by the Cripple Creek Short Line to Colorado City to be chlorinated. The cyanide process, both at

Colorado City and on the field itself, is in 1908 rapidly supplanting the chlorination process, and cyanide will probably eventually oust the older solvent. In 1906 and 1907 the Portland was the leading producer at Cripple Creek. In order to facilitate work at the lower levels of the Cripple Creek mines, ordinarily subject to considerable flows of water, a low-level tunnel was commenced at the end of 1907 to cut the lodes of the field 2,000 feet below Beacon Hill and 3,200 feet below Bull Hill. The total estimated length of the tunnel when completed will be 3½ miles.[a]

The following table shows the annual yield of Cripple Creek goldfield, and is derived from the reports of the Director of the United States Mint :—

Year.	Value.	Year.	Value.
1891	$449	1900	$13,073,539
1892	583,010	1901	17,261,579
1893	2,010,367	1902	16,912,783
1894	2,908,702	1903	12,967,338
1895	6,879,137	1904	14,499,529
1896	7,512,911	1905	15,724,344
1897	10,139.709	1906	14,253,245*
1898	13,507,244	1907	13,148,152†
1899	15,658,254		

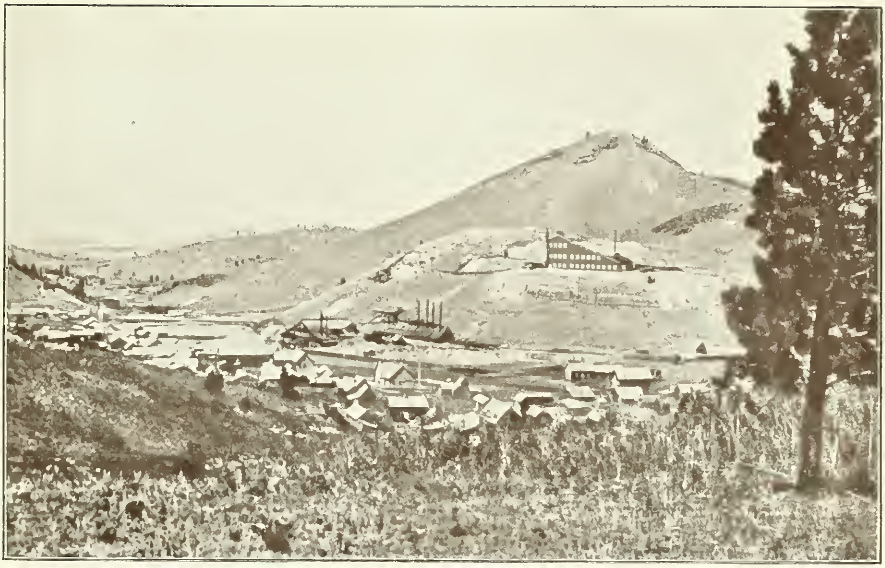
* Min. Res., U.S. Geol. Surv., 1906, p. 236.
† Estimated.

Gunnison County.—At the present time Gunnison County is a small gold producer, the value of the gold obtained in 1905 being only £5,772 ($28,156). Little is known of the geology of the country. Some, at least, of the silver-gold veins are in limestones that are intruded by Tertiary volcanic rocks.

Ouray County.—Ouray County, next to the south-west, has, on the other hand, important gold veins that furnished in 1905 gold to the value of £478,323 ($2,333,282). This is the most northerly of the counties of the San Juan group (Ouray, San Miguel, Dolores, San Juan, Hinsdale, La Plata, and Montezuma).

The eruptive regions of Rosita and Silver Cliff, and also of Cripple Creek, may be considered as outlying minor eruptions of the same character as the great flows, tuffs, and agglomerates of the San Juan and South Mountains to the south-west of Colorado. In both the first-mentioned cases the actual positions of the ancient

[a] The foregoing account of the Cripple Creek district has been largely derived from the already classic monograph of Lindgren and Ransome, Prof. Paper U.S. Geol. Surv., No. 54, 1906, pp. 1-496. Other detailed reports on the field are Cross and Penrose, 16th Ann. Rep. U.S. Geol. Surv., Pt. II, 1895, p. 1 ; Rickard, T.A., Trans. Inst. Min. Met., VIII, 1900, p. 49 ; Id., Trans. Amer. Inst. M.E., XXXIII, 1903, p. 578 ; Stevens, E. A., ib., XXXIII, 1903, p. 686.



Bassick Hill and Mount Tyndall, from the South.

Silverton, Colorado, Looking North.

(U.S. Geological Survey.)

vents may be located, a feature impossible in the San Juan region, where the volcanic forces possessed much greater activity. The general age of these eruptions is late Eocene or early Miocene.

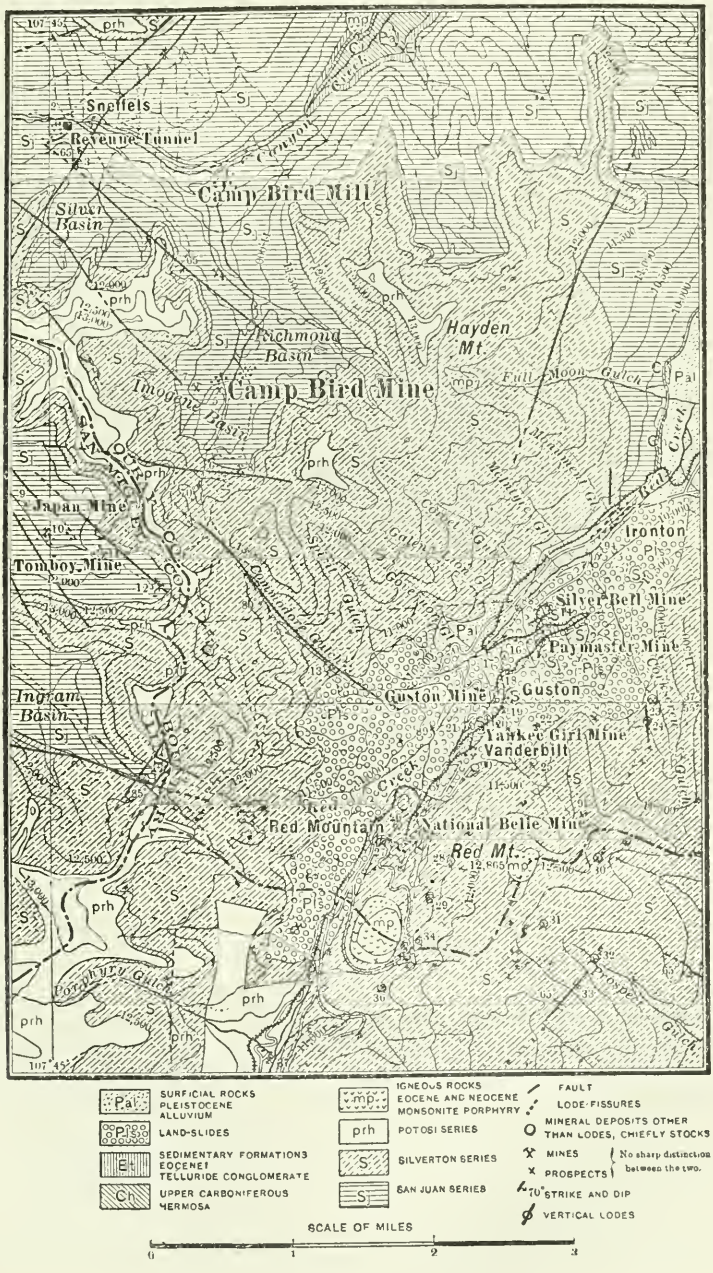


Fig. 189. Geology of Camp Bird and Neighbourhood (*Purington*).

The Camp Bird mine in Imogene Basin, 8 miles from Ouray, has proved one of the most productive of modern gold mines, producing in 1905, £446,007 ($2,175,645), or no less than 93 per cent. of the total yield for the whole Ouray County. Its vein traverses the andesitic breccias and tuffs of the San Juan formation, that overlie Mesozoic and Palæozoic sedimentary rocks and Algonkian quartzites. The San Juan formation has a thickness of some 2,500 feet in the Canyon Creek area. Its tuffs and breccias are, when considered broadly, fairly well stratified.[a] They are overlain, to the east of the Camp Bird mine, by the great Silverton series of massive andesites, rhyolitic flow-breccias, and tuff-breccias,

FIG. 189A. SHOWING STRUCTURE OF VEIN-QUARTZ, CAMP BIRD MINE (*Ransome*).
Magnified 14 diameters; black areas, fluorite; shaded areas, quartz; cross-hatched areas, calcite; nicols crossed.

that attain a thickness of 4,000 to 5,000 feet. Capping the mountain ranges at an elevation above sea-level of 13,000 feet is a rhyolite, closely akin to the wide-spread Potosi rhyolite of the south-east. Through the Silverton series small stocks of orthoclase-porphyry are intrusive.

The Camp Bird vein follows two main fissure zones, one striking N. 87° W., and the other N. 72° W. A minor zone strikes N. 51° W.; all three dip towards the south.[b] The average width of the vein

[a] Cross, Bull. U.S. Geol. Surv., No. 182, 1901, p. 31.
[b] Purington, Trans. Amer. Inst. M.E., XXXIII, 1903, p. 510.

VIEW FROM SOUTH OF OPHIR PASS.

POTOSI PEAK.

MOUNTAIN SCENERY IN THE VICINITY OF TELLURIDE, COLORADO.

(U.S. Geological Survey.)

is 6 to 7 feet. It has well-defined walls. The principal gangue mineral is white, opaque, generally crystalline quartz. Open cavities and vughs in the vein are numerous. Calcite, rhodonite, and chlorite are also vein minerals. The chief metallic sulphide is pyrite, which occurs either in the quartz or disseminated through "horses" of country within the lode. Blende is rare. Magnetite, a very unusual associate of gold (but found with the tellurides of Kalgoorlie, W.A.), occurs in an exceedingly fine state of division intimately mixed with galena in the white quartz. It has been detected only on analysis, but nevertheless appears to occur in considerable quantity, the cloudy bands ascribed to its presence indicating, as a rule, a high gold tenor. Galena and chalcopyrite are found, the latter in small quantity. The gold occurs finely divided and scattered through the quartz, and is associated generally with galena and magnetite. Its fineness is 740, the remainder being silver. The ore-bodies of the Camp Bird, as of most gold mines, are found in shoots, some of which have been worked from the surface to a depth of 800 feet. There is little or no evidence of secondary enrichment in the district. The Camp Bird mine is situated about 11,500 feet above sea-level in a region subject to snow-slides. In 1906 the crushing-mill was almost completely wrecked by an avalanche that took an unexpected course.

Other mining districts of Ouray County are Sneffels, Red Mountain and Uncompahgre. The Sneffels mines are also in the San Juan formation. The Red Mountain district includes the well-known Yankee Girl and other mines. The country of the field is the Silverton formation,[a] made up of an andesite breccia with andesite flows, all being cut by numerous andesitic dykes. The Yankee Girl vein was located in 1881. The conditions under which the ore occurred, for most of it has now been worked out, were remarkable. It was found in several cylindrical or elliptical chimneys, 20 to 30 feet in diameter, in the breccia, which is decomposed in the immediate vicinity of the ore-chimneys. Emmons[b] believed that here, as in the Bassick mine already described, the direction of the chimney was determined by intersecting fissures. Around each chimney is an envelope of quartz that is impregnated with fine-grained pyrite. The ores were exceedingly rich in silver, one car-load of 6 tons carrying 5,300 ounces silver per ton. The total yield of the mine is said to have been some £600,000 ($3,000,000).

In the Uncompahgre district at Ouray the American-Nettie is the chief mine. The country is composed of sedimentary

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[a] Ransome, Bull. U.S. Geol. Surv., No. 182, 1902, p. 215.

[b] Ib., p. 216.

rocks that range in age from pre-Cambrian to Cretaceous, are traversed by porphyry dykes, and contain intercalated porphyry sheets. Ores occur in fissure-veins or as replacement deposits of limestone or quartzites, the horizon of the top of the Dakota (Cretaceous) quartzite being especially affected.[a]

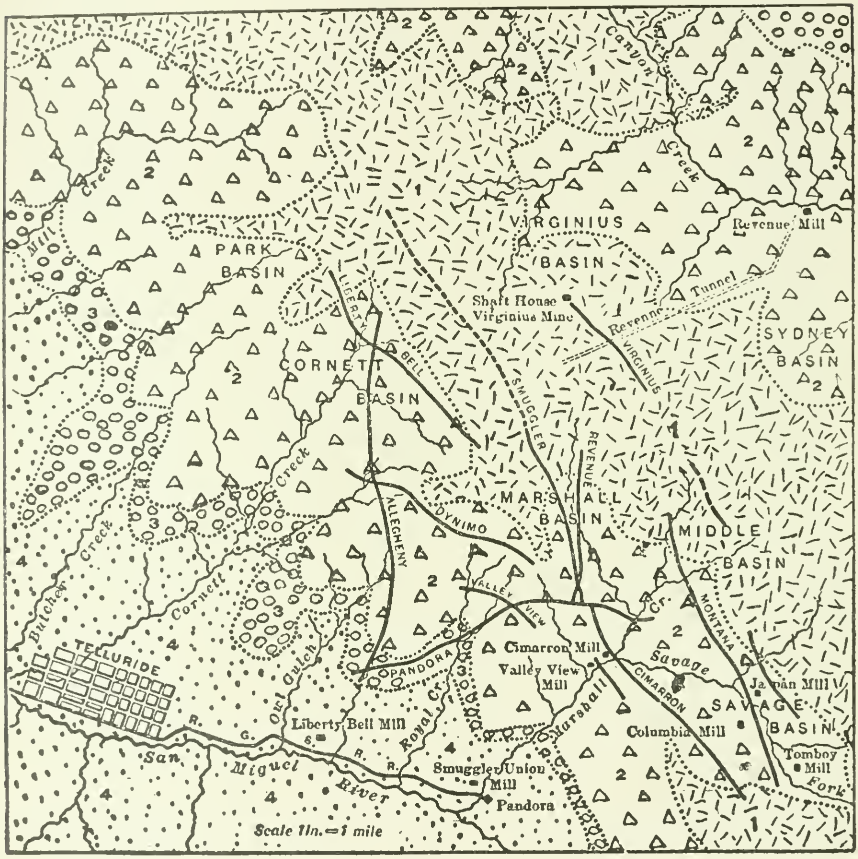

FIG. 190. GEOLOGY OF TELLURIDE AND VICINITY.

1. Rhyolite and andesite. 2. San Juan Formation—andesitic breccia. 3. San Miguel conglomerate. 4. Jurassic and Cretaceous shales and sandstones.

San Miguel County.—To the south-west of Ouray County is San Miguel County. Its chief town is Telluride, which is also the locality of the most productive mining operations. The mines near Telluride in 1905 produced more than £300,000 ($1,574,607) gold, or about 90 per cent. of the total for the county. The average value of the ore produced was £1. 19s. 3d. ($9.58). The veins are

[a] Irving, Bull. U.S. Geol. Surv., No. 260, 1905, p. 56.

THE CAMP BIRD MINE, IMOGENE BASIN, OURAY, COLORADO.

strong, well-defined bodies that, like the Camp Bird vein, traverse the San Juan tuffs and breccias. The three leading mines are the Liberty Bell, Smuggler-Union, and Tomboy. The first-named was discovered in 1876, but only the richer ores could be worked until 1891.[a]

The San Juan formation is here a bluish-grey andesitic breccia, varying in thickness from 2,000 to 3,000 feet. The veins of the district are remarkable for their strength, reaching often 5 to 6 feet in width. The Liberty Bell lode itself ranges from 3 to 8 feet, and carries well-defined and sometimes smooth and slickensided

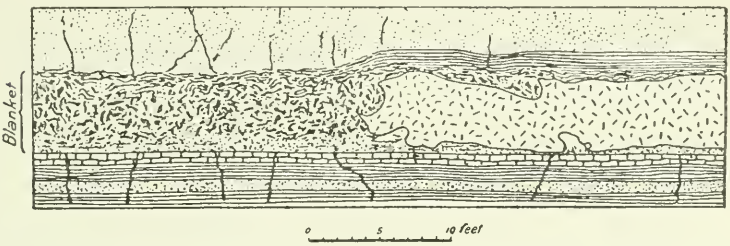

FIG. 191. DIAGRAMMATIC SECTION THROUGH ENTERPRISE BLANKET, RICO, SHOWING GYPSUM (ON RIGHT) (*Ransome*).

walls. The lode includes often large "horses" of country. Its filling is quartz together with a barren siliceous replacement of slates that are interspersed with bands of clay. The quartz layers are sometimes hard and dense. Free-gold occurs in the unaltered quartz, and is also intimately mixed with the pyrite. The lode is traversed by numerous veinlets of quartz and of calcite of secondary and contemporaneous origin. Tellurium is absent. Of the total value of the ore, two-thirds is represented by gold and one-third by silver.[b] To the end of 1897 some £5,000,000 gold had been produced from this mine. In the cases of the Smuggler and Tomboy veins it is evident that the lodes are continuous from the San Juan breccia upwards through the overlying andesite and rhyolite flows. Certain veins in the district also pass into the underlying San Miguel conglomerate, where they become somewhat more brecciated and more irregular in continuity. The lodes of the Telluride district are of unusual extension in strike, the Smuggler vein, for example, having been traced for more than two miles.

[a] Winslow, Trans. Amer. Inst. M.E., XXIX, 1899, p. 291.

[b] Purington, 18th Ann. Rep. U.S. Geol. Surv., Pt. III, 1896, p. 751; Id., U.S. Geol. Atlas, Fol. 57, 1899, p. 15.

Dolores County.—The yield from Dolores County is at the present time very small. The famous Rico district, which produced mainly silver, is now almost deserted.[a] Rico itself, however, yielded comparatively little gold, and the 1,660 ounces gold recorded as having been produced in 1905 came from isolated and outlying mines, as the Emma at Dunton, 15 miles north-west of Rico. The general range of the Enterprise ores, the richest at Rico, has been from 0·2 to 1·0 ounce gold and 100 to 200 ounces silver per ton, with lead to 10 per cent., and zinc to 15 per cent. The country of the Enterprise mine is formed by the sandstones, shales, and limestones of the Hermosa (Lower Carboniferous) formation. The total thickness of the beds is some 800 feet; the Enterprise ore-bodies occur midway between the top and bottom. The ore forms a so-called "blanket," consisting for the most part of unconsolidated breccia, resting, in the case of the Enterprise, Newman Hill, everywhere on a very thin bed ranging in thickness only to 2 inches of limestone, below which is found 5 to 6 feet of dark shales, alternating with thin lenses of limestone. The "blanket" averages 6 feet in thickness but may reach 20 feet. It is invariably overlain by a fissile black shale. It dips with the enclosing beds, and is made up of brecciated and comminuted shale in the upper portion, and of fine laminated material (pulverulent dolomite and celestite) in the lower portion that rests directly on the limestone. Wherever ore occurs it is usually as a replacement of the limestone. Ransome[b] concluded that the peculiar "blanket" bed is the remains of a once continuous bed of gypsum that formerly occupied the blanket horizon, and that has been largely removed by solution. The residue has been subsequently silicified and impregnated with ore, more particularly in the lower finer portions of the blanket. The ore is galena, blende, and rich silver sulphides. Most of the so-called contact-ore has now been worked out. The deposition of the Rico ores is probably to be considered an after-effect of later Tertiary igneous intrusions.

La Plata County.—In La Plata County the important veins fall into two divisions: (*a*) telluride-gold veins; (*b*) simple gold veins. The principal mining field is Oro Fino (California) at the head of Junction Creek on the eastern slope of the La Plata Mountains.[c] The veins lie in red calcareous clays, red sandstones,

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[a] Rickard T.A., Trans. Amer. Inst. M.E., XXVI, 1897, p. 906; Ransome, 22nd Ann. Rep. U.S. Geol. Surv., Pt. II, 1901, p. 237; Cross & Spencer, 21st Ann. Rep. U.S. Geol. Surv., Pt. II, 1900, p. 7.

[b] Loc. cit. sup., p. 278.

[c] Purington, Folio 60, U.S. Geol. Surv. Atlas, 1899, p. 13; Emmons, W. H., Bull, 260, U.S. Geol. Surv., 1905, p. 121.

and conglomerates. They are collectively known as the "Red Beds," and are of probable Permian age. They are much intruded by diorite- or monzonite-porphyries that occur both as dykes and sills. These are assumed to be of Tertiary age. The sandstones, usually red and friable, are, in the neighbourhood of the ore-bodies, highly silicified. Along certain nearly vertical planes the rocks have been fractured and fissured, and near these fissures both the sedimentary rocks and the porphyry have been impregnated with ore. The ore-deposits occur both as contact deposits and as silicified replacement bands along fissure zones near porphyry contacts. Often the ore appears to be a replacement of the porphyry and sometimes also, but less frequently, of the sedimentary beds. The gangue is quartz, kaolinite, hydrous silica, and sericite. The ore-minerals are tellurides of gold and silver (sylvanite, petzite, and probably calaverite), native gold, native mercury, amalgam, freibergite, tennantite, stephanite, pyrite, marcasite, chalcopyrite, galena, blende, realgar, magnetite, and possibly cinnabar. The principal ores are, however, the high-grade tellurides and free gold. The production of gold in 1905 was £51,647 ($251,940). The chief mines are the Neglected and the May Day.

San Juan County.—The San Juan goldfields on the southern slope of the San Juan mountains are among the richest in Colorado. Their yield has been of late more than a million dollars per annum. Their total production to 1900 was some £4,800,000 ($24,000,000). The mines extend from Silverton north-east up both sides of the Animas Valley to and beyond Animas Forks. Minor pyritous gold-quartz veins, containing small pockets of free gold, occur south-south-west of Silverton in Deer Park Creek, cutting schists and granites and sometimes the overlying San Juan tuffs.

The important lodes of Silver (Arrastra) Lake, 3½ miles south-east of Silverton, are heavily mineralised with galena, blende, and chalcopyrite, and with minor quantities of pyrite and tetrahedrite. They lie in the Burns latite division of the Silverton series, already noted as overlying the San Juan tuffs. The ore is, as a rule, low-grade, and requires concentration. It is worth from 32s. to £3 ($8.00 to $15.00) per ton. Free gold is rare, but the tenor in gold may nevertheless rise to 2 or 3 ounces per ton. About one-half the value of the output of the Silver Lake district is gold, the remainder being silver, lead, and copper.

In Sunnyside Basin and at the head of Placer Gulch, 6½ miles north-north-east of Silverton, the ores are low-grade bodies with occasional bunches of rich ore (ranging to 74 ounces per ton). The principal mine of this area, and indeed of the whole San Juan country, has been the Gold King. The Gold Prince and Sunnyside are also important producers. The Poughkeepsie Gulch veins, in the extreme north of the county, are similar to those of the Gold King and Sunnyside. They carry galena, sphalerite, and chalcopyrite, which are invariably associated with rhodonite. The ores run generally in pay-shoots within the lodes. Oxidation of the ores at the surface is unimportant at these high altitudes of from 11,000 to 12,000 feet.[a]

The veins of the two northern districts of San Juan County are, like those of Silver Lake Basin, mainly in the Burns hornblende-latite flows, but they may pass upwards into, or may occur entirely in, the overlying pyroxenic andesite flows, both rocks being members of the Silverton series.

Hinsdale County.—The gold production of Hinsdale County is small. Most of its ore-deposits are situated a few miles west of Lake City. The rocks containing the veins are rhyolitic and andesitic breccias with intrusive andesites, diabase, and latite. Gold-bearing veins are not numerous. The Golden Fleece is the most prominent. This mine produced to 1905 about £280,000 ($1,400,000) gold. The vein lies in tuffs and breccias intercalated with an andesitic flow-breccia, through which a diabase dyke is intrusive. The chief ore present is the gold-telluride, petzite.[b]

Mineral County.—In Mineral County the principal centres are Creede, Amethyst, and Teller, in the north of the county. The lodes are fissure veins in andesite flows. Their gold value is subordinate, the metals recovered being, in order of decreasing value, silver, lead, zinc, and gold. The ores at Creede contain 0·1 to 0·2 ounce gold, 1 to 3 ounces silver, 7 to 8 per cent. lead, and 4 to 6 per cent. zinc, the total average value being 36s. to 40s. ($9.00 to $10.00) per ton. The veins are strong quartz-lodes, often well banded, and carrying a comb of amethystine quartz crystals in the centre. The deeper mines are now 1,500 to 1,600 feet below the surface. A remarkable feature in Creede is the increase of the gold values in depth.[c] This is, however, characteristic of many of the San Juan lodes,[d] and arises, probably, from an impoverishment of the outcrop. Such an impoverishment is always possible

[a] Ransome, Fol. 120, U.S. Geol. Surv. Atlas, 1905, p. 33; Id., Bull. 182, U.S. Geol. Surv., 1901, p. 87.

[b] Irving, Bull. 260, U.S. Geol. Surv., 1905, p. 83.

[c] Lakes, Mines and Minerals, XXIII, 1903, p. 433.

[d] Purington, *in litt.*

when the contained gold is very fine. As an analogous example may be cited the variations in the vertical tenor of the quartz of the Waihi mine, New Zealand, where the gold is also exceedingly finely divided.

The total gold yield of Colorado between the years of 1858 to 1900 is estimated by Lindgren[a] at £51,475,500 ($251,100,000). During the present century the yield has been :—

Year.	Value, Dollars.	Value, Sterling.
1901	$27,693,500	£5,677,167
1902	28,468,700	5,836,083
1903	22,540,100	4,620,720
1904	24,463,322	5,014,981
1905	25,701,100	5,268,725
1906	23,210,629	4,758,178
1907	20,888,883	4,182,222
Grand Total to 1907.	$424,066,234	£86,833,576

UTAH.

Few veins in Utah are worked exclusively for their gold content, and the greater part of the gold yield of the State comes from copper-gold or lead-silver-gold veins. Of the former those of Tintic, Juab County, furnished in 1905 almost exactly one-half the gold yield of the State. The principal lead-silver-gold districts are Bingham and Park City. The placers of Utah have never been important, and only one, viz., at Bingham Canyon, Salt Lake County, has been extensively worked. The yield of alluvial gold from this deposit is estimated by Lindgren[b] at some £200,000 ($1,000,000). Post-Miocene propylitic gold-quartz veins do occur in Utah, but are not common ; the preponderating ore-deposits are irregular masses at contacts of sheets and dykes of porphyry with sedimentary rocks. They are, as explained above, mainly lead, copper, and silver ores with comparatively insignificant amounts of gold. Their age is believed to be Cretaceous.

Mercur.—Of purely gold deposits the most important is at Mercur, in the Oquirrh Mountains, south of Great Salt Lake, and west of Utah Lake. In this region the discovery of silver preceded that of gold. The geology of Mercur district is simple. The prevailing rock is a Lower Carboniferous limestone, through and into which quartz-porphyry is intrusive. The igneous

[a] Trans. Amer. Inst. M.E., XXXIII, 1903, p. 818.
[b] Ib., p. 836.

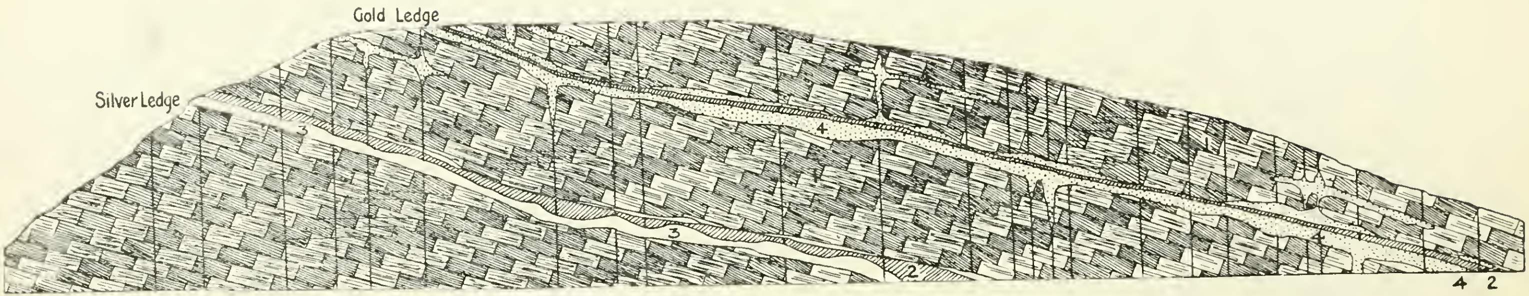

Fig. 192. Section through Gold and Silver Ledge, Mercur, Utah (*Spurr*).

1. Great Blue Limestone. 2. Altered Cherty or Shaly Limestone. 3. Chert of Silver Ledge. 4. Chert of Gold Ledge. Length of Section, 1,400 feet.

rock occurs not only as dykes and stocks, but also as thin sheets, intruded parallel to the stratification of the limestone. Beneath the quartz-porphyry sheets much of the ore-deposition has taken place.[a] All that may be said with certainty regarding the age of the intrusive rocks is that they are older than Pleistocene and younger then Carboniferous. They are, moreover, in all probability, post-Jurassic. The characteristic feature of the Mercur field is the presence, in a massive limestone, of two ore-bearing beds about 100 feet apart, the lower (the Silver Ledge) carrying silver, and the upper (the Gold Ledge) containing gold with little or no silver. Both occur at horizons near the middle of the limestone series. The Silver Ledge consisting of quartzite, or dark silicified limestone, is porous and brecciated, and in addition to silver carries a little copper and antimony, but no gold. The upper bed, or Gold Ledge, is a decomposed, sometimes bleached, sometimes red or yellow limestone and shale, with a little realgar and cinnabar in addition to gold. It was concluded by Spurr, to whom we are indebted for most of the geological information concerning the Mercur camp, that there had been two distinct and well-separated periods of mineralisation, the minerals of the Silver Ledge having been the earlier deposited.[b] In each period the minerals constituting the ore were precipitated along the lower plane of contact of a porphyry sheet with the limestone. The vein minerals of the Silver Ledge are silica, barytes, and stibnite, with copper and silver sulphides. Through the whole of the impregnated zone the limestone has been entirely replaced by silica. The characteristic minerals occurring with gold in the Gold Ledge are barytes, calcite, realgar, cinnabar, and pyrite. There are grounds for the belief that the gold was originally deposited as a telluride. At the horizon of the Gold Ledge, ore-bodies are found mainly at the intersection of certain zones of north-east—south-west, nearly vertical fissuring with the lower contact-plane of the porphyry sheet. The ore-bodies may attain a thickness of 20 feet or more, thinning away to nothing at some distance on either side of the fissure-zones. The mineralisation along the contact zone is therefore not continuous. Both sulphide and oxidised ores occur. The tenor of the ore is never very high, rarely exceeding two or three ounces per ton and averaging much less.

Tintic.—The Tintic region lies south of Mercur in Juab County. It is on the southward continuation of the Oquirrh mountains,

[a] Emmons, S. F., 16th Ann. Rep. U.S. Geol. Surv., Pt. II, 1895, p. 364.

[b] Spurr, ib., p. 367.

and is one of the oldest mining camps in Utah, having been established towards the end of 1869. Its early yield is not known with certainty, but from 1880 to 1896 the district had produced 201,967 ounces gold and 28,308,092 ounces silver.[a] As obtains further north at Mercur, the Tintic rocks are Carboniferous sedimentaries associated with intrusive igneous rocks. The Carboniferous rocks are quartzites and limestones, the ore-bodies, as a rule, occurring in the latter. These sedimentaries are bent into a simple synclinal fold along the Tintic mountains. The igneous rocks include monzonite, andesite, quartz-porphyry, rhyolite, and basalt of an age contemporaneous with those in the Oquirrh mountains. The gold deposits of the Tintic region are confined to the sedimentary rocks, and, as a rule, follow north and south fissures in the limestone. The smaller ore-bodies are generally the richer, and enrichments occur most frequently at the intersection of fissures, forming irregular shoots, pockets, pipes, and chimneys. Free gold is rarely seen, except in stopes near the surface. The average proportion of silver to gold in the ores is 400 to 1, but it varies considerably. The general tenor of the ore, reckoned from the total output to 1899, was :—

Gold	0·1356	ounces per ton.
Silver	52·4400	,, ,,
Copper	11·2000	pounds ,,
Lead	270·0000	,, ,,

The deepest workings at Tintic in 1908 had reached 2,300 feet (Mammoth mine), and at that depth showed no appreciable impoverishment.

Park City.—The deposits of the famous Park City district, south-east of Salt Lake City, are mainly argentiferous with minor quantities of copper and gold. Park City has been the most productive silver camp in Utah. The gold ores here, as at Tintic, occur in irregular masses, pockets, and shoots in metamorphic limestones adjacent to igneous intrusions. The highest gold values, however, appear to be associated with certain fissures in quartzites.[b]

Gold Hill.—In Piute County the only region of present importance is the Gold Hill, where the Annie Laurie, the principal mine, was opened up only as recently as 1900, though the veins and placers of Marysvale and Bullion Creek in the immediate neighbourhood had long been known. From 1900 to 1905 the Annie Laurie mine had produced perhaps £420,000 ($2,100,000).[c] Its

[a] Tower and Smith, G. O., 19th Ann. Rep. U.S. Geol. Surv., 1899, Pt. III, p. 615.

[b] Boutwell, Bull. U.S. Geol. Surv., No. 213, 1903, p. 38 ; Id., ib., No. 225, 1904, p. 141.

[c] Lindgren, Bull. U.S. Geol. Surv., No. 285, 1906, p. 87.

ore-deposits occur in well-defined quartz veins in a decomposed rock, probably an original dacite. Great masses of rhyolite and rhyolite-tuffs are found to the north, but contain no veins of economic importance. Dioritic dykes are known, but appear to have exercised no influence on ore-deposition. The quartz is white and friable and is often associated with calcite. The average value of the ore is 29s. to 33s. ($7.00 to $8.00) per ton. The average bullion is 250 fine in gold. Lindgren draws attention to the similarity of the Annie Laurie mine in country, ore, and structure, to the famous Waihi mine in New Zealand, and to the De Lamar mine in southern Idaho.

The total production of gold from Utah from the 'sixties to 1900 is estimated at £5,535,000 ($27,000,000). Later years have given :—

Year.	Value, Dollars.	Value, Sterling.
1901	$ 3,690,200	£756,491
1902	3,594,500	736,872
1903	3,697,400	757,967
1904	4,189,292	858,804
1905	5,140,900	1,053,884
1906	5,218,386	1,069,769
1907	4,654,930*	954,260
Grand Total to end of 1907..	$57,185,608	£11,723,047

* Estimated.

TEXAS.

The gold yield of Texas is trifling. In 1905 only 12 ounces fine gold were produced, all of which appears to have come from the Shafter mine in Presidio County, on the Mexican frontier. No placer deposits are worked.

NEW MEXICO.

The mineral belt of New Mexico stretches from north-east to south-west diagonally across the territory. It therefore lies as a broad band on both sides of the Rio Grande (Rio Bravo), but leaves that river in Sierra County, and passes, still striking south-west, into Grant County. Along this belt the mines are small and widely scattered. The fullest account given of the auriferous resources of

New Mexico is that by Lindgren and Graton.[a] The northern portion of the central mountain belt of New Mexico is composed of pre-Cambrian crystalline rocks, mainly red and grey gneisses and granites, quartz-sericite-schist, and amphibolite-schist. The last-mentioned, together with chlorite-schists, both apparently derived from basic intrusives into the original granite, carry the pre-Cambrian ore-deposits. These are found in the northern counties of Rio Arriba, Taos, and Santa Fe, and are for the most part pyritous with low tenors in gold and silver—perhaps 3 dwts. of the former and 3 ounces of the latter per ton. They are, therefore, of little economic importance. In general relations they present some analogies with the pre-Cambrian metalliferous rocks of Encampment, Wyoming, and of the Southern Appalachian States.

Post-Cretaceous ore-deposits, on the other hand, furnish the major portion of the mineral wealth of New Mexico, the thick Palæozoic and Mesozoic sediments that intervene in geological time between the pre-Cambrian and the post-Cretaceous, being generally barren. Post-Cretaceous ore-deposition took place at two well-defined and widely separated periods, one at the beginning and the other at the end of the Tertiary period. The older is directly connected with great intrusive masses of acidic porphyries and granitic rocks, and is represented by contact-metamorphic deposits, fissure veins, and siliceous replacements in limestone. The Elizabethtown (Colfax County) ore-bodies furnish an example of deposition during this period. They occur as contact-deposits on the margin of a great porphyry stock intrusive through Carboniferous and Cretaceous strata, and carry chalcopyrite and gold. Numerous small auriferous veins of later development are found cutting through the porphyry, the contact-deposits, and the adjacent Cretaceous rocks. The Ortiz and San Pedro mountains, Santa Fe County, are porphyritic laccoliths in Cretaceous and older rocks. On the southern contact line of the Ortiz laccolith with calcareous Cretaceous strata, low-grade contact-metamorphic deposits occur and contain garnet and chalcopyrite, the latter carrying a little gold. A system of narrow auriferous quartz veins is developed here, in the same fashion as at Elizabethtown. On one of these gold-quartz veins a celebrated mine, the Ortiz, was opened up. At Jarilla a porphyry laccolith has domed the Carboniferous limestones and has produced auriferous contact-deposits associated with garnet, epidote, and hæmatite. In the porphyry mass and extending out into the enclosing sedimentary rocks are gold and gold-copper veins. The granite of the Organ mountains, which lie immediately to the north of El Paso, in Texas, is traversed

[a] Bul. U.S. Geol. Surv., No. 285, 1906, p. 74.

by an east and west system of fissures, now filled with auriferous and, sometimes, argentiferous quartz. At the well-known camp of Pinos Altos, in the north of Grant County, narrow fissures carrying zinc and copper-ores occur in a limestone that has been disturbed by intrusive porphyry. In the porphyry itself, gold-copper veins occur with minor amounts of silver, lead, and zinc. It will thus be apparent that gold-quartz veins nearly always accompany the contact-deposits of New Mexico. The association is explained by Lindgren[a] on the assumption that the baser sulphides have separated out in the earlier stages of segregation and have been deposited at the boundaries of the porphyry stocks, while the gold-quartz veins cutting as they do alike through porphyry, contact-deposit, and sedimentary rock, are of a much later date. The auriferous veins of this period are, on the whole, regular, and show little or no brecciation. Their gangue filling is quartz, which often shows ribbon or comb-structure. These veins are the source of the richer placers of the territory.

Gold-pyrite fissure veins in late Tertiary andesitic lavas are known at Red River, Taos County ; Cochiti, Sandoval County ; Rosedale (in rhyolite), Socorro County ; and at Chloride, Phillipsburg, Grafton, and Hillsboro', Sierra County. Perhaps the most important veins of this type are those of the Mogollon mountains, in south-west Socorro County. These are brecciated fissure deposits of large size. Their gangue is quartz and calcite, which also have replaced much of the brecciated matter within the lodes. The valuable metals are found as finely divided gold and as argentiferous sulphides. Auriferous deposition appears to have persisted in New Mexico almost down to the present time. An interesting example is adduced by Lindgren and Graton.[b] At Ojo Caliente, Rio Arriba County, a small silver-gold vein appears to be directly connected with hot-spring tufaceous deposits that are indeed so recent as to have escaped serious modification by erosion. Fine-grained, almost chalcedonic quartz is characteristic of many of the late Tertiary veins, as also are barytes and fluorite. The vein-walls are usually brecciated, and the veins themselves have been formed very close to the present surface, thus differing materially from the older Tertiary veins, which lie in deeply dissected regions.

The output of gold from New Mexico has increased considerably of late years, mainly owing to large increase in the production of auriferous copper, lead, and zinc ores, in which the gold may generally be regarded as a by-product. Gold-mining in the territory

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[a] Loc. cit. sup., p. 84.

[b] Loc. cit. sup., p. 85.

is greatly hindered by the smallness of its mining camps and by their wide separation, entailing a consequent lack of transport facilities.

Placer-mining is an old-established industry. Alluvial gold is said to have been worked by the Indians at San Pedro, Santa Fe County, before Spanish occupation, but the amount thus recovered was probably insignificant. The gravels are certainly among the richest now known within the United States, and they are also widely distributed. Lack of water has, however, been the great factor in hindering the development of placer-mines. Dredging has been resorted to in the west of Colfax County, where the streams flowing from the Elizabethtown porphyry stock are nearly all auriferous. The Apache Canyon, Sierra County, has also furnished a considerable quantity of alluvial gold.

The total gold production of New Mexico from 1860 to 1900 inclusive is estimated by Lindgren at £3,608,000 ($17,600,000). Since the latter year the annual gold yield has been :—

Year.	Value, Dollars.	Value, Sterling.
1901	$688,400	£141,122
1902	531,000	108,855
1903	244,600	50,143
1904	381,930	78,295
1905	265,800	54,489
1906	293,019	60,069
1907	249,569*	51,161*
Grand Total to end of 1907	$20,254,318	£4,152,134

* Estimated.

MONTANA.

In its early yield of placer-gold Montana was second only to California. Its most famous placer deposits were those of Bannack and of Alder Gulch, Virginia. The latter are reported to have produced in the early 'sixties some 6,000,000 sterling ($30,000,000). After the Alder Gulch deposits the rich placers near Helena were discovered and worked.

The western part of Montana is considered by Lindgren[a] to form part of the great Idaho uplift. It is characterised by the presence of great intrusive masses of granitic and dioritic rocks of

[a] Trans. Amer. Inst. M.E., XXXIII, 1903, p. 825.

apparently later age than those of California, Oregon, and Idaho. The Montana intrusives are indeed relegated by Weed to a late Cretaceous or even an early Tertiary age. The auriferous veins of Montana show marked analogies with those of the Sierra Nevada, but there are at the same time considerable variations from the Californian type, and normal gold-quartz veins of the latter type are rare. Gold-silver veins as that of the Drumlummon, Marysville, are more common. Much of the gold product of Montana is obtained as a by-product from the smelters, and more especially from the copper-gold veins in the granitic intrusives near Butte. Lindgren regards these veins as connecting links in age between the distinctly Mesozoic gold-quartz veins of the Sierra Nevada, Oregon, and Idaho and the propylitic post-Miocene veins of Colorado. In the Little Rocky and Judith mountains towards the north-east of the State, and in other isolated groups, numerous siliceous replacements in limestone and porphyry are gold-bearing. These replacement deposits are probably to be associated with the early Tertiary phonolitic eruptions.

In the west of Montana, on the Idaho border, the Bitter-root mountains are composed mainly of a biotite-granite (quartz-monzonite), certainly of post-Carboniferous and probably of late Mesozoic age. In these intrusives two metalliferous belts are distinguished, one in Montana, and the other further to the west in Idaho. The latter have furnished rich placer deposits, of which the more important, viz., those near Florence, Dixie, Elk City, &c., have already been mentioned. The Montana occurrences have not, on the other hand, proved of great value. Lindgren[a] points out an important feature in the disposition of the veins of the Bitter-root and Clearwater area. The central granite area, whether massive or sheared, lacks veins of economic value, which are developed only close to the sedimentary and metamorphic rocks at the periphery of the granitic mass.

Marysville.—At the present time one of the most productive districts is that of Marysville, Lewis and Clark County. The rich placers of the Silver Bow basin furnished the clue to the position of the parent veins, which are situated on the edge of an irregular batholith of quartz-diorite, probably related in origin to the very much larger quartz-monzonite batholith of the Boulder region. The latter contains the great copper-silver mines of Butte, as well as those of Elkhorn and of Unionville, south of Helena. The Marysville district is 18 miles north-west of Helena. It is formed by a central batholith of quartz-diorite intrusive through sedimentary

[a] Bull. U.S. Geol. Surv., No. 213, 1903, p. 70.

rocks of the Belt group (Algonkian).[a] The sedimentary rocks are shales, sandstones, and limestones, little altered by regional metamorphism, despite their Algonkian age. The igneous rocks are of more importance, in view of the veins developed in them. With the main quartz-diorite batholith are associated micro-diorite and diorite-porphyry dykes. The veins occur either in close proximity to the igneous contacts or adjacent to the intrusive dykes. The absence of vein-fissures in the centre of the batholith is explained by slower cooling in that portion, while general shrinkage produced the radial fissures that are found near the circumference. The richest mines of the Marysville district have been the Drumlummon and the Bald Butte. The former up to the year 1903 had produced ore worth nearly £3,000,000. Its vein is parallel with the quartz-diorite contact, and is perhaps typical of those of the district. The ores occur in a fault plane with quartz-filling. The quartz is white and opaque, enclosing angular fragments of black, green, and drab slate, many of which have been completely replaced by ore. While the vein has been opened up to 1,600 feet vertically, little ore has been found below the 1,000-foot level. The uppermost 200 feet was especially productive of bonanzas or rich shoots, but below that level the grade of ore decreased rapidly with increasing depth. The ore-shoots were well defined and pitched to the right-hand as the observer looked down the dip of the vein. The shoots were separated by intermediate barren stretches. The ores are sulphide and sulph-antimonide of silver, associated with gold, the latter forming some 60 per cent. of the total value.

Veins showing similar characters occur in the Granite-Bimetallic and Cable mines of the Phillipsburgh quadrangle, Granite County. The values are mainly in enriched silver sulphides. Surface waters have leached the ore from an upper zone, 50 to 300 feet in thickness. Below the surface zone is a rich oxidised zone with large quantities of horn and native silver. Next in depth is a belt of enriched sulphides, while below the enriched sulphides lies the low-grade primary ore.

Judith Mountains.—The placer deposits of the Judith mountains, Fergus County, attracted attention about 1880. Gold and silver veins were soon afterwards opened out. In the vicinity of Maiden, the Spotted Horse and Maginnis mines have produced largely, while a few miles further south are the Gilt Edge mines. The Judith mountain ores are mainly gold, and are formed of country

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[a] Barrell, Prof. Paper U.S. Geol. Surv., No. 57, 1907; Weed, Bull. U.S. Geol. Surv., No. 213, 1903, p. 88.

impregnated with or replaced by quartz and fluorite. The ores occur: (*a*) in fissures in the great rhyolite-porphyry laccoliths of the region; (*b*) as deposits along contacts with phonolite dykes; and (*c*) in the Carboniferous limestones at the contact of an irregularly intruded mass of igneous rock, or beneath intruded sheets of rhyolite-porphyry.[a] The two first-mentioned occurrences are of

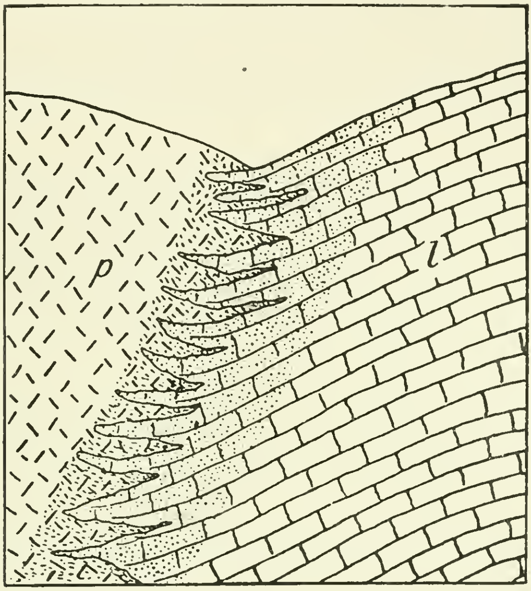

Fig. 193. Ore-deposit at contact of Porphyry (*p*) and Limestone (*l*), Maginnis Mine, Montana (*Weed*).

little economic importance, while the last has yielded all the producing mines of the district. As shown in the Spotted Horse mine the contact is very irregular locally, but maintains, nevertheless, a general dip or hade when viewed broadly. The richest ore has been found, not at the contact, but a few feet away from it and well within the limestone. Gold is most abundant in the masses of quartz and fluorite. Tellurides of gold appear to have furnished much of the free gold. Fluorite occurs usually in a finely crystalline condition intimately mixed with quartz, or else forming small angular blocks in the limestone. The contact zone is thoroughly impregnated with silica. The association of gold and fluorite is, according to Weed, fairly intimate, the higher-grade ores of the Spotted Horse mine, for example, carrying the greater quantity

[a] Weed and Pirsson, 18th Ann. Rep. U.S. Geol. Surv., 1898, Pt. III, p. 588.

of fluorite. There is thus afforded a striking contrast to the occurrence of gold and fluorite at Cripple Creek, where the latter mineral bears no relation whatever to auriferous deposition. The method of ore-deposition, as at Marysville, is by siliceous replacement of limestone. The ore-bodies are exceedingly irregular in form, occurring in pockets, chimneys, and shoots. The richest deposits, as a rule, are those directly underneath an inclined contact plane of rhyolite-porphyry and Carboniferous limestone, with the former for a hanging-wall. Similar contacts of porphyry with Cambrian or Mesozoic shales, have, however, proved unremunerative. In rare cases, auriferous deposits, apparently unconnected with porphyry, have been found.

Little Belt Mountains.—The Little Belt mountains lie south-west of the Judith mountains and on the boundary of Fergus and Meagher counties. The principal mining camp is Neihart. The ores are almost entirely lead-silver, but occasionally carry small quantities of gold. The veins are in gneisses and schists of supposed Archæan age.[a]

Elkhorn.—The silver-lead veins of the Elkhorn district, Jefferson County, contain also small quantities of gold. Surface ores yielding as much as 1,447 ounces of silver carried, however, only 8 dwts. gold. The present ratio of silver to gold is fairly constant in the lower levels and may be taken at 1,000 to 1.[b] The ore-deposits lie in a massive dolomitic limestone near a gabbro-diorite intrusion, which, while it has exercised no apparent influence on ore-deposition, is nevertheless believed to have a genetic connection with the ore-body.

The total production of gold from Montana to 1900 inclusive is estimated at £41,717,500 ($203,500,000). Later yields are :—

Year.	Value, Dollars.	Value, Sterling.
1901	$4,744,100	£972,540
1902	4,373,600	896,588
1903	4,411,900	904,439
1904	4,267,062	874,748
1905	4,889,300	1,002,306
1906	4,469,014	916,148
1907	4,206,345	862,300
Grand Total to end of 1907..	$234,861,321	£48,146,569

[a] Weed, 20th Ann. Rep. U.S. Geol. Surv., Pt. II, 1900, p. 413.
[b] Idem, 22nd Ann. Rep. U.S. Geol. Surv., 1901, Pt. III, p. 475.

WYOMING.

Compared with the adjacent States to the west and to the south, and especially with Colorado, the goldfields of Wyoming are insignificant. This disparity in richness is largely due to dissimilarity of geological structure. The greater portion of the mountain mass of Wyoming is composed of pre-Cambrian granites and schists that have never been covered or even intruded by those Cretaceous and Tertiary igneous rocks to which Colorado, Nevada, and Idaho owe their extensive mineralisation. The Wyoming auriferous veins are entirely in pre-Cambrian rocks, and in this respect are comparable with the gold-quartz veins of eastern rather than of western North America.

Simple gold-quartz veins are found in the Atlantic City and South Pass districts in the southern part of Fremont County. This area forms the southern end of the Wind river range, which may be regarded as the great continental divide of the United States. Its western drainage is taken by the Snake river to the Pacific, its southern drainage by way of the Green river to the Gulf of California, while its eastern rainfall finds its way by means of the Bighorn and North Platte rivers eventually to the Gulf of Mexico. The Fremont veins are in pre-Cambrian schists. Owing to their great isolation (125 miles from a railroad), little work has been done on them and little is known of the geology of the district.[a]

Copper-gold veins occur in Carbon and Albany counties near the Colorado border. The principal district is the Encampment, described by Spencer.[b] The chief mines (Rambler and Haggarty) are working on impregnated brecciated zones in pre-Cambrian quartzite. The sulphides present are chalcopyrite, pyrite, and chalcocite, the last arising from secondary enrichment. The proportion of gold is small.

Placer gold in small quantities has been found derivative from veins of both the foregoing classes. It also occurs in the Snake river, which runs through the western part of Idaho. On the Snake river the Davis diggings at the mouth of the Grand Canyon of the Snake are the most noteworthy. The Snake river gold, as in Idaho and in Oregon, is exceedingly fine. No less than 4,000 to 4,800 " colours " are required to make up one grain weight of gold (1,000 to 1,200 to one cent).[c] The method of recovery of the gold of the Snake river has already been indicated. In the north-east of Wyoming, near the South Dakota border, placer gold, believed to

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[a] Lindgren, Min. Res. U.S., 1905, p. 338 ; Id., Trans. A.I.M.E., XXIII, 1903, p. 839.

[b] Prof. Papers, U.S. Geol. Surv., XXV, 1904, p. 50.

[c] Schultz, Bull. U.S. Geol. Surv., No. 315, 1907, p. 77.

be derived from Cambrian conglomerates resembling those of the Black Hills, has been washed.

The yield of gold from Wyoming to 1900 has been estimated at £205,000 ($1,000,000). Since then there has been obtained :—

Year.	Value, Dollars.	Value, Sterling.
1901	$12,700	£2,603
1902	38,800	7,954
1903	3,600	738
1904	17,305	3,548
1905	23,700	4,858
1906	6,521	1,337
1907	4,860*	1,000*
Grand Total to 1907.	$1,107,486	£227,038

* Estimated.

SOUTH DAKOTA.

Gold mines in South Dakota are restricted not merely to the Black Hills, which cross the south-west frontier of the State into Wyoming, but also to an area, within the Black Hills, of less than 100 square miles, lying in the immediate vicinity of Deadwood City. The attention of miners was directed to these deposits in the usual way, viz., by the discovery of placer-gold. The gravels of Whitewood and Deadwood gulches were first washed for gold towards the end of 1875. In the following year the now famous Homestake lodes were traced on the surface, and by the end of 1877 the principal Homestake companies—the Homestake, Father de Smet, Highland, and Deadwood Terra—had been established. These have, until quite recently, been uniformly successful. A fire occurred in the mine in March, 1907, and necessitated its flooding, with a consequent cessation of activity for some three months. The mine operations were also adversely affected in 1907 by labour troubles. As early as 1880 no less than 740 stamps had been installed to crush the ores of the Homestake belt. In 1900 the annual amount of ore crushed was some 900,000 tons. The average mining and milling costs were then a little more than 8s. 4d. ($2.00) per ton, of which milling charges amounted to 3s. 4d. ($0.80) per ton. The Homestake Company alone, for a complete period of 10 years, from June 1st, 1881, to June 1st, 1900, had crushed 5,685,771 tons ore for a yield of £6,288,197 ($30,674,132), and had paid in dividends £1,777,094 ($8,668,750). Prior to 1881, about £120,000 ($600,000) had already been distributed among shareholders. The total product of the Homestake belt to June, 1900, appears to have been about £12,270,648 ($59,856,822), and the total dividends from this yield £2,351,913 ($11,472,750).[a]

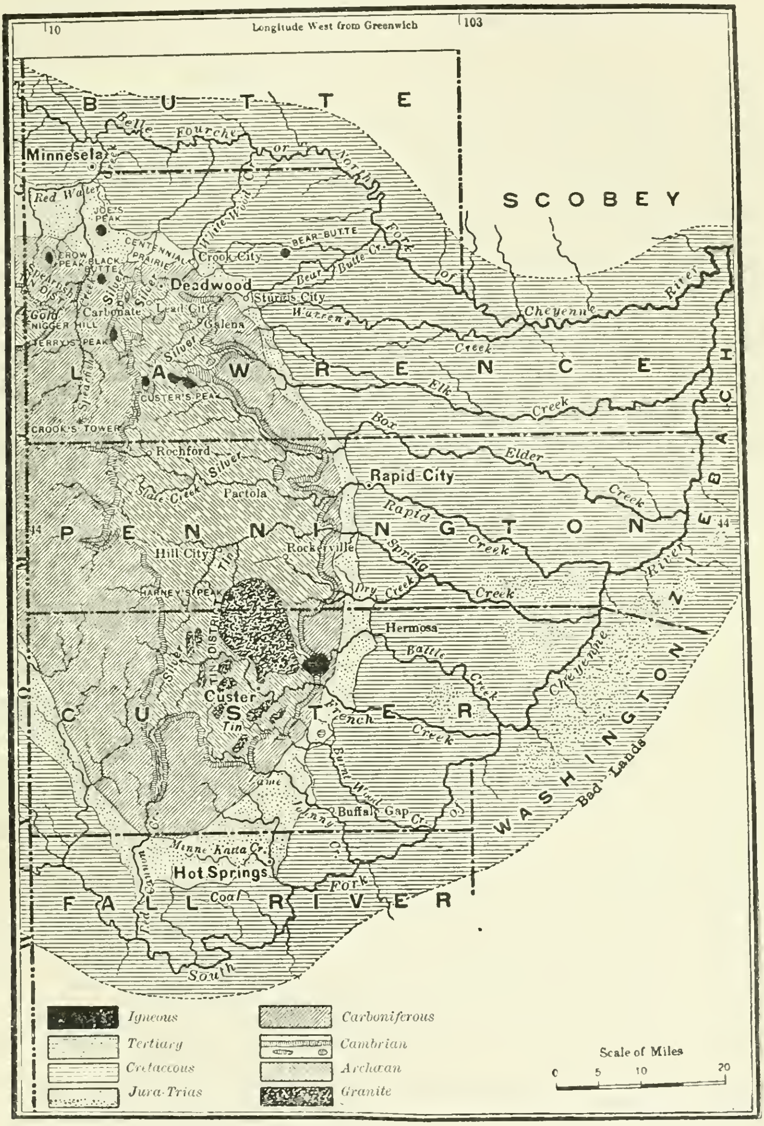

Fig. 194. Geological Map of the Southern Black Hills, South Dakota (*Newton*).

The Black Hills rise like a long island above the level of the plains. They form a typical geological dome with a central core of metamorphic crystalline rocks. About the core are grouped later

[a] Emmons (S. F.) and Jaggar, Prof. Papers U.S. Geol. Surv., No. 26, 1904.

sedimentary strata, disposed in plan in rudely concentric rings, all the beds dipping away from the central dome of elevation. In the northern hills four groups of rocks may readily be distinguished. The lowest is the central core of Algonkian metamorphic schists, for the most part of sedimentary origin. They are crystalline mica-schists, quartz-schists, mica-slates, or phyllites, with which are associated graphitic, garnetiferous, and chloritic slates and quartzites. Metamorphosed igneous rocks are represented by amphibolites that probably occurred originally as irregular dykes in the Algonkian rocks. In the southern portion of the Black Hills, the place of the amphibolite is largely taken by a granite, which is occasionally tin-bearing.

Above the Algonkian rocks are those of the Deadwood (Middle Cambrian) system. Their basal member is almost invariably a conglomerate. Succeeding members are alternating quartzites, limestones, and shales, the whole having a total thickness of some 400 feet. Overlying the Cambrian rocks is a buff-coloured Ordovician limestone, which, in its turn, is succeeded by the Carboniferous limestones of the Pahasapa and Englewood series. Later Mesozoic and Cainozoic rocks occur in the region, but need not now be considered, auriferous deposits occurring only in the Algonkian, Cambrian, and Carboniferous rocks.

Numerous porphyry dykes, differing widely in type, are intrusive through the sedimentary rocks. These volcanic rocks have been divided by Irving [a] into grorudite (a highly alkaline rock containing orthoclase, quartz, aegerine-augite, and aegerine), phonolite, rhyolite-porphyry and dacite, andesite-porphyry, diorite-porphyry, and diorite, together with more basic (lamprophyre) dyke rocks. The evidence available points to an Eocene age for the majority of these eruptives.

The Homestake belt of mines in the Algonkian schists extends from the town of Lead and from Gold Run Gulch north-westward to Deadwood and Sawpit Gulches. The three principal mines on this belt are the Homestake, Clover Leaf, and Columbus. The ores of the Homestake belt in the metamorphic schists are ill-defined masses of rock sufficiently impregnated with gold to pay the expenses of working. The gold is exceedingly fine and can rarely be detected, even with a hand-lens. Arsenopyrite and pyrite are generally present, but carry no more gold than quartz, the ordinary and most abundant matrix, which occurs mainly in lenticular masses. Calcite and dolomite are also abundant. Silicification and ore-deposition appear to have taken place along two converging zones of crushing, one striking N. 10° W. and the

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[a] Ann. New York Acad. Sci., XII, No. 9, p. 244.

other N. 30° W. Along the same channels a comparatively recent mineralization, yielding pyrite and gold, has taken place at the period of or subsequent to the intrusion of the presumably Tertiary rhyolite-porphyry. Secondary surface enrichment in the Homestake belt has been a factor of little importance, since the outcrop ores

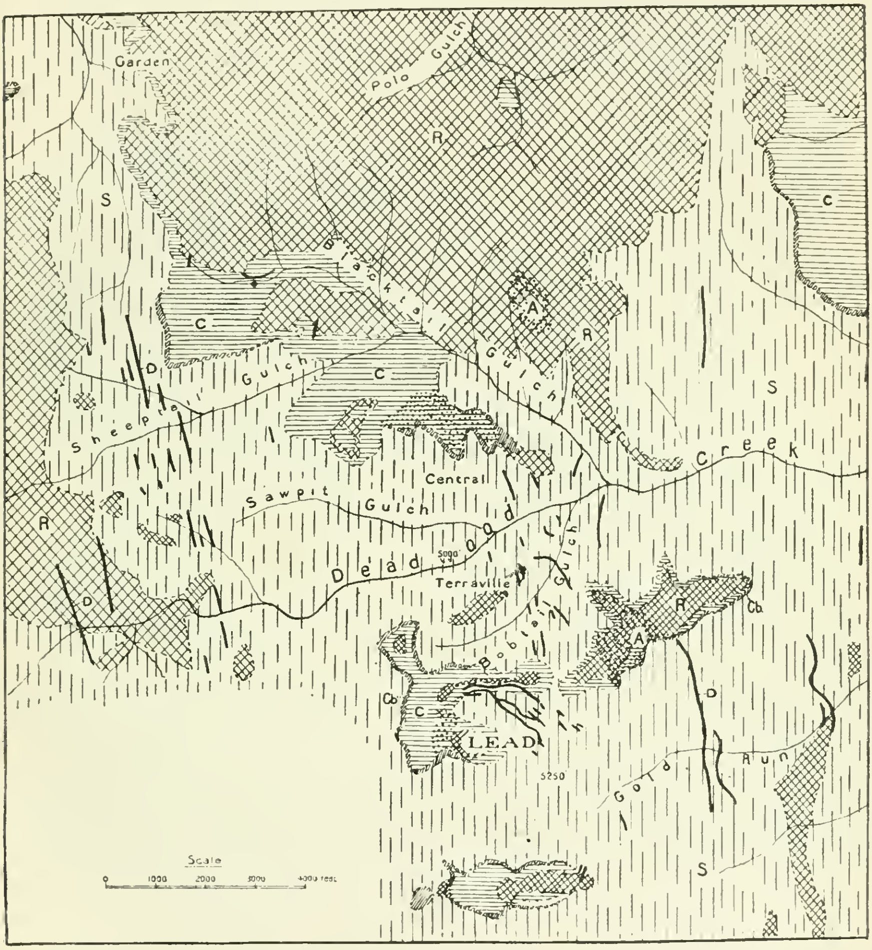


FIG. 195. GEOLOGICAL MAP OF NEIGHBOURHOOD OF LEAD CITY, SOUTH DAKOTA (*Irving*).
S. Algonkian schists. *Cb.* Basal Cambrian conglomerate. *C.* Cambrian. *R.* Eruptive rocks (chiefly rhyolite). *D.* Dykes. *A.* Areas underlain by gold-producing basal Cambrian conglomerate.

are said to have assayed no more than £3. 3s. 8d. ($16.00) per ton. In depth the general tenor of the ore is perhaps 23s. ($5.50) per ton. In the Clover Leaf mine the gold is always associated with galena, and sometimes occurs there as small nugget-like masses, ¼-inch in diameter, and completely enclosed within galena. The smaller masses of gold frequently show crystal faces.

The auriferous deposits of the Cambrian rocks of the Black Hills have of late years grown considerably in importance. They are subdivided by Emmons[a] into:—

(*a*) Gold-bearing conglomerates.
(*b*) Refractory siliceous ores.
(*c*) Pyritous ores.

The auriferous conglomerate lies at the base of the Cambrian and on the upturned edges of the Archæan schists. It varies in

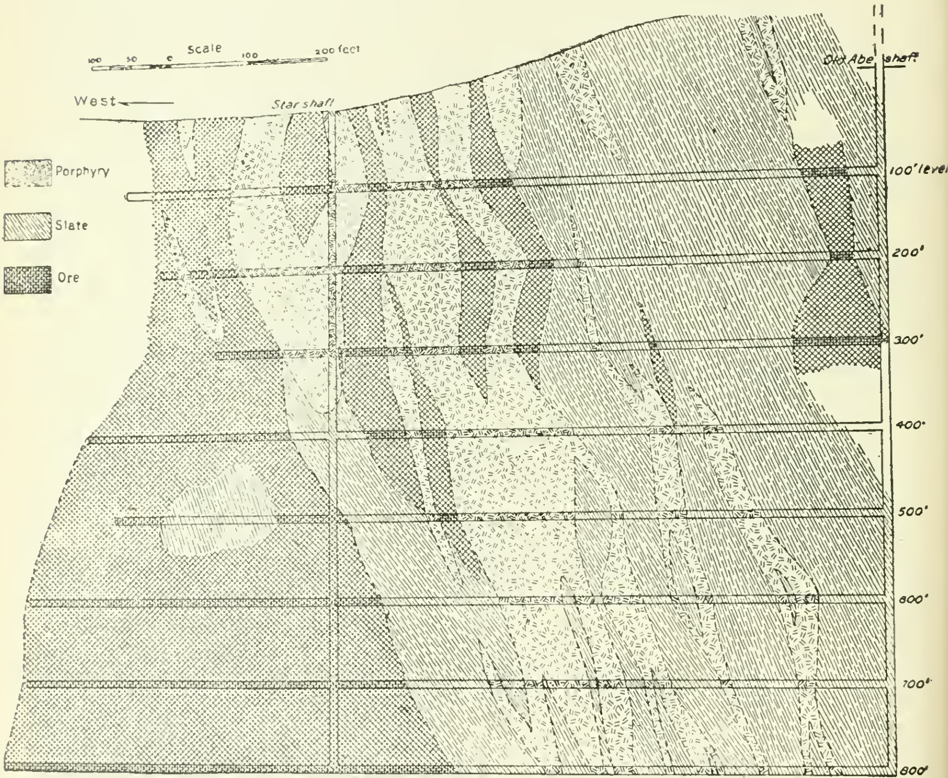


FIG. 196. STAR-OLD ABE SECTION, HOMESTAKE MINE (*Emmons*).

thickness from a few inches to 30 feet, with an average of perhaps 3 to 4 feet. It passes upward into a hard dense quartzite of the same character as that which forms the interstitial matter between the pebbles of the conglomerates. The conglomerate pebbles are well-rounded and water-worn fragments of Algonkian quartz or quartzite with a few schist pebbles intermingled. Their average size is from 1½ to 3 inches in diameter, though boulders a foot thick may be

[a] Loc. cit., p. 98.

encountered. The auriferous portions of the conglomerate are easily recognised by the invariable association of pyrite with the gold, or by the ferruginous cement derived from the oxidation of the pyrite. Barren conglomerate is cemented by quartzite or by calcite free from pyrite. Emmons concludes, from its water-worn character and from its concentration near bed-rock, that some of the gold is detrital in origin, and that this portion was derived from the erosion of the outcrops of the ore-bodies of the neighbouring Homestake belt, along the strike of which outliers of the rich conglomerate lie; and further, that while some of the gold is detrital, the increase from a low tenor of, say, 4s. ($1.00) per ton to the higher

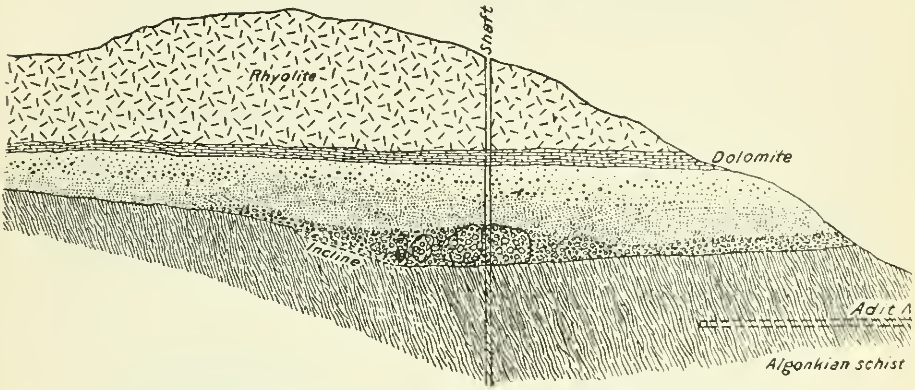


Fig. 197. Section through Hawkeye-Pluma Mine, showing Gold-bearing Conglomerate (*Emmons*).

average of 40s. ($10.00) per ton, is nevertheless due to local secondary enrichment. The enriching gold is considered to have been introduced with the pyrite, which is certainly subsequent in age to the deposition of the conglomerate along the ancient shores of the Homestake area. That this is the case is shown by the pyrite occupying fissures and cavities in the pebbles. The argument for secondary enrichment is strengthened by the occurrence of films of gold in the laminations of the schist and from 3 to 10 feet below the base of the conglomerate. At the Hawkeye-Pluma ore enrichment appears to have taken place from above through fissures in the sandy roof. According to Devereux, however, the gold of the Cambrian conglomerates is to be considered entirely detrital.[a]

The richest conglomerate area worked lay between Bobtail and Deadwood Gulches, and was worth in places £10 ($50.00)

[a] Trans. Amer. Inst. M.E., X, 1889, p. 465.

per ton. Small water-worn nuggets weighing nearly 3 dwts. have been obtained in the matrix.[a]

A third and increasingly important source of gold in the Black Hills is the refractory siliceous ore of the Cambrian rocks. These ores are widely distributed over a broad irregular belt extending from Yellow Creek on the south-east to Squaw Creek on the north-west. The ore is a hard, brittle rock, made up mainly of secondary

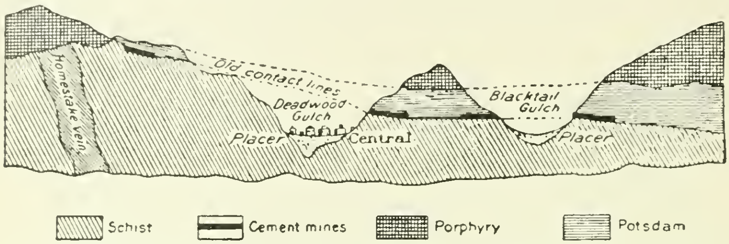
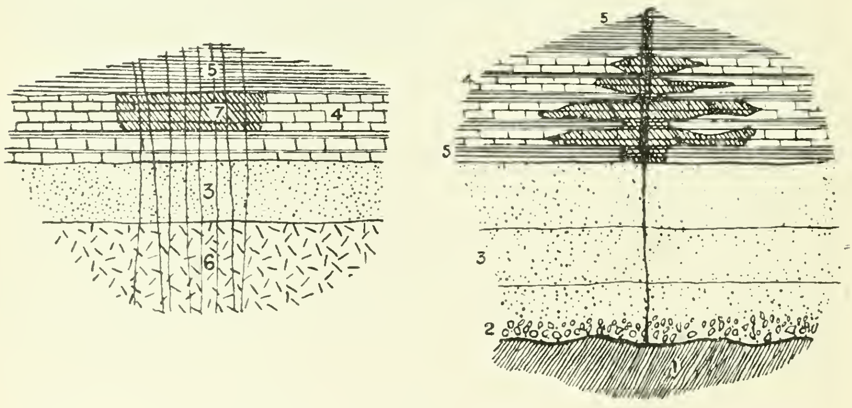


FIG. 198. GEOLOGICAL SECTION FROM HOMESTAKE MINE EASTWARD (*Devereux*).

silica, and carrying, when fresh, pyrite, fluorite, and other accessory minerals. It occurs as flat, more or less banded masses which have a channel-like form, and are parallel or nearly parallel to the bedding planes of the gently-inclined fine-grained dolomitic limestones in which they are found. The "shoots," as they are termed,



FIGS. 199 AND 200. SECTIONS SHOWING SILICEOUS ORE-SHOOTS IN DOLOMITE, BLACK HILLS (*Irving*).
1. Algonkian schists. 2. Conglomerate. 3. Hard quartzite. 4. Dolomite. 5. Slate (impervious). 6. Porphyry. 7. Ore-shoot.

follow in horizontal extension almost vertical fissures ("verticals"). In wide ore-bodies the bottom of the ore-body may drop along fractures far below the base of the dolomitic belt in which the mass of the ore lies. In a few cases it is possible to trace the "verticals" into the Algonkian schists below. There are

[a] Loc. cit., p. 469.

apparently two auriferous horizons: (*a*) the "lower contact," 15 to 25 feet above the Algonkian schists and therefore immediately over the basal quartzite or conglomerate; and (*b*) the "upper contact," 18 to 30 feet below the *Scolithus*, or "worm-eaten," sandstone, the uppermost bed of the Cambrian. The width of the "shoots" varies from a few inches to 300 feet, while they have an average thickness of perhaps six feet. Their extension along the vertical fissure may reach three-fourths of a mile. The ore is high in grade. In the main or Bald Mountain area it is £3. 11s. ($17.00) per ton, while in the Lead and Yellow Creek districts it may reach £9. 4s. 6d. ($45.00) per ton. A genetic relation between the eruptive porphyries and ore-deposition has been traced by Smith,[a] but the relation is denied by Irving.[b]

Low-grade pyritous ores in limestones have also been mined in the Black Hills, but have not so far proved of great value. They show a great analogy with the refractory siliceous ore, from which they differ only in that the dolomitic country has been replaced by pyrite instead of silica.

The Carboniferous limestones of the Black Hills, like the underlying Cambrian limestones, carry gold and silver ores of the refractory siliceous type. These occur chiefly in the vicinity of Ragged Top Mountain; they were not discovered until 1896. The ore is largely a siliceous replacement of a brecciated limestone. Tellurides are present, as shown by analysis, but have not certainly been detected in hand specimens.[c]

The total gold production of South Dakota is shown in the following table:—

Year.	Value, Dollars.	Value, Sterling.
1900	$90,000,000	£18,450,000
1901	6,479,500	1,328,297
1902	6,965,400	1,427,907
1903	6,826,700	1,399,473
1904	7,363,977	1,509,615
1905	6,913,900	1,417,350
1906	6,841,469	1,392,501
1907	4,085,446*	837,516
Grand Total to end of 1907.	$135,476,392	£27,762,659

* Estimated; Prelim. Rep. Dir. U.S. Mint, Jan., 1908.

[a] Smith, F. C., Trans. Amer. Inst. M.E., XXVII, 1897, p. 420.

[b] Loc. cit., p. 116.

[c] Loc. cit., p. 418.

MINNESOTA.

The auriferous region of the Rainy Lake in Canada extends southward across the international boundary into Minnesota. The geology of the Minnesota occurrences is similar to that of the Ontario region already described. The oldest rocks are Laurentian granitoid gneisses and granites. These are succeeded by Huronian rocks, separable into upper (Keewatin) and lower (Coutchiching) members. All are intruded by diabase dykes of possible Keeweenawan age. The auriferous quartz veins, as in Ontario, lie for the most part within Keewatin "greenstones" or "green schists," which represent ancient lavas and ash-beds. Associated with the "greenstones" of the Keewatin series are conglomerates, slates, sericite-schists, agglomerates, and grauwackes.

Auriferous veins were not worked in the State until 1893, when the Little American mine, on an island in Rainy Lake, was discovered. A small mill was erected and crushed about 500 tons for a yield of £950 ($4,635). The available ore was then exhausted and the mine was closed down. In addition to gold-quartz veins, impregnated bands of country, carrying gold, have been met with, as at the Lyle mine, near Rainy Lake City.[a]

MAINE.

Various cupriferous lodes have from time to time been reported to contain gold in small quantities. At Baileyville, in the south-east of the State and near the New Brunswick border, gold-quartz veins occur in pyritous mica-schist. These are apparently of no present economic value.[b]

NEW HAMPSHIRE.

Schistose rocks, similar to those forming the bed-rock of the Chaudiere goldfields in Quebec, occur along the Connecticut river in the north of New Hampshire. These schists, as well as the talcose schists of the Green mountains in Vermont, are probably of Huronian age.[c] They contain small auriferous veins. The Dodge vein, at Lyman, near the Lower Ammonoosuc river, is the most important. It is 16 feet wide, with well-defined ore-shoots. Its gangue is quartz, slate fragments, and ankerite. Free gold occurs with galena and barren pyrite. The gold is 917 fine.

[a] Winchell and Grant, Geol. Surv. Minnesota, IV, 1896–1898, p. 192.

[b] Holmes and Hitchcock, 2nd Ann. Rep. Geol. Surv., Maine, 1862, p. 423.

[c] Becker, 16th Ann. Rep. U.S. Geol. Surv., Part III, 1895, p. 331.

The value of the ore varies between 12s. 6d. and 79s. ($3.00 and $19.00) per ton. The vein is said to have produced £10,000 ($50,000) to the end of 1877.[a]

VERMONT.

Gold has been found along a belt some 20 miles in width lying to the eastward of the Green mountains. The rocks of the belt are talcose (sericitic ?) schists and slates with mica-gneiss. The Long Ditton auriferous belt near the head of the St. Francis river in Quebec is apparently the north-easterly continuation of the belt. The age of the Vermont rocks, is therefore, probably pre-Cambrian. With the schistose rocks are found steatite and serpentine, representing basic igneous rocks intrusive through the schists. The gold deposits are possibly in intimate genetic connection with these basic rocks.[b] The more important auriferous occurrences are those which were found in 1853 in the vicinity of Plymouth and Bridgewater, Windsor County. Small pockets of gold have occasionally been met with in the quartz veins of the district, but the yield has always been too small to warrant the establishment of a gold-mining industry. A small placer deposit near Plymouth is said to have produced between 1855 and 1861 from £1,800 to £2,600 ($9,000 to $13,000) gold.[c] Even this amount failed, in all probability, to cover the high working expenses due to extravagance and inexperience.

NEW YORK.

Gold has been recorded from quartz veins in mica-schist at Rhinebeck and Wassaic, near the Hudson river, Dutchess County; also from quartz from the north end of Manhattan Island. Assays of the latter quartz gave returns of 16s. 8d. ($4.00) per ton.[d]

MARYLAND..

The auriferous occurrences of Maryland lie immediately to the north-east of the Potomac river in the picturesque region of the Great Falls, 16 miles from Washington. They are small pockets of free gold in veinlets in Algonkian mica-schist. The total breadth of the schist belt is here about 50 miles, but the gold-quartz veins are restricted to a band 7 to 8 miles wide. They lie along a well-marked zone of fissuring and are directly on the strike of a diabase dyke traceable far to the south in Virginia.

[a] Hitchcock, "Geology of New Hampshire," Pt. V, 1878, p. 7.
[b] Smith, G. O., Bull. U.S. Geol. Surv., No. 255, 1904, p. 88.
[c] Hager, Vermont Geol. Surv., II, 1861, p. 844.
[d] Becker, loc. cit. sup.

The gold is found in pure, often drusy, white quartz, free from pyrite; associated with pyrite; and in the pyrite itself. It is also found impregnating the schists adjacent to the veins. Alluvial gold derived from the local veins has formed the greater part of a total Maryland yield estimated at about £9,200 ($46,068). From the Montgomery mine, gold valued at £1,600 ($8,000) was obtained prior to 1890. Most of the gold recovered was coarse, containing nuggets weighing 3 and 4 ounces.[a]

In December, 1904, the Maryland mine, which was working from a shaft 180 feet deep, crushed 504 tons for a yield of £1,054 ($5,144).[b] The total quantity of gold ore treated in Maryland in 1905 was only 2,698 tons, containing an average value of 23s. ($5.51) per ton.

VIRGINIA.

The Great Falls schist belt is continued south-west across the Rappahannock through Spotsylvania, Orange, Louisa, and Fluvanna counties to the James river, and across that river into Buckingham County. The characters of country and veins are those of the Potomac area. The total yield of Virginia to 1900 is estimated at £656,706 ($3,203,443). The greater part of this appears to have been obtained before the Civil War. According to Whitney[c] the Marshall mine on the Rappahannock river had before 1854 produced about £60,000 ($300,000) gold. At the present time one of the few profitable gold mines of the Appalachian States appears to be the Goldbank, six miles north of Virgilina.[d]

SOUTHERN APPALACHIAN STATES.

For the better consideration of the auriferous occurrences of the Southern Appalachian belts, five political divisions—North Carolina, South Carolina, Georgia, Tennessee, and Alabama—may be conveniently grouped and regarded as a single area. The already-mentioned scattered gold mines of Virginia and Maryland are to be considered as merely the northern prolongation of the most easterly southern auriferous zone of the Southern Appalachian region.

Nebulous rumours of gold in the interior reached the ears of the earliest of the Spanish adventurers on the North American

[a] Emmons, S. F., Trans. Amer. Inst. M.E., XVIII, 1890, p. 391.

[b] Weed, Bull. U.S. Geol. Surv., No. 260, p. 129.

[c] "Metallic Wealth of the United States," 1854, p. 125.

[d] Judd, Eng. Min. Jour., Feb. 16, 1907; Nitze and Wilkens, Bull. N.C. Geol. Surv., X, 1897, p. 71.

main. In 1513, Ponce de Leon, seeking in Florida the elusive fountain of eternal youth, heard them, but it was only some 14 years later that they took definite shape. Narvaez then learned from the Indians that the gold in their possession came from a region called *Appalache*, far in the interior. Fugitive references to gold are made by subsequent explorers, but it was near the end of the eighteenth century before statements of actual occurrences in clearly specified localities were made. In 1782 a fragment of quartz four pounds in weight and containing 17 dwts. gold was found in the Rappahannock river in Virginia. In the first years of the nineteenth century large nuggets of gold, one of which weighed 28 pounds, were obtained near the present Reed mine, Cabarrus County, North Carolina. Gold-washing appears to have first been practised in this State about 1804. By 1827 there had been recovered some £22,500 ($110,000) alluvial gold. Two years earlier the first gold-quartz veins of the State were worked in Montgomery County. Both in South Carolina and in Georgia the first extensive gold discoveries were made about 1829. In the former State the famous Brewer mine was being worked in 1830 or 1831. The Georgian discoveries caused general excitement, and in 1830 a miniature rush to the placer deposits of Habersham County took place. At one time no less than 6,000 to 7,000 men were busily engaged in washing gravels. The excitement engendered by the Georgian discoveries led to vigorous prospecting in the neighbouring States. As a direct result, many auriferous veins were located in Virginia; and the Cherokee Indian reserves in Georgia and Alabama, known to be gold-bearing, but up to then closed for mining, were thrown open to prospectors. Prior to the opening, in 1849, of the great goldfields of California and the west, the mines of Virginia, the Carolinas, Georgia, and Alabama, were vigorously worked, and indeed supplied most of the gold coinage of the United States. In the 'fifties they declined considerably, while the long cessation of industrial operations during the Civil War dealt a blow from which they have not even yet recovered. The following table shows the gold production of the various Appalachian States from 1901 to 1906 inclusive:—

State.	Value, Dollars.	Value, Sterling.
Maryland	$20,200	£4,141
Virginia	45,532	9,334
North Carolina ..	546,631	112,059
South Carolina ..	565,159	115,858
Georgia	509,150	104,376
Alabama	105,721	21,672
Tennessee	13,238	2,714

Details of the total yields of the separate States are not accessible. Combined yields of the various Appalachian States are :—

Year.	Value, Dollars.	Value, Sterling.
1799 to 1900	$47.000,000	£9,635,000
1901	235.100	48,195
1902	318,500	65,293
1903	252,400	51,742
1904	382,400	78,392
1905	380,500	78,003
1906	236,731	48,530
1907	215,275	44,131
Grand total to end of 1907..	$49,020,906	£10,049,286

Following Becker,[a] the Southern Appalachian gold regions may be conveniently divided into three main belts : (*a*) the Georgia belt extending from near Montgomery, Ala., in a north-easterly direction by way of Dahlonega through North Georgia, and so into North Carolina ; (*b*) the South Mountain belt in North Carolina ; and (*c*) the Carolina belt, the most easterly and, like the first, parallel in strike to the Appalachian trend. It stretches from South Carolina north-east by Charlotte into North Carolina. The Virginian and Maryland occurrences already described are on the strike of the last-named belt.

The Georgia belt runs north-east from near Montgomery in eastern Alabama through northern Georgia as far as the North Carolina boundary. The direction of the belt and of the schistosity of its rocks is therefore parallel with that of the axes of Appalachian folding. The rocks of this belt are Archæan micaceous and hornblendic gneisses and schists, representing possibly sheared granitic and dioritic rocks. Diabase dykes are almost unknown, their place being apparently taken by granitic intrusions of probable Algonkian age. The Archæan schists are bounded to the north-west by the Ocoee formation (Palæozoic or Algonkian). The majority of the veins of the belt, as indeed of the Appalachian region generally, conform closely to the strike and dip of the enclosing rocks. Occasionally, however, while remaining parallel in strike they may cut across the dip at low angles. The ore-deposits are generally contained as numerous narrow and discontinuous lenses in zones of fracture and fissuring. The better-known mines on the belt are all in northern Georgia, and more particularly in the vicinity of Canton, Auraria, and Dahlonega. The Franklin veins, 14 miles

[a] 16th Ann. Rep. U.S. Geol. Surv., Pt. III, 1895, p. 252.

north-west of Canton, lie in gneissoid mica-schists. The wall rocks are undulating, and corrugated quartz veins that recall the "barrel-quartz" of Nova Scotia, have been produced. The ore is low-grade, being worth about 25s. ($6.00) per ton. Half the gold is free milling, clean concentrated sulphides carrying somewhat less than £12 ($56.00) in gold. Numerous gold mines are found near Dahlonega and Auraria, where the deposits lie nearly all on contacts either of the prevailing mica-schist and amphibolite or of mica-schist and granite. At no place are the veins far from granitic intrusions. The dominant quartz-mica-schist is regarded by Lindgren[a] as an altered sedimentary rock, while the amphibolite is a highly metamorphosed original diabase or diorite. The country generally has been greatly eroded, perhaps to the extent of 15,000 to 20,000 feet, since the period (Algonkian) of vein-deposition. The outcrops now showing represent, therefore, the roots of the original fissures. Lindgren compares the Dahlonega occurrences with those of California and of Victoria, Australia, especially in their association with and possible dependence on granitic intrusions, but the evidence here is by no means so clear as in the two richer regions. Indeed, some granitic intrusions are certainly later than the period of vein-deposition, as is shown in the case of the faulting of quartz veins by a pegmatite dyke at the Thompson mine near Nacoochee, Ga. In the present case, however, it is considered more probable, when the general relations of the whole series are considered, that the amphibolitic schists were originally auriferous, rather in respect of gold-quartz veins than in disseminated gold, and that, having reached by simple loading and by flexure considerable depths, the distribution of their gold was modified by the action of heated solutions. The granitic intrusions are therefore to be looked upon rather as evidence of the heat prevailing and of the stress to which the region has been subjected than as actual carriers of gold. Their heat must certainly have assisted in the redistribution of the metalliferous content. A rare association of gold and garnet is reported from the Lockhart and other mines. Assays of clean garnet from the former mine have shown a value of nearly £2. 15s. ($10.74). Garnets showing free gold have also been obtained.[b] It is not difficult, from the general principles of metasomatic replacement, to construe this association to denote a deposition of gold *in situ* prior to the formation of the garnet, followed by contact-metamorphism arising from the granitic intrusion.

The Lockhart mine is typical of the Dahlonega occurrences. It has been worked successfully, but on a small scale, for many

[a] Bull. U.S. Geol. Surv., No. 293, 1906, p. 120.

[b] Becker, loc. cit. sup., p. 297.

years. The veins lie in mica-schist underlain by amphibolite. The ore occurs in shoots or lenticular masses of quartz in the mica-schist, but very close to the amphibolite contact. The vein is some 7 feet wide, consisting of lenticular masses of quartz intercalated within the lode with streaks and bands of a gangue consisting principally of garnet, dark-green mica, and hornblende. Sulphides (pyrite, chalcopyrite, pyrrhotite, and galena) occur with the quartz. Most of the gold is said to occur native in the reddish-brown garnets.[a] The garnet-mica-hornblende rock is considered by Lindgren to be a replacement of the original country.

The Loud mine, 11 miles east of Dahlonega, is noted for its coarse and well-crystallized gold, often reaching 800 in fineness. Its placer deposits are among the richest and most extensive in

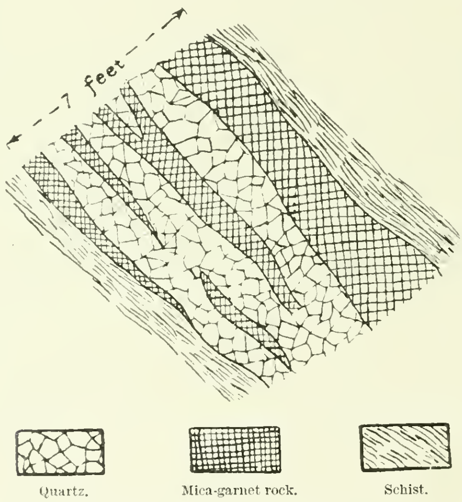


Fig. 201. Diagrammatic section across Lockhart Vein, Dahlonega (*Lindgren*).

the Southern States. Near the Nacoochee Valley, in a region of mica- and hornblende-schists with numerous granitic dykes, rich alluvial ground has been worked, as at Duke's Creek. The Boilston mine, Henderson County, N.C., is the most north-easterly deposit on the Georgia belt. Here a large dyke of granite strikes parallel to the vein and at a little distance away. The pay-ore is confined to small shoots in a large quartz vein often 20 feet wide.

The South Mountain belt of western North Carolina extends from near Morganton south-south-west to the vicinity of Rutherfordton, a distance of some 25 miles. Its average width is 10 to 12 miles. The rocks of the mountain system are Archæan mica- and

[a] Lindgren, Bull. U.S. Geol. Surv., No. 293, 1906, p. 127.

hornblende-gneisses and schists of similar character to those of the Georgia belt. The auriferous quartz veins form a system of fissures of remarkable regularity, striking always east-north-east and dipping southward. The majority are thin milky-quartz stringers containing pyrite, galena, chalcopyrite, and blende. Five principal zones have been distinguished. The veins are as a rule too small to admit of profitable working, but they have furnished placer deposits that have been attacked from time to time with considerable energy.

The Carolina belt is the most extensive and most productive of the Southern Appalachian belts. It lies parallel to the axis of Appalachian folding but is far to the east of the higher ranges. It extends from the Virginia frontier south-west by way of Monroe across North Carolina into South Carolina. Here it disappears for a short distance beneath the sediments of the coastal plain, but reappears in Abbeville County, S.C., and passes into Wilkes County, Ga. The belt is 10 to 40 miles wide. Its auriferous rocks are (*a*) argillaceous, sericitic, and chloritic metamorphosed slates and schists ; (*b*) devitrified ancient volcanics (rhyolite, quartz-porphyry, and pyroclastic breccias of the same) ; (*c*) igneous plutonic rocks (granite, diorite, diabase, &c.) ; (*d*) siliceous magnesian limestone ; (*e*) sedimentary pre-Jura-Trias slates. These rocks are all non-fossiliferous and must be provisionally classed as Algonkian. The belt is flanked on the north-west by granites and gneisses, and on the south-east towards the coastal plain by Jura-Trias sandstones and conglomerates which have yielded gold in insignificant quantities.[a] Auriferous deposition in this belt is believed by Becker[b] to have taken place at the close of the great Algonkian volcanic era ; it is also believed that the same relation holds true of the South Mountain and Georgia belts. Gold deposition was seemingly renewed with diminished activity after the formation of the Ocoee series and the Monroe Beds, and is probably to be attributed to the heated waters set in circulation by the diabasic intrusions of a later period.

The gold-ores of the Carolina belt are found both in quartz fissure-veins and as pyritous impregnations, the latter being accompanied by irregular stringers and lenticles of quartz striking with the foliation of the schists and the lamination of the slates. The sulphides are ordinarily pyrite, chalcopyrite, galena, mispickel, and blende. The tellurides, nagyagite and tetradymite, have a wide distribution, but are nowhere present in large quantities.

The Carolina belt contains several workable gold occurrences of which the Haile and Brewer mines in South Carolina, and the

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[a] Nitze and Wilkens, Bull. N.C. Geol. Surv., X, 1897, p. 15.

[b] Loc. cit., p. 261.

King's Mountain and Colossus mines in North Carolina, are perhaps the most notable.

Haile Mine.—The country of the Haile is a light-grey quartz-sericite-schist, very hard and dense. It probably is a member of the great group of metamorphosed Algonkian volcanic rocks described by G. H. Williams[a] as having a large development in eastern North America. As pointed out by Becker[b] it is certainly of volcanic origin, still showing flow-structure, and represents an acid rock. The determination has been confirmed by Graton,[c]

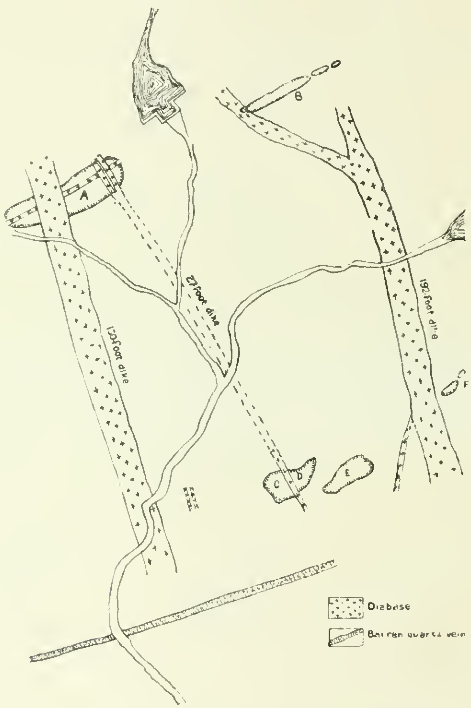

FIG. 202. SKETCH MAP SHOWING PRINCIPAL ORE-BODIES, HAILE MINE (*Nitze and Wilkens*).
A. Beguelin pit. *B*. Chase Hill pits. *C*. New Haile pit. *D*. Old Haile pit. *E*. Bumalo pit. *F*. Red Hill pit.

who refers the rock to an original acid porphyry-tuff. The bedding of the tuffs is in some places still well preserved. The general strike of the schists is north-east to east-north-east, and their dip from 45° to 80° north-west. The Haile mine is traversed by three approximately vertical olivine-diabase dykes crossing the schists

[a] Jour. Geol., II, 1894, p. 28.

[b] Loc. cit., p. 307.

[c] Bull. U.S. Geol. Surv., No. 293, 1906, p. 16.

Side of Diabase Dyke Exposed in the Haile Pit.
Corrugations in dyke show dip of ore-bearing country. Vertical stains due to rain-water.

Beguelin Ore Body, Haile Mine, South Carolina.
Showing Interfoliated and decomposed diabase dyke.
(U.S. Geological Survey.)

from south-east to north-west, as shown on the accompanying sketch. Their widths are, respectively, 27, 130, and 192 feet. The Haile ore-bodies are lenses of silicified tuff impregnated with auriferous pyrite. Silicification and pyritization appear to have been contemporaneous, and the richness of the ore varies in direct proportion to the degree of siliceous replacement. True quartz veins are few and are generally worthless. Molybdenite is often associated with the pyrite. Gold occurs free, both as a primary and a secondary deposit and also within the pyrite crystals. The ore-bodies are large but low-grade, that of the Haile proper being about 200 feet long and disposed for about 100 feet on both sides of a diabase dyke. The width of the ore-body is determined solely by the values. The Bumalo ore-body to the east of the Haile is about 250 feet long by 40 feet wide. The Beguelin to the north-west and on

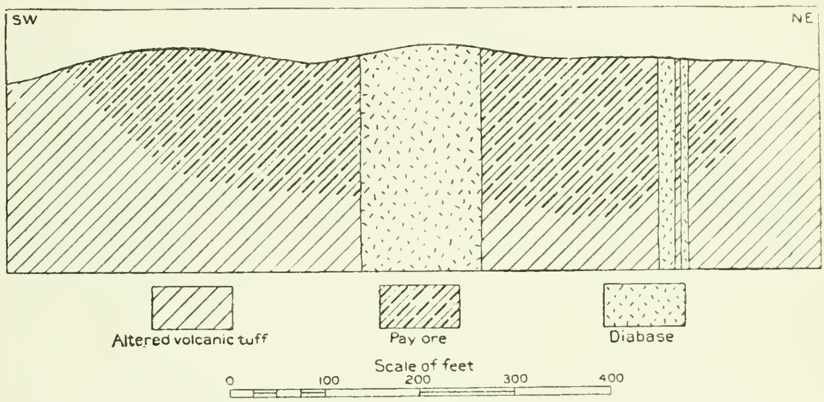

FIG. 203. VERTICAL SECTION OF THE BEGUELIN ORE-BODY, HAILE MINE, SOUTH CAROLINA (*Graton*).

the course of the two main dykes is much larger, carrying ore for nearly 300 feet on each side of the 130-foot dyke. Recently, the energetic prospecting drilling carried on by the manager, the late Mr. E. A. Thies, disclosed a valuable ore-body further north-west, and 300 feet away from the diabase dyke. This ore-body was being worked at the time of the present writer's visit to the mine in May, 1907. The ore is decidedly low-grade, averaging, as sent to the mill, perhaps 12s. 6d. ($3.00) per ton. The total costs are said to be only 6s. 8d. ($1.60) per ton.[a] The total output of the Haile mine to 1905 is estimated at about £666,250 ($3,250,000). The mine has been worked almost continuously since 1830, and in the early days of working very rich ore was obtained at and near the outcrops, the result obviously of secondary enrichment.

[a] Graton, loc. cit., p. 82.

Attacking the problem with an obvious bias towards the hypothesis of a genetic connection between auriferous deposition and granitic magmas, Graton has concluded[a] that, notwithstanding the relative positions of diabase dykes and ore-bodies, the diabase is subsequent to and has consequently exercised no effect on the deposition of the ore-bodies. For his interesting argument in support of his hypothesis, which can be fairly quoted only *in extenso*, the student is referred to the original memoir. The result, however, of the present writer's examination of the mine led him to adopt in its entirety the hitherto generally-accepted assumption that the Haile ore-bodies were directly due to the influence of the diabasic dykes traversing the mine. It may further be mentioned that the nearest known granite is two miles away from the pits. The Haile mine is interesting in another respect as having been the home of the Thies barrel-chlorination process, that, until the introduction of cyanide of potassium, was among the most successful of lixiviation processes.

Brewer Mine.—The Brewer mine lies 10 miles north-east of the Haile, and 13 miles north-east of Kershaw. It is believed to have been the first important gold producer in South Carolina. As at the Haile the first operations were on the placer deposits of the small streams of the neighbourhood. The rocks and the ore are practically identical with those of the Haile, though the great amount of decomposition makes the determination of the character of the country very difficult. A diabase dyke lies on the west bank of Flat Creek near the mine, and granite intrusions are said to occur within half a mile of the ore-body. The ore is a dense blue rock similar to that of the Haile, but is even more siliceous. It has been formed by siliceous impregnation and replacement, and is now low-grade in depth. The Tan-Yard placer deposit at the Brewer mine was for long the richest of the Southern Appalachian alluvial deposits.

Colossus Mine.—The Colossus mine lies in Union County, N.C., some four miles south of Waxhaw. Its geology is similar to that of the Haile, 25 miles further south. Quartz-sericite-schists intruded by diabase dykes are silicified along certain bands. The ore is a dense and highly siliceous rock impregnated with pyrite. The ore mined is on the whole richer than that of the Haile, averaging some £3 ($15.00) per ton. The greater value is probably due to closer selection.

King's Mountain.—The King's Mountain mine, Gaston County, N.C., has yielded since its discovery in 1834 about £184,500 ($900,000). The country is micaceous schist overlying

[a] Loc. cit., p. 70.

a schistose impure limestone closely associated in origin with interlaminated biotite-schist. A zone of graphite and pyrite directly underlies the limestone. A granitic dyke is reported to have been met with in the workings. The valuable ore was derived in the past from narrow quartz veinlets and stringers in the upper oxidised zone. In depth the ore became very complex, containing free gold, pyrite, pyrrhotite, chalcopyrite, galena, mispickel, blende, and tetrahedrite, with the rare minerals nagyagite (gold telluride), altaite (lead telluride), and bismite. Sericite and fluorite form gangue minerals in addition to quartz. The ore-bodies are said to have been exceptionally rich at the limestone contact.

The Iola mine, Montgomery County, N.C., is one of the most important of recently-opened mines. Its yield is about £24,000 per annum.[a]

Placers.—Placer gold in the Southern Appalachians is found, as elsewhere, in valley bottoms and gravels. Much more important than the stream gravels are the auriferous deposits resulting from the decomposition and disintegration *in situ* of impregnated ore-bodies, veins, and country. For such loose decomposed rock the term *saprolite* has been proposed by Becker.[b] In the Southern States decomposition often extends to a depth of 50 to 100 feet. When the decomposed rock has been seamed by auriferous quartz veins, little of the gold passes into the streams, and the great bulk, falling into crevices, remains on the hillsides to materially enhance the value of the surface soil and rock. The quartz of the original veins, especially when it has contained very little pyrite, is but slightly disintegrated, and contains gold. To obtain such gold the so-called Dahlonega method has been developed. The decomposed rock is washed by water under pressure into sluices, where the quartz is caught on grizzlies and passed through amalgamating stamp-mills. Amalgamation is, however, often ineffective owing to the gold being coated with a film of iron-oxide. In some saprolites little residual quartz is found with the gold. The gold of the saprolites is naturally very rough, and, in some cases, as at the Loud mine near Dahlonega, masses of wire gold are met with. For such occurrences the present writer suggests a secondary origin, akin in operation to the growth of nuggets *in situ* or to the secondary enrichments of vein outcrops. The general low-grade of the ores in depth certainly indicates some such explanation of the wide surface enrichment. In addition to hydraulicking by the Dahlonega method, dredges have been employed to work the gold deposits

[a] Min. Sci. Press, March 28, 1908.

[b] Loc. cit., p. 289.

of the shallow valleys and also of the rivers, and have been of late moderately successful on the Chestatee river, Lumpkin County, Georgia, where they have been in operation for many years. The earlier dredges, however, having been built before the broad principles underlying dredging were understood, were invariably failures.[a]

Negro miners, when working the saprolites on a small scale, make extensive use of rockers made from logs hollowed in the form of a rocking cradle, but with the upper end alone closed. The length of the rocker is from 5 to 10 feet. Three or four are often so joined as to move in unison, and are thus worked by one man or woman. A reciprocating motion is given to the rocker which, combined with the inclination at which it is set, and the flow of water from the head, gradually works off the lighter materials.

A small portion of the North Georgian auriferous belt passes through Polk and Monroe counties in the extreme south-west of Tennessee, where lenticular veins occur in the pre-Cambrian Ocoee slates. The Coco Creek placers in this region are worked by dredging. These deposits have been known since 1833. Some portion of the small gold yield of Tennessee comes from the famous Ducktown copper veins. The ores from these contain about 1·8 per cent. copper, while the copper pig produced yields from 0·02 to 0·04 ounce gold per ton. Not all the contained gold is recovered, since a considerable portion of the copper obtained is not electrolytically refined.

[a] Eng. Min. Jour., Nov. 2, 1901.

CENTRAL AMERICA AND WEST INDIES.

MEXICO.

The great mineral-bearing zones of Western North America are continued southward into Mexico. The Pacific Coast belt has, it is true, no very great or extensive development, but the hitherto subordinate belt of south-western Nevada assumes great importance in the north-western States of Sonora and Sinaloa, while the later Tertiary propylitic zone of Colorado loses none of its prominence on reaching the southern republic. The mineral wealth of Mexico lies rather in silver than in gold, but its production of the latter metal is nevertheless very large. For many years it has occupied the fourth position in the list of gold-producing countries, being surpassed in this respect by the Transvaal, the United States, and Australasia. In September, 1906, there were in the republic 1,572 gold mines (of which one-third were in Sonora), 6,467 gold-silver mines, 1,373 gold-silver-copper mines, 1,317 gold-silver-lead mines, and 262 gold-copper mines. It will therefore be abundantly apparent that much of the gold yield of Mexico is largely a by-product, and that it fluctuates with the demand for the baser metals, lead and copper. The most notable gold producers are the three mines of the El Oro group (Esperanza, El Oro, and Dos Estrellas) lying some 80 miles west of Mexico City, and the Dolores mine in Western Chihuahua. The Esperanza mine was in 1906 the first in the list of the world's gold mines both in respect of actual output and of profit earned, producing £1,580,321 ($7,708,883), and paying in dividends £952,077 ($4,644,279). Its place was, however, taken in 1907 in the former respect by the Goldfield Consolidated (Goldfield, Nevada), and in the latter by the Robinson Mines, Transvaal.

Gold occurs in Mexico, as already indicated, in simple gold-quartz veins, in silver-gold veins, and, in subordinate quantity, in copper veins. Veins of the first class lie for the most part in crystalline or metamorphic schists, pegmatites, granites, and diorites, always in the vicinity of recent eruptives. Examples of this class are found most abundantly in Lower California and in the Pacific Coast States of Sonora, Sinaloa, &c. The Lower Californian zone may be considered the southern continuation of the Californian granodioritic gold belt. The auriferous deposits of Sonora, west of the Sierra Madre, apparently belong to the same type as those developed in Arizona.

Gold-silver veins in propylitic rocks are numerous and show all the characteristics of such veins. Their gangue is ordinarily quartz with subordinate calcite, accompanied by occasional fluorite, gypsum, and rhodochrosite. The sulphide minerals occurring in depth are pyrargyrite, proustite, miargyrite, polybasite, argentite, stibnite, pyrite, galena, chalcopyrite, and a little blende. Numerous veins of this type are found also on the western slopes of the Sierra Madre, but they attain their greatest development in the central southern plateau, where lie the great silver mines that contributed so largely to the wealth wrested from Mexico by the Spaniards. The famous El Oro mines, among the most productive of recent years, belong to this type, notwithstanding the fact that their veins lie in Cretaceous shales, for they are certainly dependent on late Miocene andesitic intrusions for their metalliferous content.

Contact metamorphic deposits of Lower Tertiary age occur along the planes of contact of Cretaceous limestone and diorite, especially on the eastern flanks of the Sierra Madre. Examples are to be seen at Encarnacion, Hidalgo ; San Jose del Oro, Tamaulipas ; Mazapil, Zacatecas ; and at Santa Fe, Chiapas.[a]

Numerous veins in the provinces of Sonora and Tepic, are in granulite country. In Oaxaca and Jalisco they occur in diorites, and in Sinaloa and Guerrero in crystalline schists. These veins have a quartz matrix and are generally pyritous. In the San Cristobal mine, Guerrero, veins pass from the crystalline schists into andesites where they contain a notably greater percentage of silver. In the Los Ocotes mine, Sultepec district, State of Mexico, veins in phyllite are intimately associated with pyroxene-andesite. There is thus a fairly well-defined zone[b] lying entirely to the west of the Sierra Madre mountains in which the veins are in the older rocks (granite and crystalline schists), and are probably of Lower Cretaceous or Early Tertiary age, owing their mineralisation to intrusions of this age. This belt or zone is continued northwards, as has been seen, into the south-western part of New Mexico.

The mineral zones of Mexico are among the richest in the world. The veins are perhaps most numerous along the western range of the Sierra Madre, but the largest and richest have been found in the Central Plateau region. The veins occur always in connection with volcanic rocks. Gold, unaccompanied by silver, is found mainly in the crystalline gneisses and schists that outcrop in the low country towards the Pacific Coast. The largest (mainly silver) deposits are in the Upper Mesozoic sediments (Cretaceous

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[a] Ordonez, Mem. y Rev. Soc. cient. "Ant. Alzate," XI, 1897, p. 216 ; Aguilera, Trans. Amer. Inst. M.E., XXXIII, 1902, p. 517.

[b] Sonoran of Merrill, loc. cit. inf.

limestones, shales, and slates) intruded and accompanied by numerous volcanic dykes and flows.[a]

The yield of gold in Mexico is steadily increasing. Its production, since it is often merely a by-product, is largely proportional to that of the baser metals, silver, copper, and lead.

Exact figures of the total gold output of Mexico are, of course, unattainable. It is, however, estimated by Lindgren[b] at at least £37,043,500 ($180,700,000) from 1690 to 1900 inclusive. Since the latter year it has been as follows :—

Year.	Kg.	Crude Ounces.	Value, Dollars.	Value, Sterling.
1901	13,458	432,674	$9,089,800	£1,863,409
1902	13,792	443,412	9,315,257	1,909,627
1903	15,134	466,558	10,222,318	2,095,575
1904	17,518	563,203	25,842,563*	2,584,256
1905	23,599	758,707	31,793,841*	3,179,384
1906	20,247	650,941	13,174,331	2,699,658

* Mexican dollars or pesos.

Lower California.—The Lower Californian goldfields may be considered the most southerly members of the great Pacific belt of Cretaceous veins, best exemplified by the Mother Lode of California. Thus the mines of Santa Clara, Real del Castillo, El Alamo, Camalmahi, and San Borja are all in granite country. Their gold is associated with quartz, auriferous pyrite, and copper sulphides.

In Lower California the principal auriferous region is Alamo, originally a placer field, and discovered about 1889. The district is 70 miles east of La Encinada. The mines lie in the Alamo basin. The rock of the region is granite, traversed by diorite dykes.[c]

In the Viznaga mine gold occurs in lenticular quartz varying in width from 6 to 18 feet. The workings here reach a depth of more than 400 feet. Very rich pockets are occasionally found.[d]

Sonora.—The district of Sonora has long been prominent for the great number of its ancient gold mines, generically termed *antiguas*, many of which have been abandoned since the War of Independence of 1810, or were exhausted even before that date, for the mining industry had then been in existence in Sonora for nearly three centuries. The district is the southern continuation of the Arizona desert and present the same characteristic features—a sandy

[a] Merrill, Eng. Min. Jour., Ap. 6, 1907, p. 667.

[b] Trans. Amer. Inst. M.E., XXXIII, 1903, p. 844.

[c] Wankowski, Mines and Minerals, June, 1901, p. 507.

[d] Trentini, "El Floreceimento de Mexico," Mexico, 1906, Vol. II, Eng. Ed.

plateau, at an elevation of some 2,000 feet, from the level of which isolated granite peaks or short granite ranges rise. The oldest rocks are granites and gneiss overlain by Palæozoic (Cambrian to Carboniferous) limestones and quartzites, on which Triassic beds, containing coal and graphite, rest. Cretaceous limestones and shales are exposed in the central region of Sonora and often carry copper deposits. The latest deposits of the region are the great volcanic lavas and tuffs of quartz-porphyry, rhyolite, dacite, and andesite, that contain so many of the more important ore-bodies.[a]

Extensive dry placers occur in the Altar district near La Cienaga and Palomas. These have yielded hundreds of thousands of ounces to the dry-pan. The Altar region has also been long noted for rich gold-quartz veins, of which El Tiro vein and the Cerro Colorado Hill, near La Cienaga, have been the most productive.

The gold-quartz veins of the Sierra Pinta del Bajio, Altar district, lie in pegmatites intrusive into metamorphic schists. These carry also auriferous pyrite and chalcopyrite with minor galena and blende. The Altar region was the chief source of the gold supply of the Aztecs, of the *conquistadores*, and of the later Spaniards.

East of Altar is the Magdalena district, containing numerous ancient gold mines, many of which are now being opened anew. The mines of the Sierra Pinitos lie a few miles south and south-east of Nogales on the Arizona frontier. Their ore-bodies are quartz veins carrying gold. Several of the deposits occur on the contact between the prevailing andesitic rock and an intrusive dacite. Others are fissure veins filled with shattered and altered andesite and with long thin lenses of white or rusty quartz. The gold veins vary from 5 to 7 feet in thickness, and carry low values in the altered and pyritized country.[b] The Sierra Azul mines lie on the eastern edge of the Magdalena district. Their auriferous ore-deposits are quartz veins in granite. The ore lies often in a vein-filling of brecciated granite. The Cerro Prieto, 30 miles south-east of Magdalena, is one of the most extensive of the *antiguas* in the country. It is now being worked by the Black Mountain Company (Chicago) with 120 stamps. An enumeration of the names alone of the *antiguas* of these districts would occupy pages.

Arizpe, the next district to the east in Sonora, is famous rather for its copper camps (as Cananea) than for gold. The old Santa Rosalia gold mine, famous in former days, lies to the north-east of Cerro Prieto. El Tigre is the best known gold and silver mine in the Moctezuma district. In Ures district is the San Ricardo, a formerly

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[a] Merrill, Min. Sci. Press, Jan. 4, 1908, p. 33.

[b] Weed, Trans. Am. Inst. M.E., XXXII, 1902, p. 428.

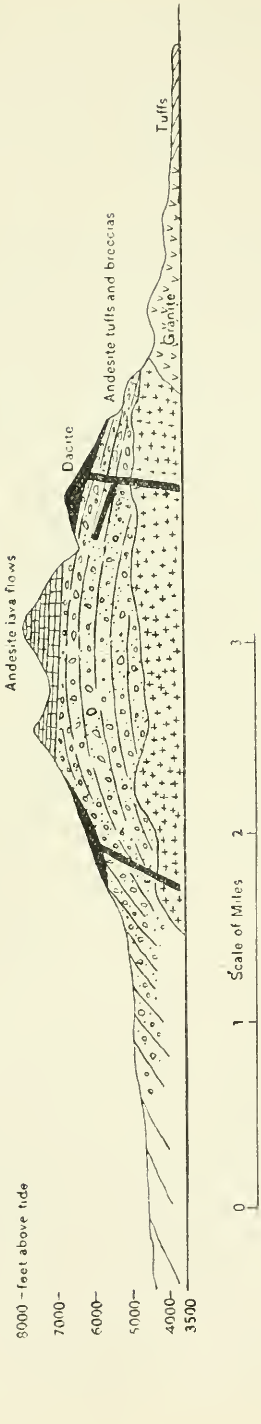

FIG. 204. IDEAL CROSS-SECTION THROUGH PINITOS RANGE, MAGDALENA DISTRICT, SONORA (*Weed*).

rich gold mine that was escheated to the Mexican Government from American owners for smuggling gold out of the country in order to evade royalty. The most important mining camp in Hermosillo district and the largest gold camp in Sonora is Minas Prietas. Its mines were long worked in Mexican fashion, but are now controlled by American capital and are worked successfully by modern methods.

Sonora was overrun by Apache Indians from the time of the revolution against Spain until the capture of the notorious Geronimo in 1884. Since then it has been vigorously prospected and numerous *antiguas* have been re-opened. Gold occurs usually in small quantities in the copper ores of Sonora, the free gold-quartz veins occurring chiefly in the Altar district. The zone of oxidation in Sonora is usually very deep. Vein-filling occurs principally in shear-zones, with attendant splittings, horses, &c.

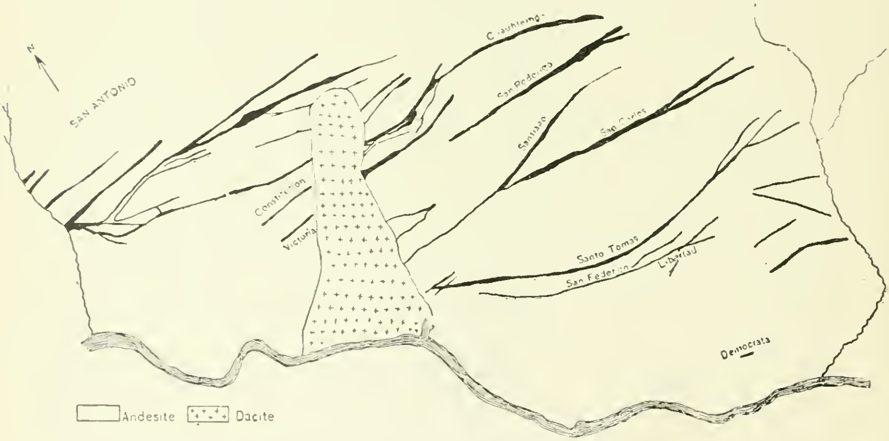

FIG. 205. GUADALUPE Y CALVO (*Weed*).

Chihuahua.—The Descubidoro mine, a few miles north of the town of Chihuahua, lies in limestone almost entirely surrounded by volcanic rocks (andesites and rhyolites). The ore-bearing zone is about 40 feet thick, and dips at 8° to 10° south-east. The ore occurs in brecciated cherty patches through the limestone, and is generally associated with earthy manganese ore,[a] carrying about 12 ounces silver and 0·3 ounce gold per ton. Free gold also occurs locally in the siliceous portions of the rock.[b]

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[a] Cf. Pilgrim's Rest, Transvaal, and Rico, Colorado.

[b] Lakes, Mines, and Minerals, May, 1903, p. 447.

The Guadalupe y Calvo mines in the south-west corner of Chihuahua are among the most famous in Mexico for their production of gold in former days. The gold occurs in fissure veins traversing altered and fractured andesitic rocks. Veins are not found in the younger rhyolites, but are restricted to the light-coloured chalky-white or pink porphyry-tuffs. The principal mines are the Rosaria and the Independencia. The former is a huge vein 60 to 150 feet wide, averaging perhaps 100 feet, and dipping with the hillside so that it yields a conspicuously exposed hanging-wall. Four distinct ore-shoots separated by low-grade quartz have been worked. It has been mined since 1835. The early yield was so great that a mint was established at the mine. The value of the total output from 1838 to 1847 is estimated at £8,000,000 ($40,000,000).[a] The Independencia veins in the same locality lie in an andesite that is associated with intrusive dacite. They are considered by Weed to be replacement veins. The La Cumbre mines, further west near the Sinaloa frontier, are in andesites, altered breccias, and lava flows. Their quartz veins also were formed before the deposition of the rhyolite. They are well-defined reefs with bold outcrops, and contain much pyrite, the sulphide zone commencing at a very short distance below the surface.[b]

Numerous old gold-districts, some of which are now being re-opened, lie near Parral in the south-west.

The Lluvia de Oro mine is also in the west of Chihuahua, about 5 miles from the Sinaloa boundary, near the Rio Fuerte. Though long known to the Indians, it was discovered by the Mexicans only in 1900; two years later it was bought by an American company for £358,750 ($1,750,000). It owes its name ("Shower of Gold") to the extraordinary richness of its outcrop. It has a present output of some £16,400 ($80,000) per month. The ore-bodies occur along an escarpment of Jurassic limestone that has been intruded by diabase and raised by faulting about 2,300 feet. The diabase now underlying is believed to be at least 4,000 feet in thickness. Eruptions of rhyolite later than the diabase have been of frequent occurrence, one, indeed, occupying, as shown in the accompanying sketch, the plane of the great fault. The ore-bodies are metasomatic replacements of the limestone with quartz. They are confined to the limestone and occur in irregular lenses along zones of sheeting parallel to the fault system of the district, and transverse to the bedding. Thus they differ from the Mercur and Pilgrim's Rest occurrences which lie parallel with the

[a] Weed, loc. cit. sup., p. 408.

[b] Idem, loc. cit., p. 426.

bedding. The ore is a solid grey cherty quartz with little pyrite. Average ore in depth gave 3 ounces gold and 30 ounces silver per ton. At the surface it was much richer.[a]

The Dolores mine, next to the El Oro group, perhaps the most productive of the gold mines of Mexico, lies on the western slope of the Sierra Madre in the Tutuaca Valley, due west of Chihuahua and on the Sonora border. It is in an extremely isolated part of the State, is more than 100 miles from a railway, and may be reached only by rough mule trails. The country is diabase greatly intruded by dykes that are partly responsible for the zones of shearing

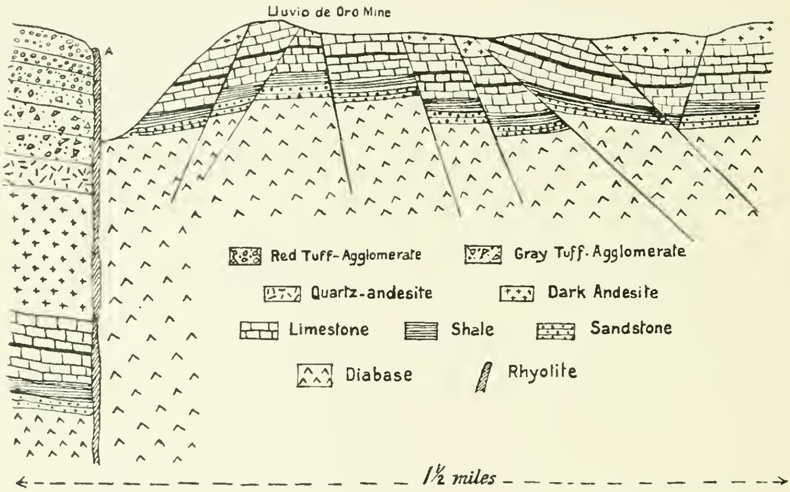

FIG. 206. GEOLOGICAL SECTION OF THE LLUVIA DE ORO DISTRICT (*Burrows*).

that constitute the auriferous belts of the district. The largest of the old workings is on the Alma de Maria zone, but two other zones (San Francisco and Barrow) are also worked.[b]

Other camps in the same neighbourhood, but further south, are the Ocampo, Pinos Altos, and Soyopa. Ocampo was discovered in 1821, and has produced several rich gold mines, the Watterson being the most notable of recent times. The country of the neighbourhood of the Ocampo gold-silver quartz veins is rhyolite, andesite, diabase, rhyolite tuff, and breccias.[c]

Durango.—In Durango the Indé gold mines are the best known. They lie in the north of the State.

[a] Burrows, Min. Sci. Press, May 25, 1907, p. 664.

[b] Farish, Eng. Min. Jour., May 4, 1907, p. 849.

[c] Bagg, Min. Sci. Press, Aug. 8, 1908, p. 188.

Hidalgo.—The celebrated mines of the Pachuca district yield silver with very little gold. The veins lie in a complex of Tertiary volcanics, the principal member being a pyroxene-andesite, with which is associated rhyolite and basalt, the last being always barren. The silver ores occur as sulphides and are associated with pyrite, galena, blende, stephanite, and polybasite. The veins are simply-filled fissures. Silicification and pyritization has gone on in the adjacent country to a considerable extent. The general conditions therefore much resemble those of the Comstock in Nevada.

Mexico.—The famous El Oro mines are 90 miles north-west of Mexico City on the Michoacan border. The mines are situated on the slope of a ridge rising 600 feet above the valley. On the eastern side of the ridge are the Mexico, Esperanza, and El Oro mines, and on the western side the Dos Estrellas, the last being in the State of Michoacan. The country consists of Cretaceous shales covered by late Tertiary andesites. The shale is thinly laminated, black, and calcareous ; it contains occasional layers of limestone, and is intruded in many places by andesite stocks of apparently the same magma as that which furnished the overlying flow. There are also andesitic intrusions of an older date. Rickard[a] summarises the geological sequence of events as follows :—

(1) Deposition of shale.
(2) Intrusion of andesite as dykes and sills.
(3) Successive faulting, with formation of San Rafael lode.
(4) Ore deposition.
(5) Eruption of younger andesite.
(6) Cross faults.

The period of vein-formation appears to have been intermediate in time between the two andesitic intrusions. In some places ore has been found in the older andesite, but only when adjacent to an ore-body in the shales. The lode consists of a broad zone, 80 feet wide, of banded quartz veins with intervening country, the veins being formed largely by siliceous replacement of brecciated country. The ore occurs in pay-streaks along the walls of the veins. The largest ore-bodies lie on the footwall and hanging-wall respectively, and are connected by cross stringers. The shale and the veins have obviously, as may be seen from the accompanying section, undergone considerable erosion before the deposition of the later andesite. The apex of the vein did not in all places reach the old eroded surface of the shale, in these cases fraying out some depth below the old surface. The pay-ore is not

[a] Rickard, T.A., Min. Sci. Press, Sept. 22, 1906, p. 352.

confined to any particular vein in the zone. The main lode-channel is faulted by a fairly parallel series of faults dipping north 65° to 70°.

The San Rafael Lode is the main lode of the Mexico, Esperanza, and El Oro mines. It follows a great fault line, and is itself faulted. The lateral displacement caused by the later fault is 130 feet, the vertical 500 feet. Other Esperanza ore-bodies (in the Esperanza mine) are the West vein, which opened up a roughly lenticular pay-shoot 680 feet long, 9 feet wide, carrying 2·4 ounces or 75 grammes gold ($49.70) and 37 ounces or 1,150 grammes silver ($19.55) per ton. Small bands of shale included within the quartz assayed equally well. The ore itself is beautifully ribboned; minute crystals of pyrite encrust the quartz, especially in geodes and vughs, while the richest ore contains magnetite. The gold is free and in fine particles; is rarely visible; and is associated with argentite in the lower levels. The ore, both in andesite and in shale, is a siliceous replacement of the country. The andesite country near the vein often contains silver and traces of gold on assay.

The West vein of the El Oro, 90 feet west of the San Rafael, is small, rich, and unoxidised, while the great San Rafael lode is oxidised to great depths. At the 1,050-foot level, however, a rich body of sulphide-ore worth £8 ($40) per ton[a] has been struck in the San Rafael lode, giving a new lease of life to the mine, which had formerly been rather poor. The total depth attained by January, 1908, at the El Oro mine, was 1,150 feet. In the oxidised ore the ratio of the gold to silver was 1 to 6½, and in the sulphide ore, 1 to 15, the ratios in both being fairly constant.

The Somera mine is on the dip of the great San Rafael lode, but has, by arrangement, no rights over that lode on the dip. On another lode is the Dos Estrellas, the third great mine at El Oro. Its lode is divided into two portions, one 3 to 5 feet thick, with rich bodies of ore in it, and beyond it another vein 40 feet thick with 12 dwts. ore.

In 1906 the three El Oro properties produced more than £1,200,000 ($12,000,000 Mexican) of which 80 per cent. of the value was from gold. The Esperanza is one of the most productive of the world's gold mines, producing $400,000 per month. In 1905, the monthly yield was over a million dollars, thus contributed :—

Esperanza	$650,000
El Oro	$200,000
Dos Estrellas	$240,000

Electricity for the mines is brought from a distance of 176 miles, or from 100 miles beyond Mexico City.

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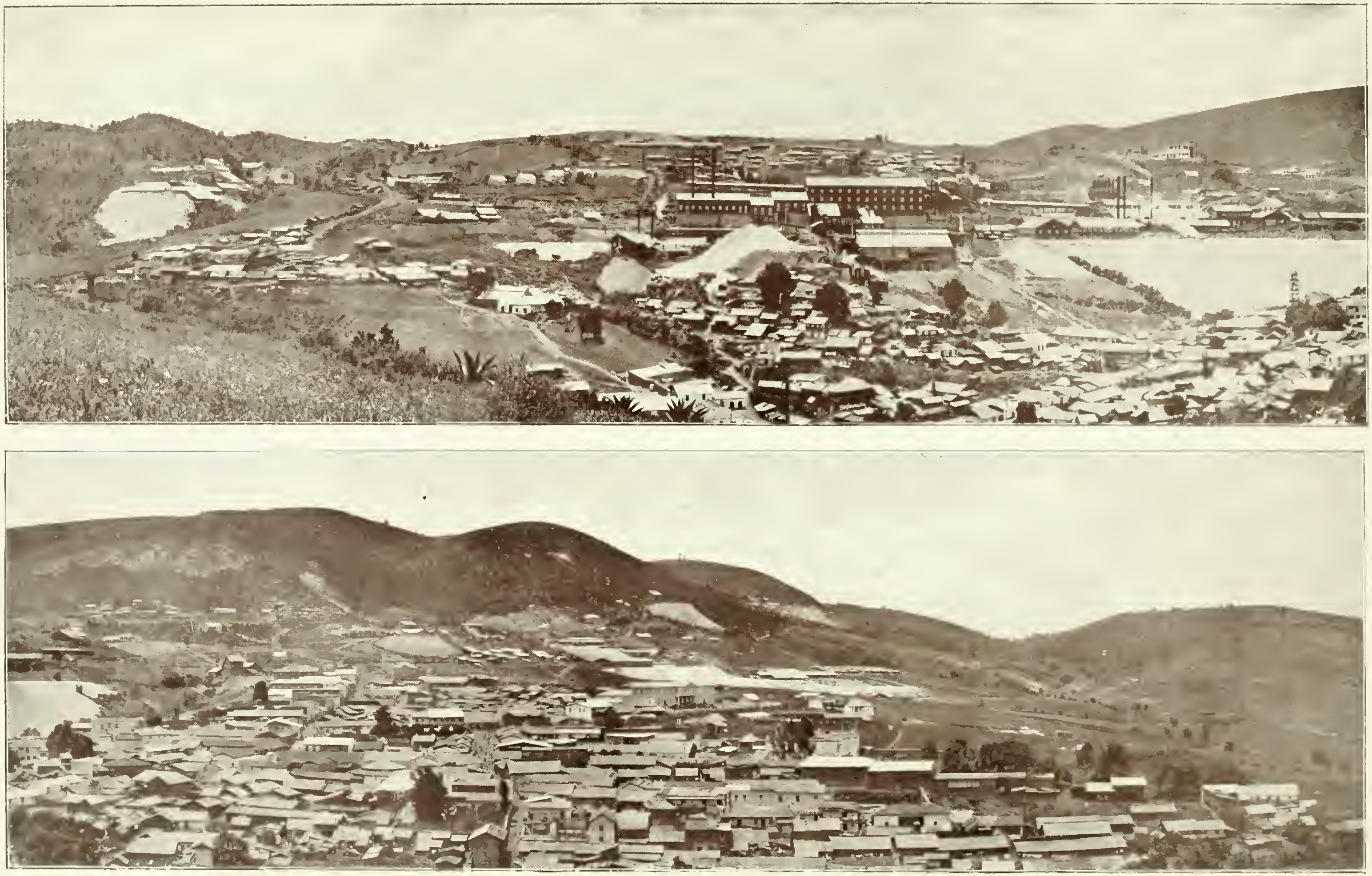
[a] Min. Jour., Oct. 26, 1907.



Panoramic View of El Oro, Mexico.

San Luis Potosi.—The country of the San Pedro district is andesite, underlying and probably intrusive into a limestone, which is capped on the higher summits by rhyolite. The rhyolite is barren, the ores occurring at limestone-andesite contacts or in the limestone near the andesite. Veins in the andesite itself are ordinarily small and barren. The ores carry both gold and silver, free gold having been found in masses from 300 to 350 ounces in weight.[a] The gold-ore mined in the upper levels is hæmatite-chert

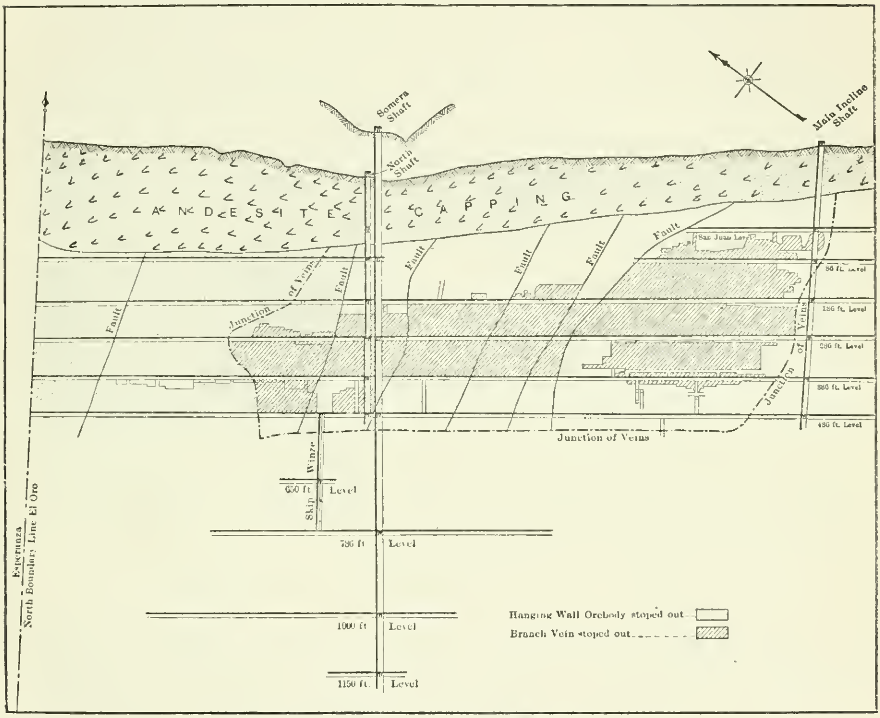


FIG. 207. LONGITUDINAL SECTION, EL ORO MINE.

carrying large quantities of free and visible gold with little silver. In depth the ores are generally cherty and are low in gold and high in silver. Samples of the andesite country on analysis gave 2 grammes gold and 20 grammes silver per metric ton.

Guanajuato.—The vein systems of the Guanajuato State are three, viz., the Sierra, Veta Madre, and La Luz. They furnish mainly silver mines, the output of gold being comparatively insignificant. The proportion of gold to silver in weight is only about 1 to 250. The Pinguico is a fault vein entirely in rhyolite in the

[a] Laird, Trans. Am. Inst. M.E., XXXV, 1905, p. 863.

hanging-wall of the great Veta Madre, and is one of the few Mexican mines discovered in recent years. The country of the Veta Madre is not uniform, schists, agglomerates, andesite, and rhyolite occurring at various points. The thickness of the rhyolite near the Pinguico vein is from 1,500 to 1,700 feet. The vein is 17 feet wide on an average, with a value of £7. 10s. ($36.00) per ton.[a]

The veins of La Luz are of great length. They traverse the La Luz (Cretaceous) schists for 7,200 feet, and may be traced for 4,000 feet further in the adjacent granite. The ore-bodies are formed by the local union of the numerous stringers ("ramaleos") that lie along the ore-zone. The La Luz mine from 1843 to 1856 (14 years) is estimated to have produced £8,200,000 ($40,000,000) gold and silver. The value of the production of the whole district is estimated at £22,960,000 ($112,000,000).[b]

Chiapas.—At the Santa Fé mine in Chiapas, Southern Mexico, gold is found associated with bornite lying in a gangue of wollastonite. The bornite has an average value in gold of an ounce per ton, and in silver 60 ounces per ton. Free gold is found in the upper portions of the vein. It is also found with a sulphide of nickel, cobalt, iron, and copper, akin to linnaeite.[c] The deposit is in massive wollastonite (silicate of lime) apparently due to local thermo- and dynamo-metamorphism arising from the intrusion of the igneous rocks that are found in the mine. Schistose, garnetiferous, and quartzose rocks are met with in the neighbourhood. The ore-bodies occur irregularly disposed in the wollastonite matrix, and are largely associated with garnet.[d]

GUATEMALA.

Tradition places a famous ancient gold mine in the mountains of Illon, department of Quiche, Guatemala Republic. It is said to have been worked by the Jesuits, and numerous references to it are made in ancient ecclesiastical records. All recent attempts to rediscover the mine have failed.

The only placers of present importance in Guatemala are those of Las Quebradas, 15 miles from Morales, and near the banks of the Motagua, or Rio Grande, flowing north-east into the Gulf of Honduras. The placers of the Yzabal department, in which is situated Las Quebradas, were a source of great revenue to the Spaniards between 1627 and 1820.[e] The gravel deposits of Las

[a] Church, Eng. Min. Jour., Nov. 24, 1906, p. 960.
[b] Idem, ib., July 27, 1907, p. 153.
[c] Collins, Trans. Inst. Min. Met., VIII, 1900, p. 303.
[d] McCarthy, E. T., ib., IV, 1896, p. 169.
[e] "Guatemala," Bureau of American Republics, Washington, No. 32, 1892.

Quebradas are now being worked by hydraulic methods, and are yielding a profit. Three monitors are employed. The surface gravels carry about 5 grains, the pay-streak from 2 dwts. to 9 dwts. per cubic yard.[a]

BRITISH HONDURAS.

Auriferous quartz veins are reported from the broken mountainous region between Garbutt's Falls on the Belsize river and the sea-coast at Deep river. The value of these veins is unknown, as also is the geology of the country in which they occur.[b]

SALVADOR.

Very little information is available regarding the mineral wealth of this republic. Gold-quartz veins occur, but the principal metal mined is silver. The country rocks, so far as they are known, are ancient eruptives. The gangue of the veins is largely calcite. The disposition of gold is extremely capricious, and the metal is obtained merely as a by-product of the silver mines.[c]

Numerous small gold mines are known ; as those of Pepita de Oro, in the Department of Cabañas ; of El Porvenir, south-west of Sesuntepeque ; of San Sebastian, in the Department of La Union ; of La Poza and others in the Department of San Miguel.[d]

The following is an estimate of the gold production of Salvador from 1901 to 1906 :—

Year.	Pesos.	Sterling.
1901	53,467	£5,346
1902	4,000	400
1903	30,144	3,014
1904	16,127	1,612
1905	652,568	65,256
1906	2,662,092	266,209

HONDURAS.

Of the six minor Central American States Honduras is the richest in mineral wealth. Its gold deposits were known to Columbus who, on his arrival on the coast in 1502, was informed of the golden sands of the streams of the interior. Not long after, the placers of the Olancho department were discovered and worked by the famous *conquistador*, Gil Gonzalez Davila, who obtained as his reward 120,000 golden crowns (perhaps £48,000). There are no exact records

[a] Eng. Min. Jour., Aug. 25, 1904, p. 302 ; Ib., June 13, 1908.

[b] Bristowe, "Handbook of British Honduras," 1892, p. 17.

[c] Annales del Museo Naçional, San Salvador, I, 1904, pp. 328, 424.

[d] Barbarena, Eng. Min. Jour., Ap. 18, 1908, p. 810.

of the yield of the mines of Honduras during Spanish rule, but the royal fifth (*quinto*) in the year 1594 is said to have amounted to 1½ million piastres (£300,000). In the beginning of the seventeenth century the exceedingly rich placers of El Clavo Rico, at El Corpus, department of Choluteca, were discovered. Their gold was very coarse and nuggets were numerous. With the promulgation of the edict of 1729 prohibiting the employment of forced labour many mines were abandoned, but the gold industry, as a whole, flourished for many years longer, and commenced to decline only in the early years of the nineteenth century, when Central America was given over to internecine warfare. During the last 15 years a revival in Honduras mining has taken place, largely owing to the introduction of foreign capital.

Gold-quartz veins occur both on the Caribbean and on the Pacific slopes. On the former slope the veins are of minor importance. They occur, as at Santa Cruz, in foliated gneiss, mica-schist, and talcose schist, through which penetrate numerous hornblende-diorite dykes.[a] On the Pacific side the country of the veins is Tertiary andesite and associated volcanic rocks. The veins in these rocks show all the irregularities characteristic of andesitic quartz veins. The common associates of the silver-gold, for the gold content is here comparatively unimportant, are pyrite, galena, and blende. The most important enterprise at the present time is the Rosario silver-gold mine, in the San Juan mountains, 21 miles from Tegucigalpa. The production of this mine in 1903 was about £180,000 ($900,000) and it had in 18 years distributed nearly £400,000 ($2,000,000) in dividends. The Aramecina mine, Valle department, also giving a silver-gold product, has likewise had a successful career. The richest departments in Honduras are undoubtedly Tegucigalpa and Valle. Other departments in which auriferous deposits, vein or alluvial, are known, are El Paraiso, Choluteca, Gracias, Comayuga, Copan, Santa-Barbara, and Yoro.[b]

The following is the estimated value of the produce of gold and gold-ore in Honduras during recent years :—

Year.	Value, Sterling.	Year	Value, Sterling.
1900	£7,247	1904	£14,896
1901	16,491	1905	19,495
1902	14,363	1906	7,350
1903	14.896		

[a] Jalhay, Bull. Soc. Geog. d'Anvers, XXVIII, 1904, p. 39.

[b] Leggett, Trans. Am. Inst. M.E., XVII, 1887, p. 432; Bourdariart, Bull. Soc. Belge de Geol., VII, 1893, p. 35.

NICARAGUA.

The mineral resources of Nicaragua are second in importance only to those of Honduras. Its placer deposits were worked probably before the advent of the Spaniards. Of its mining history during Spanish rule few records are extant, and indeed the mining industry appears to have been of little importance during the eighteenth century. At the time (1821) of the declaration of Central American independence there was not a single producing goldmine. A revival of interest in mining took place about 1860, but, of the many mines then opened up, few are now working.

The principal veins lie in the central chain of mountains, and particularly in the departments of Chontales (north-east of Lake Nicaragua) and Nueva Segovia, on the Honduras frontier. The districts of La Libertad and Santo Domingo, in the latter department, are perhaps the most promising. Their veins are high-grade (1½ to 2 ounces per ton). The mining development of Nueva Segovia is greatly hindered by lack of roads, and in most cases yields of even an ounce per ton are hardly profitable.[a]

About 1888 rich placers were discovered on the Prinz Apulca and other rivers flowing north-east into the Caribbean Sea. These, despite crude methods of washing, produced great quantities of gold. In a few years they were exhausted, and attention was then turned towards the gold-quartz veins of the region. Many of these showed considerable secondary surface enrichment, raising hopes that were dashed when the mines were sunk below the zone of oxidation. There are, nevertheless, several mines working at a profit on the Caribbean slope. They appear to be located on veins in andesite.[b] The country of the mining districts at the head of the Prinz Apulca is diabase. The veins in the diabase are of clear quartz carrying free gold, 835 to 871 fine.[c]

The value of the gold exported from Nicaragua for the period 1902 to 1904 is :—

Year.	Value, Sterling.
1902	£96,870
1903	114,336
1904	137,303

[a] Jalhay, Bull. Soc. Geog. d'Anvers, XXIII, 1899, p. 323.

[b] Min. Jour., Nov. 16, 1907.

[c] Mierisch, Petermann Geog. Mittheil, XXXIX, 1893, p. 35.

COSTA RICA.

This region now known as Costa Rica was overrun by the *conquistadores* somewhat later than was Mexico and Honduras, but by 1514 the Spaniards were firmly seated in power. Costa Rica (*Sp.*, rich coast) is a portion of the Castille d'Or, both names showing the estimation in which it was held, and the high hopes that were entertained by the early adventurers. Little is known of the history of its gold deposits. The famous placer deposits of the Monte del Aguacate are said to have yielded £1,400,000 ($7,000,000) to the end of 1892.[a] Most of the mines being worked in 1907 in Costa Rica were dependent on United States capital. Two main groups of mines occur near the north-west coast, viz., the Bella Vista mines near Miramar, 15 miles from Puntas Arenas, and the Abengares group, 18 miles from Puerto Yglesias on the Gulf of Nicoya. At the latter place the principal mines are the Abengares and Esperanza. The former, with a 40-stamp battery, is crushing easily-mined quartz of a reputed value of 15 dwts. per ton. Much of the gold obtained in Costa Rica is placer-gold, mainly derived from the Aguacate district, still the most important in this respect in Costa Rica. The Aguacate quartz veins were discovered about 1815 and are now of some importance.[b]

The following are the annual gold and silver returns from Costa Rica in recent years :—

Year.	Value, Sterling.	Year.	Value, Sterling.
1900	£32,000	1904	£8,367
1901	27,632	1905	58,058
1902	29,482	1906	110,645
1903	46.914		

PANAMA.

The first gold obtained by Europeans on the mainland of the Americas was that washed from the river gravels of Panama in 1502 during the fourth voyage of Columbus to the west. Since that time the sands of Darien have been more or less continuously worked by Spanish or by native industry.

The best-known gold-quartz mine of the Panama regions and, indeed, the only one of importance, is the deservedly-famous

[a] Calvo, "Republic of Costa Rica," Washington, 1894, p. 19.

[b] Crespi, Min. World, Chicago, Nov. 9, 1907.

mine of Espritu Santo in the Isthmus of Darien. It is situated on the plateau of Cana, about 2,000 feet above sea-level and at the head-waters of the Tuyra river on the Pacific slope of the ranges. The placer deposits of Cana were first worked about 1665, and the gold-quartz vein of Espritu Santo about 1680.[a] The mines were captured and the village sacked by English pirates in 1702. The village was held by the invaders for some time, but they were eventually forced to retreat; work was at once resumed by the Spaniards and was carried on with great success. In the beginning of the eighteenth century Espritu Santo was undoubtedly the richest known gold mine. About 200 miners were employed underground day and night. The ore was passed from hand to hand along the working until it reached the bottom of the shaft, when it was hauled to the surface by a windlass. At the surface the ore was taken to the river to be crushed and washed. The miners were nearly all free negroes who received, as wages at the end of the week, a small dish of crushed gold-quartz for each day that they had worked. As in modern rich "pocket" mines, a considerable amount of gold-quartz was stolen. In 1727 a great cave took place in the mine, and this, coupled with a succession of determined attacks on the camp by the Cana Indians, led to the abandonment of the mine. In course of time its very site was forgotten, and was re-discovered only about 25 years ago by Señor Vincente Restrepo, to whom most of our knowledge of ancient mining in Columbia is due. Work on the old mine was resumed about 1884. After some desultory and futile work by the Darien Gold Mining Company, the old Spanish workings were drained in 1893 by an adit level and rich ore was at once obtained.[b]

The country of the vein is an andesite, which is ordinarily greatly propylitised. The greater part of the ore-body is composed of boulders and fragments from the adjacent walls, some of the masses being many tons in weight. The rock fragments are generally completely surrounded by concentric shells of sulphides and calcite. The order of deposition has apparently been pyrite, blende, and galena, with an outermost layer of calcite in which acicular quartz-crystals occur. The gold occurs for the most part crystalline, but is often met with as wires or strings. As a rule, the greater the percentage of blende and galena present the richer is the ore. The prevailing matrix is quartz and calcite. The gold is of a very much higher grade—from 932 to 940 fine—than would be expected from its occurrence in a Tertiary andesite. Of late years the ore

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[a] Restrepo, "Gold and Silver Mines of Colombia," New York, 1884, p. 160.

[b] Woakes, Trans. Am. Inst. M.E., XXIX, 1899, pp. 249, *et seq.*

is becoming poor in depth, and the returns of gold from this mine have diminished so far that prospecting work is being carried on in neighbouring veins rather than on the main Espritu Santo lode.

Elsewhere in Panama, several futile attempts have been made to mine the erratic gold-quartz veins in the decomposed andesites of the province of Veraguas. The Remance mines lying about

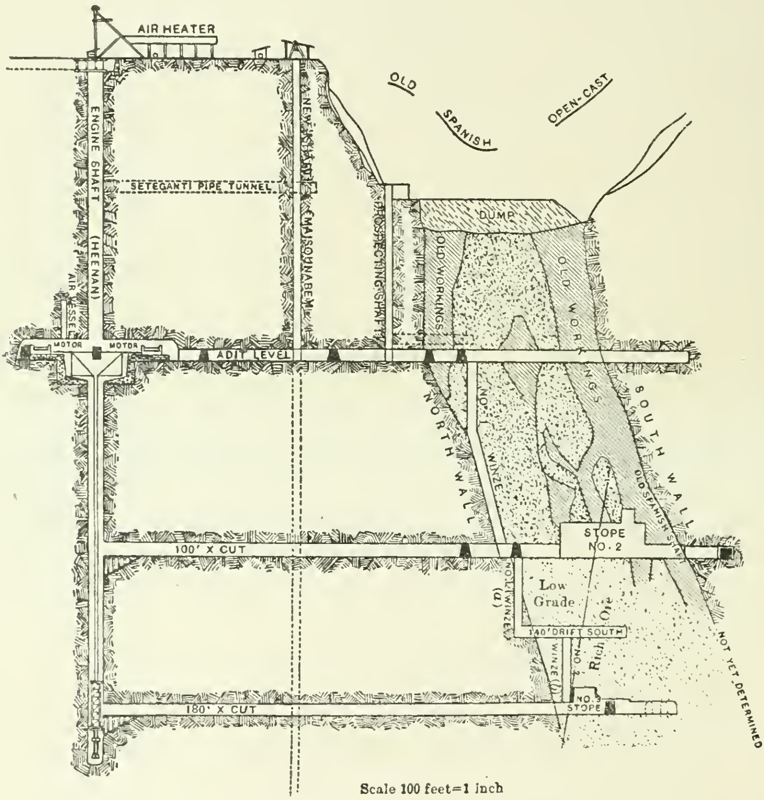

Fig. 208. Section of the Espritu Santo Mine, Cana (*Woakes*).

100 miles south-west of Panama and near Santiago in this province, have been working unsuccessfully for 20 years on a hard quartz vein 6 feet wide and of a tenor of about 29s. per ton. The centre of mining activity in Veraguas is Cañazas. In its neighbourhood several small veins have been worked in augite-andesites and dacites. At Viriguas, 30 miles north of Cañazas, are the remains of extensive reservoirs and sluices constructed at least a century ago to wash a residual clay (saprolite) containing a little gold.[a]

[a] Turner, Scott, Min. Sci. Press, 1908, p. 130 ; Hershey, Ib., p. 226.

Cana, Isthmus of Darien. (*Woakes*)

The Porce Valley, Antioquia, Colombia.

No placer mining of any importance is now carried on in the Panama State. In 1903 gold to the amount and value of 40,570 ounces and £160,189 respectively was exported from Panama.

CUBA.

It would appear that the alluvial auriferous deposits of Cuba became known to the Spaniards very soon after the discovery of the New World. As early as 1512 a proportion of the gold sent from Puerto Rico to Spain is recorded as having been obtained in Cuba. In 1514, Diego Velasquez wrote to the effect that he had completed an examination of the Cuban gold-gravels. Even then, negroes were being imported from Africa to work in them. From 1515 to 1534 gold to the value of 260,000 pesos (say £62,000) was shipped from Cuba to Spain. The royalty due to the Spanish crown was 10 per cent. of the amount collected by Spaniards and negroes, and 20 per cent. of that obtained by Indians. In 1521 the latter royalty was also fixed at 10 per cent.

The gold occurrences of Cuba have been minutely described by Castro (1868), special attention having been paid to the veins of the Guaracabulla district, in Santa Clara province, in the middle of the island. Castro made numerous assays of the vein-matrix in the neighbourhood of Holguin, obtaining an average return of £17 per ton. Later information has, however, showed that the true value of the ore, when, indeed, ore is available, is only from 50s. to 70s. per ton. The Holguin veins are apparently thin clay seams in serpentine. Alluvial gold has been found near Puerto Principe, in the province of that name. It is also reported to occur in the vicinity of Mantua, Pinar del Rio province, on the west of the island.[a]

HAITI (Santo Domingo or Hispaniola).

On the arrival of Columbus from Cuba, December 6th, 1493, the *caciques* of Haiti were found to be in possession of considerable quantities of gold and golden ornaments, derived from the streams of the interior. Two years later Pablo Belvis arrived from Spain with a great quantity of mercury, and initiated the search for gold in the New World that was destined to be fraught with consequences so terrible to the unfortunate inhabitants, not only of the West Indies, but also of Central and Southern America. The first gold recovered was at once sent to the King of Spain, and was by him forwarded to Pope

[a] Hayes, Vaughan, and Spencer, "Report on a Geological Reconnaissance of Cuba," Washington, 1901.

Alexander VI. in Rome, where it was dedicated to the service of religion in the gilding of a cathedral dome! The old Spanish historians are agreed that the early yield of gold from Haiti was enormous. It is said that, as early as 1502, 240,000 gold crowns (£96,000 or $468,000) were minted at La Vega, and that most of this gold came from the Cordillera de Cibao. The mines of La Vega and the Cibao were visited by Bartholomew Columbus in May, 1496, and very soon after the San Cristobel mines were discovered. The largest nugget recorded was that sent by Bobadilla to Spain in 1502. It was said to weigh about 600 ounces, but was lost by shipwreck on the voyage across the Atlantic. According to the Spanish historian Herrera, writing about 1601, the gold mines of La Española, in their earlier years produced some £92,000 ($460,000) per annum! This is probably an exaggeration, and it is at least certain that the gold yield of Haiti during the seventeenth and eighteenth centuries was insignificant.

The central core of the northern mountains, the Cordillera de Cibao, is a post-Cretaceous hornblende-granite that is intrusive through Cretaceous limestones and shales. Associated with the granites are diorite and dioritic porphyry.[a] The last are the metalliferous rocks of the country, gold-quartz veins and stringers occurring in them. These veins have furnished the alluvial gold of the streams. When the latter flow entirely through granite areas, their sands are devoid of gold. The gold-dust is of high quality, ranging from 940 to 970 in fineness. The principal auriferous streams are the Jaina and Yaqui on the northern slope of the Cordillera de Cibao. All the tributary streams of the Yaqui carry gold.

In the south of the island the Gosseline river, flowing into the sea at Jacmel, is auriferous below its junction with the Mabial. The doleritic basalt through which the Gosseline flows, contains ·0003 per cent. (2 dwts. per ton) gold.[b] No free gold was visible in the basalt, though flakes half an inch in diameter have been found in the Gosseline sands.

Puerto Rico.—The placer gold of Puerto Rico was first worked by the famous Ponce de Leon in 1508 A.D., using native labour and native methods, and the first gold from this island reached Spain in August, 1509. For many years the placers yielded considerable quantities of gold, and the outcrops of gold-quartz veins were also worked. By 1535, however, the yield had appreciably diminished,

[a] Rothwell, Trans. Am. Inst. M.E., X, 1882, p. 345; Garrison, Eng. Min. Jour., June 15, 1905, p. 1128; Id., ib., Sept. 14, 1907, p. 491.

[b] Tippenhauer, Petermann Mittheil., XLVII, 1901, p. 169.

and the industry may be said to have ceased some 3 or 4 years later. The streams worked by the Spaniards were the Cibuco and the Maunabo, the latter stream flowing to the south-east corner of the island. The total gold production of Puerto Rico is estimated by McKinley at 2,294,054 pesos (£1,222,730 or $5,964,541).[a]

Gold has been washed in small quantities from many streams, and especially from the Luquillo and Loiza, in the north and east of the island of Puerto Rico ; and from the streams of the Corozal district, 25 miles south-west of San Juan, in the north of the middle portion of Puerto Rico.[b] From El Yunque, the highest mountain on the island, and situated to the north-east, several auriferous streams descend. The Mameyes, with its numerous tributaries, is the richest. A considerable amount of washing was done in 1868 on the Anon, one of these tributaries. The rocks commonly found in the watershed of the Mameyes are eurite and porphyry.[c]

In the Corozal district no great quantity of gold has been found, but gold-washing gives employment to a number of peons, who are believed to earn from 2s. to 4s. ($0.50 to $1.00) per diem. Hydraulicing plant has been installed by an American, who proposes to divert a portion of the Mabille river. No placer mining is at the present time carried on elsewhere in the island. There are, however, evidences of former washings at San German, 10 miles south-east of Mayaguez, on the west side of the island. The valleys of the Negros, Congos, Cibuco, Mavilla, and Manati rivers are all known to contain auriferous sands. Near the source of the Congos river pieces of quartz have been found containing 120 to 150 grains gold. Nuggets and coarse gold are not uncommon, the largest reported from the Corozal river weighing more than 10 ounces. The natives use the wooden batea, here termed "gaveta."

The central mountains of Puerto Rico are composed of water-sorted volcanic ejecta—tuffs and agglomerates—together with dykes of hard black igneous rock containing white porphyritic crystals. Sub-crystalline bluish limestones occur with the igneous rocks. In the east, the underlying rock appears to be granite and syenite. It is considered that the original source of the gold is not gold-quartz but auriferous pyrite scattered through the igneous rocks of the island.[d]

Up to the present the experience gained by prospectors tends to show that the placer deposits of Puerto Rico are neither rich nor extensive. The annual yield of gold is estimated at nearly 400 ounces, worth perhaps £1,200 to £1,600 ($6,000 to $8,000).

[a] Min. Sci. Press, July 25, 1908, p. 129.
[b] Day, Eng. Mag., XVII, 1899, p. 242.
[c] Rep. Dep. Commerce and Labour, Washington, 1907.
[d] Hill, 20th Ann. Rep. U.S. Geol. Surv., 1900, Pt. VI, p. 794.

JAMAICA.

The occurrence of gold with oxidised copper ores is reported by Sawkins[a] from the Charing Cross and Stamford Hill mines in the parish of Clarendon. Selected fragments assayed at the rate of 15 ounces per ton. A tradition is still extant that the Spaniards worked for gold at these mines, and Herrera, writing about 1601, mentions Jamaica, together with Cuba, Haiti, and Puerto Rico, as containing gold.

TRINIDAD.

The southern slopes of the north-coast mountains of Trinidad have from time to time furnished small gold-specimens. These have been obtained from Caura, St. Ann's, and Arima. The possibly auriferous belt is considered by Guppy[b] to extend from the valley of the Caura eastward along the low hills at the foot of the main range. These rocks of the northern range of Trinidad form part of the same *massif* that is found in Tobago and in the Parian range in Venezuela. They are limestones, graphitic schists, mica-schist, talc-mica-schist, and quartzose grits. Basic intrusive rocks (epidiorite) are also found. While shoadings of quartz and quartz veins have furnished gold on assay, no workable veins have as yet been found.[c]

DUTCH WEST INDIES.

Aruba.—In the island of Aruba, lying at the mouth of the Gulf of Maracaibo, 42 miles from Curaçoa, gold-quartz veins occur in syenitic granite and schistose rocks that are traversed by diorite and diabase dykes forming the heights and the isolated plateaux of the island. The occurrences are therefore in all probability to be grouped with those of the Guianas, to be described later.

Mining for gold in Aruba was commenced by the Spaniards who worked the shallow but rich placer deposits of the "roois," or normally dry thalwegs that run with water only during the rains of the wet season. Numerous outcrops of gold-quartz are known and have been worked from time to time. A stamp mill was erected in 1872, and to the end of 1874 had crushed 252 tons ore for 556·6 ounces gold worth £1,667. Another company working from 1878 to 1880 obtained 2,075 ounces gold from 2,938 tons ore.[d]

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[a] Geology of Jamaica, London, 1869, pp. 34, 189.
[b] Proc. Vict. Inst. Trinidad, 1902, p. 522.
[c] Cunningham-Craig, Council Paper, Trinidad, No. 76, 1907.
[d] Rickard, T., "Aruba Co. Report," 1885.

An English company, holding a concession from the Dutch Colonial Office, carried on extensive mining operations for some years, sinking to a depth of 600 feet, but finally, owing to failure to find and open up new ore-bodies, abandoned the concession towards the end of 1907. The recent gold yields have been :—

Year.	Kg. Gold.	Ounces, Gold.	Value, Sterling.
1901	16	514	£2,129
1902	20	643	2,734
1903	21	675	1,904
1904	98	3,151	11,110
1905	123	3,954	16,768
1906	72	2,315	9,639
1907	—	—	27,134

SOUTH AMERICA.

The goldfields of South America are disposed in three somewhat sharply-separated areas. The chief is that extending the length of the Andes from the Isthmus of Panama to Central Chile. In its northern portion and certainly as far south as Valdivia in Chile, auriferous impregnation must be attributed to Tertiary igneous activity, manifested largely by the extrusion of andesitic and kindred rocks. An analogy with the auriferous Californian Sierra Nevada granodioritic belt may also be made out in Chile, but in the absence of data concerning the general geology of the Andes, no great accuracy in comparison is possible. Further south, in southern Chile and in Tierra del Fuego there are, however, grounds for the belief that the minor primary gold occurrences of those regions are of much earlier origin, occurring, as they do, mainly in ancient metamorphic rocks. The general geological relations of the northern and southern occurrences, however, suggest here, as in certain other regions of Tertiary auriferous impregnation, that the gold content of the later effusives may have been derived from deposits in underlying metamorphic rocks that have yielded up their gold either by absorption of the whole in an upward-moving magma, or, more probably, by the leaching action of solutions either contained in and attendant on the magma or merely set in circulation by it.

The second group is contained in a well-marked petrological province extending for 650 miles across the hinterland of the Guianas from the El Callao mine in the Yaruari basin, Venezuela, to Carsavéne in the disputed Franco-Brazilian territory. The country is essentially one of metamorphic schists and ancient plutonic rocks seamed with dykes of diabase and diorite. Everywhere the deposition of gold (primarily as auriferous pyrite) is clearly to be associated with the intrusion of the basic dykes. The gold production of the Guianas is at the present time rather from placers than from veins.

The third auriferous area of South America is contained within the Minas Geraes province of Brazil. The country of the auriferous deposits is a series of ancient, possibly pre-Cambrian, not greatly metamorphosed sedimentaries, which lie on a floor of granite-gneiss and schist. Clear evidence of connection of gold deposition with igneous intrusions is lacking, and, indeed, dyke rocks are not anywhere abundant in the neighbourhood of the gold mines. At Passagem and possibly also at Morro Velho, some faint relation may be traced between ore-deposition and acid igneous rocks, but a few diabase dykes are also known, and must be considered in this connection.

The isolation of the South American auriferous areas is due to the orogenic conditions prevailing during the Tertiary period, conditions that permitted of the deposition of the great masking plains of the Orinoco and Amazon and of the rivers of the Argentine. It is possible that with fuller knowledge a genetic relation may be established for the gold-deposits of the Guianas, Brazil, and southern Chili, and that the auriferous occurrences of South America may thus be brought into two groups instead of three.

COLOMBIA.[a]

From those highlands of northern South America now included within the boundaries of the Republic of Colombia, came much of the treasure obtained by the Spaniards after the discovery of the New World. Colombia was then the northern portion of the Peruvian dominions and was inhabited by a harmless inoffensive people with a civilisation akin to that enjoyed by the more southerly subjects of the Incas. Possessing only the crudest of weapons and unskilled in the use of even these, the Indians offered but a feeble resistance to the onslaught of the *conquistadores*. Their churches and their temples and, not least, their graves, furnished abundant spoil to the ruthless marauders whose sole purpose—the acquisition of the gold and the treasures of the country—was

[a] Restrepo, "Gold and Silver Mines of Colombia," New York, 1884, pp. 1–320; Owen, Trans. Inst. Min. Met., IV, 1896, p. 3; Granger and Treville, Trans. Amer. Inst. M.E., XXVIII, 1898, p. 33; Nichols and Farrington, Public. No. 33, Field Columbian Mus., Chicago, 1899 (with bibliography); Granger, Eng. Min. Jour., Aug. 4, 1906, p. 194; Petre, "The Republic of Colombia," London, 1906, p. 222; Halse, Trans. Amer. Inst. M.E., XXXVI, 1906, p. 160.

but thinly veiled under the cloak of Christianity. It is related of Don Pedro de Heredia, who set out in 1534 in search of the golden city of Mañoa and its ruler, El Dorado, that, failing in his quest, he remained in Colombia, and from the graves alone of the Indians collected booty to the value of £100,000. Of this, as indeed of other treasures wrung from the unfortunate inhabitants of the country, one-fifth went to the King of Spain as royalty. Even at the present day there exists in Colombia a semi-nomadic class of Indians (*guaqueros*) devoted to the search for Indian graves (*guacas*) of pre-Spanish times. One such grave found in recent years yielded no less than 300 ounces gold.

It is probable that all, or at least the greater portion, of the Indian gold was derived from placer deposits by simple batea-washing. After the Conquest, however, the Spaniards by means of their unfortunate slaves, searched the country systematically for gold. Spanish mining, placer and vein, commenced about the year 1537. Both sources of gold were so productive that until comparatively recent years Colombia ranked next to California and Victoria in the list of the gold-producing countries of the world. Its place is now taken by the Transvaal. Negro slaves were introduced at the same period as into Peru and Chile, and their employment was continued until the middle of the nineteenth century. In Antioquia the first vein mines were opened up about the end of the sixteenth century, and about the same time the placers of the Pacific-flowing streams were first worked.

It is difficult to estimate the past gold production of Colombia, since the greater part of it was obtained before the days of accuracy in statistical information. It has, however, been estimated by Señor Vincente Restrepo, than whom no one is more competent to judge, to the end of 1886, as follows :—

16th century (from 1534)			£10,600,000
17th century			34,600,000
18th century			41,000,000
19th century (to 1886)		£41,600,000	
(1886–1900)		8,216,000	
			49,216,000
20th century :—	Kg.	Sterling.	
1901	4,215	£575.216	
1902	3,796	517,988	
1903	4,100	559,425	
1904	2,971	405,421	
1905	3,888	530,595	
1906	3,296	449,114	
			3,037,759
Grand total to end of 1906			£138,453,759

The following table compiled by Restrepo shows the comparative richness of the various states, or rather departments, of Colombia. The yield is calculated to the year 1886 :—

Antioquia	£50,000,000
Cauca	49,800,000
Tolima	10,800,000
Santander	3,000,000
Bolivar	14,000,000
Cundinamarca	360,000
Magdalena	200,000
Boyaca	40,000
	115,600,000
Panama	12,200,000
	£127,800,000

The foregoing estimate is probably rather under than over the truth, since evasions of the heavy Crown royalty (20 per cent.) were common. Of the total amount, probably three-fourths was derived from placers and the remainder from veins.

The chief auriferous departments of Colombia are Cauca, Antioquia, Tolima, Santander, and Bolivar. Very little gold is derived from Cundinamarca, Boyaca, and Magdalena. Until a few years ago Panama was a state in the Colombian confederacy, but its autonomy may now be considered to be secured.

Antioquia.—In Antioquia the principal southern auriferous district is Manizales, where there are many veins and numerous small mines. The best known are perhaps those of Diamante, Gallinazo, and Tolda Fria. The elevation of the first-named above sea-level is some 12,000 feet. The vein-filling is a soft breccia of trachyte and rhyolite.[a] The lode is 3 to 4 feet wide and is traversed by small quartz veinlets ½ to 1½ inches wide, carrying free gold, auriferous pyrite, argentite, and a little chalcopyrite. Free gold is also disseminated through the brecciated vein-filling. With increasing depth the tenor of the lode in silver increases greatly ; at the outcrop it shows free gold with only a trace of silver.

The Gallinazo workings are hydraulic, the decomposed surface rock (originally a granite) being washed away to depths of 9 to 60 feet. The rock was originally highly pyritous, and it seems probable that the decomposition of auriferous pyrite has liberated the gold. The average tenor of the pay-dirt varies between 12 and 25 grains per cubic yard.

The Tolda Fria mine, 10,000 feet above sea-level, was opened up in 1873. Its vein is in decomposed talcose schist, and lies parallel

[a] Nichols and Farrington, loc. cit., p. 156.

to the cleavage planes. It is only from ½ to 2 inches in thickness—perhaps on an average ¾-inch—but is of very high-grade, reaching tenors of 100 ounces gold per ton. The schist on either side of the lode is freely interlaminated with quartz veinlets, and the whole width of the lode-channel is estimated to carry from 1½ to 2 dwts. gold per ton.

The El Zancudo mine, 4,000 feet above sea-level, and situated near Titiribi, south-west of Medellin, was discovered about 1793. It was worked by crude native Colombian methods until 1883, in which year it was acquired by a foreign company with a consequent application of modern knowledge to its exploitation. The main Zancudo workings have been in contact veins that lie at the junctions of metamorphic schists (Silurian ?) with overlying conglomerate. In close proximity are great bodies of diorite. From the contact-vein several droppers fall that eventually form a strong lode in the schists. The contact-vein carries free gold and silver, but the free gold is replaced at depth by auriferous pyrite. The gangue is quartz and calcite, while the sulphides are mispickel, chalcopyrite, blende, galena, stibnite, and dyscrasite, together with nickel, cobalt, and manganese ores. The vein varies in width from a few inches to 6 feet. The average tenor in gold is 17 dwts., and in silver 18 ounces per ton.

The Buritica mines on the west bank of the Cauca, below Antioquia, are in thin but exceedingly rich veins. These mines are famous throughout Latin South America on account of the enterprise and energy shown towards the end of the sixteenth century by their proprietress—Dona Maria del Centeno—who brought, at great expense, water from many miles distant to work these mines.

The Frontino mine lies in the north-west of the Antioquia department. The country of the mine is a coarsely crystalline diorite. The ores are auriferous copper sulphides with pyrrhotite disseminated through a quartz and calcite gangue. Gold-telluride of an undetermined species is reported to be present. In the oxidised zone cubo-octahedra of gold were common. The average tenor of the ore is 12 dwts. per ton. This mine was originally owned by the Frontino and Bolivia Company, but in 1877 was handed over to the Antioquia (Frontino) Company.

At the Quiuna mine the country of the gold-quartz vein is a limestone. With the vein is developed a chloritic schistose rock similar in character to the metamorphic andesites common in some of the Mexican mining fields.[a]

The Frontino and Bolivia Company, working the La Salada mines in the Remedios district, has for long been the most important

[a] Nichols and Farrington, loc. cit. sup., p. 142.

of the foreign gold-mining companies operating in Colombia. It was formed as far back as 1823, as the New Granada Company and was reconstructed in 1864 under its present title. The La Salada mines are El Silencio and La Salada, both on the same lode. The former had in 1906 attained a vertical depth of 366 feet. Until 1878 they were worked in the crude Colombian fashion; in 1888 modern methods were introduced with fairly successful results. The country of the lode is granite, which near the vein is often highly decomposed and strongly impregnated with pyrite. When the last is auriferous the adjacent country is sent to the mill, together with the true lode-filling.

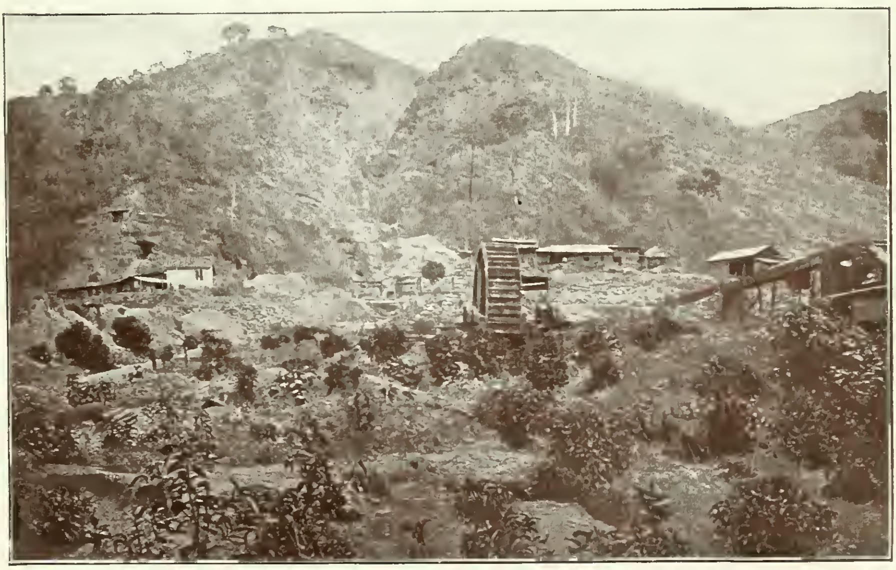
Other gold-quartz mines, lying to the north and north-east of Remedios, are the Cristales, San Nicholas, Sucre, and Cogotes. The country of the Sucre lode is hornblende-granite. Frequently one wall of the lode, especially in the neighbourhood of the ore-shoots, is hornblende-diorite-porphyrite.[a] The matrix is normally a rudely-banded quartz and, more rarely, calcite. The associated sulphides are pyrite, marcasite, blende, and galena, with occasional arsenopyrite, chalcopyrite, and pyrrhotite. The galena is highly auriferous, the pyrite much less so. Free gold is also met with even below water-level. The fineness of the bullion recovered is 609 in gold with 358 of silver. The pay-ore occurs in shoots that have a decided pitch to the east. Their length is short, varying from 100 to 300 feet, and they are separated by great stretches of barren quartz. They appear to go to considerable depths and had, indeed, not been bottomed as late as 1906.

The Santa Isabel mines are at El Coco, 12 miles south of Remedios. They were for 50 years the property of a Colombian family, but are now worked by a London company employing electrical power and the cyanide process. Their country is a dark, fine-grained, very basic, hornblendic gneiss. Three veins, varying in width from 3 to 5 feet, are worked. These mines are famous as having produced from vughs in their upper zones probably the finest specimens of "wire gold" extant.

Cauca.—In the Cauca department, lying in the west of Colombia, the Marmato is the principal quartz-mining district. Its history dates back to 1539. The mines lie about 4,500 feet above sea-level, or 2,200 feet above the bed of the Cauca, and on the mountain side to the west of that river. The country is a hard porphyry (rhyolite). Several silver veins are known, but the majority of the Marmato quartz veins carry gold alone enclosed in sulphide-ore. Six parallel veins, varying in width from 2 to 9 feet, are

[a] Flett, quoted by Halse, loc. cit. sup., p. 160.

Santa Isabel Mine, Colombia.



Portovelo Mine, Zaruma, Ecuador. (Showing ancient Spanish open-cut in hill.)

worked. The tenor is high, ranging from 12 dwts. to 1½ ounces gold per ton, but owing to the refractory nature of the ore the yield in 1898 was only some 6 to 8 dwts. per ton. A feature of Marmato is its gold-gardens (*jardin-de-oro*) in which the pyrites is collected by the peons from tailings, and is washed in the batea from time to time as it becomes oxidised.

The Echandia mine, a few miles south of Marmato, is one of the most famous of Colombian mines, not so much for its total output, which from 1867 to 1898 was about £600,000, as for its extraordinarily rich pockets. The country is hard blue porphyry (rhyolite), called by the peons *ojo de muerto*, or "dead man's eye," because of the large size and dead white colour of the porphyritic crystals. A dyke of diorite is intrusive through the acid rock. The veins mined range in width from 1 to 5 feet. Their gangue is calcareous. The ores are pyrite, galena, chalcopyrite, mispickel, native silver, and gold. The average value of the ore is about £6 per ton, of which silver represents 10 per cent.

The gold and silver veins of Colombia occur either in the andesite or more acid lavas (dacites, trachytes, &c.) that have been erupted in later Tertiary times, or in the granites, or intercalated in the Archæan schists (as at Tolima) in close proximity to these lavas or to their intrusive representatives. Owing probably to the vigorous chemical action due to tropical influences a remarkable amount of secondary surface-enrichment has taken place, and has formed those bonanzas that helped so largely to fill the Spanish galleons with their precious freight. In the oxidised zones crystallized gold is common. Cubo-octahedra, trapezohedra, and rhombic dodecahedra are the predominant forms. The average fineness of the vein-gold of Colombia is only 698, a feature in itself indicative of andesitic association.

Placer Deposits.—As already stated, the greater part of the gold yield of Colombia has been derived from placer deposits. These still give employment to great numbers of peons who live along the water-courses, often waiting for periods of drought to enable them to reach the submerged gravels. All the larger rivers passing through Antioquia are auriferous, as also are, or have been, the majority of the smaller tributaries. Of the former, the principal are the Magdalena, Cauca, Porce, and Nechi. On the two last the principal placer centres in the upper waters are Yarumal, Campamento, and Anori, but these rivers are washed as far down their courses as Caceres and Zaragoza. At Zaragoza the placers were discovered in 1581, and are said to have yielded in 18 years no less than £1,200,000. The largest nugget recorded from Antioquia was found in 1851 and weighed 80¼ ounces. Hydraulicing with elevators and monitors has been successfully carried on at various spots on the Porce and Nechi rivers. All attempts at dredging hitherto made have, however, ended in failure.

Choco.—Perhaps the most promising placer-deposits in Colombia are those of the Choco district. They lie in the basins of the Atrato river, flowing north to the Gulf of Darien, and of the San Juan river, which flows south and finally west to the Pacific Ocean. The district is unfortunately one of the most pestilential regions in South America, and for that reason its gold output diminished rapidly when in 1851 slavery was abolished in Colombia. The placers of the Choco were known to Vasco Nuñez de Balboa in 1513, but owing to the savage nature of the inhabitants of this region they remained unworked until 1654. Nevertheless, for the 46 remaining years of the seventeenth century they produced £4,000,000 gold. In the following century the yield mounted to £10,200,000. These rich fields were first worked by the compulsory labour of the Indians, but owing to the merciful intervention of the Spanish missionaries the supply of Indian slave labour was cut off in 1729. The Choco is a country of heavy tropical rains and of dense vegetation, and the placers are worked by the resident negroes only so far as is necessary to furnish a bare existence. The gravels, both of the Choco and the San Juan, are undoubtedly rich, but the deadly climate and difficulties of transport have hitherto prevented their successful exploitation by modern methods. Nevertheless, several hydraulic claims have been worked near the heads of the rivers with promising results. On the Andagueda, near the head of the Atrato, the average amount of gold recovered by extensive sluicing was $4\frac{3}{4}$ grains per cubic yard, including the overburden. The pay-streak was, however, worth from $1\frac{1}{2}$ to 3 dwts. per cubic yard. The largest nugget that has been obtained on the Choco weighed 300 ounces. As on the eastern slopes of the Cordilleras all attempts at dredging have hitherto failed. Yet the negroes have obtained as much as 12 ounces per day on the Cauca river in extraordinarily prolonged droughts. The Barbacoas district, lying along the Patia river in the extreme south-west of Colombia, carries rich placer deposits, but its climate is no better than that of the Choco. The average fineness of the placer gold of Colombia is 834 with 136 silver. The fineness of the vein gold is only 698 with 302 silver.[a]

Tolima.—The Tolima department in the south of Colombia is noted rather for its silver than for gold. Placers of considerable value occur at Ibague and also at Victoria, near Mariquita.

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[a] Restrepo, loc. cit. sup.

Bolivar.—The Bolivar department is auriferous only in the south-west, where the gold belt of the Remedios district is continued for a short distance into Bolivar.

Santander.—The comparatively small yield of the Santander department has been derived from mines in the neighbourhood of Pamplona on the Venezuelan border, and from placers in the vicinity of Bucaramanga and Giron. These last were productive in the eighteenth century, but have now greatly declined.

ECUADOR.

The gold deposits of Ecuador, though situated in wild mountain regions accessible only with difficulty, were known to the *conquistadores* within the first half-century after the discovery of America. The famous Zaruma mines, discovered, or perhaps only re-opened, by the Spaniards in 1549, are still the only known gold veins of value within the republic. They were worked vigorously by the Spaniards and by their successors. The industry flourished for more than two centuries, and, indeed, until the oxidised zone was exhausted. During the earlier and middle decades of the nineteenth century gold-mining was almost non-existent in Ecuador. Successive attempts have been made in recent years to mine the sulphide-zones of Zaruma at depth, first by a French company, then (in 1878) by an English company, and finally in 1897 by an American company. The last has been successful. Zaruma lies about 50 miles distant from the coast in the south-west portion of the republic, and in a mineral region that extends for several miles north and south. Its elevation is about 3,000 feet above the sea. The oldest rocks in the neighbourhood are gneisses and crystalline schists, apparently overlain by slates.[a] The country of the gold-bearing veins is andesite.[b] According to Finlay, however, the rock is a fine-grained holocrystalline diorite. Three veins have been worked. The "Portovelo" vein consists almost entirely of calcite and contains a little pyrite. The "Mina Grande" vein is characterised by the banded appearance of its bluish-white quartz and by the presence of galena and blende. Both the foregoing veins are faulted by the "Abundancia" cross-fissure, which has a downthrow of 100 feet. The fissure is now filled with quartz. The average thickness of the Zaruma veins is about 3 feet. The oxidised zone worked by the Spaniards extended to a depth of 100 feet only. The quartzose ore, as a whole, carries about 10 to 12 per cent. of sulphides—galena, pyrite, chalcopyrite,

[a] Finlay, Trans. Am. Inst. M.E., XXX, 1900, p. 248.
[b] Mercer, Eng. Min. Jour., Aug. 15, 1903, p. 233.

and blende. Not more than 50 per cent. of the gold is free. The free gold is 734 fine.[a] The average yield was 15 to 20 dwts. per ton in 1901, being worth £3 per ton over a quantity of 40,000 tons. The produce is exported as gold bars and as cyanide zinc-slimes. In 1905 the value of the bullion thus exported from Zaruma was £35,500, and in 1906 £49,000.

All the streams that flow from the mountains toward the Pacific carry gold in small quantities, but placer gold is worked only in the Esmeraldas district, along the Rio Santiago, where the gravels are some 80 feet in thickness.[b] Early washings gave values of 9d. per cubic yard, but the average tenor of these gravels is estimated at 4d. to 5d. per cubic yard. This tenor apparently does not admit of a profit, for the Playa de Oro, the principal mine in the Esmeraldas district, was abandoned in 1906.

The gold yield of Ecuador for the years 1901 to 1906 inclusive is reported as follows :—

Year.	Fine Gold. Kg.	Fine Gold. Ounces.	Value.
1901	165	5,321	£22,500
1902	301	9,675	41,000
1903	413	13,288	56,345
1904	200	6,430	27,290
1905	284	9,130	38,706
1906	360	11,574	49,000

BOLIVIA.

The auriferous deposits of Bolivia may be grouped into three divisions. The first extends from the Inambari basin on the western frontier across to the eastern frontier of the republic on the Upper Paraguay. It embraces the mountainous section of the provinces of Caupolican, Muñecas, Larecaja, Cercado, Yungas, Inquisivi, and Loayza in the department of La Paz, and thence stretches eastward through Cochabamba and Santa Cruz to the Paraguayan boundary. The second region lies to the south of Potosi, and east of the great Atacama desert in Chile. The third and the richest lies to the north of Lake Titicaca and east of the Carabaya district of Peru and includes the headwaters of the eastward-flowing Madre de Dios, Acre, and Puru rivers.[c] In the first region the principal

[a] Van Isschot, Ann. des Mines, Ser. 9, XX, 1901, p. 97.

[b] Higgins, Bol. Soc. Naç. de Min. de Santiago de Chile, Ser. 3, XI. 1899, p. 310.

[c] Bollivian and Zarco, "El Oro en Bolivia," Monografas de la Industria Minera, La Paz., 1898, I, pp. 1–248.

centre is the San Juan del Oro, which must not be confounded with the river of the same name in the south of the republic. At the headwaters of the Suches river, north-west of Lake Titicaca, there are extensive gravels and conglomerates that have been estimated to contain tenors of 8 grains per cubic yard.

The Tipuani river in the Larecaja province is the richest in Bolivia. It flows from the flanks of Illampu or Sorata (21,500 feet). Its deposits appear to have been discovered about the year 1562. Nine years later they were extraordinarily productive, and mining was continued most successfully until native labour became very scarce. This drawback was remedied in 1620 by the extensive importation of African negro slaves, whose labour initiated a second period of prosperity that lasted until 1760. During the next 20 years the output declined largely owing to political troubles, and in 1780 work was completely stopped by revolutions. But even immediately before 1780 gold had been so abundant that in that year one of the principal owners had a stock awaiting sale of no less than 400,000 ounces. A company working in the Tipuani river from 1818 to 1867 is reported to have obtained 150,766 ounces gold. Sorata was the chief town of the gold region, and as such was famous throughout the world in the seventeenth century.

The auriferous gravels of the Tipuani are of great depth, and true bed-rock is seldom reached. Concentration of gold generally occurs on "false-bottoms" of ferruginous conglomerates, locally known as *cangalli.* The pay-streak lying on the *cangalli* varies in thickness from 1 to 3 feet, and may carry an ounce of gold to the dish (200 to 250 ounces per cubic yard). The thickness of the *cangalli* is unknown, since it is rarely penetrated. The gold is 980 fine and occurs in flattened, oval flakes. Nuggets are rare.[a]

Other placer deposits of value are at Yani, Tacacoma, and Chuquiaguillo. The last are near La Paz, and were the only placers being worked in 1906. They have yielded much coarse gold and many nuggets. The heaviest of the latter weighed 703 ounces (95 marcos) and was sent to Madrid in 1718. Other nuggets of 162 ounces and 133 ounces respectively have been found in recent years. Of lesser importance are the auriferous gravels of Choquecamata (75 miles from Cochabamba), Chiquitos, and Rio de la Paz, near the capital.

Of gold-quartz mines, the Araca, in the province of Loayza, is the chief. The tenor of the quartz is low, ranging from 3 to 8 dwts. per ton, but as the lode is very wide and the ore free-milling, immense profits have been made in past years. It is believed to still hold large reserves of low-grade ore, but is no longer worked,

[a] Frochot, Ann. des Mines, Ser. 9, XIX, 1901, p. 159.

owing partly to the low tenor of the ore and partly to the difficulty of transporting stores and machinery to the mines.

In the second auriferous area lying to the south of Potosi the only veins calling for present mention are those of Poconota, a mountain in the department of North Chichas. They are small ferruginous quartz veins that carry sometimes as much as 10 ounces gold per ton. These veins were mined by the Spaniards on a very large scale.[a]

Alluvial gold occurs in several of the rivers of southern Bolivia. A recent attempt on an extensive scale to dredge the gravels of the Rio San Juan do Oro near Tupiza resulted in failure. Three dredges had been erected. One of these was dismantled and was being re-constructed in 1908 on the Quebrada de Esmorca, a neighbouring tributary of the San Juan.

The northern regions of Bolivia, east of Carabaya, are little known and are inhabited mainly by wild Indians.

Soetbeer estimated the yield of the Bolivian mines from 1540 to 1750 at £420,000,000, and from 1750 to 1870 at £250,000,000. These estimates are certainly far too high, and the estimate quoted by Frochot[b] for the period 1545 to 1875, viz., £41,013,000, is probably much nearer the truth. From 1895 to 1899 an average of 505 kg. gold worth about £65,000 was annually produced. Since then the yield has diminished considerably, the average for the three years, 1903 to 1905, being only about £4,583 ($21,995).[c]

PERU.

Peru may be divided from west to east into three lateral belts—the Coast, Sierra, and Montana zones—the physiographical character of each being sufficiently indicated by its designation. Gold occurs in all three belts, but its method of occurrence is different in each. In the Coast region it is found in thin veins in granites. The gangue is, in the oxidised zones, quartz with ferruginous oxides ; in depth the gold is partly free and partly associated with pyrites. The principal veins of this region are those of Andaray, Montes Claros, and Otaca.[d]

The Sierra region contains numerous veins of auriferous quartz, whilst most copper-pyrites veins also carry a little gold. The departments of Ancachs, Apurimac, and Cerro de Pasco are the most noteworthy. In the Cerro de Pasco district, famous for its

[a] "Bolivia," Bureau S. Amer. Republics, Washington, 1904, p. 119.

[b] Loc. cit. sup.

[c] Min. Industry, 1906, p. 884.

[d] Laroza, Mining Mag., New York, XI, 1905, p. 50.

great silver mine of the same name, is the Quinua mine of the Chiquitambo Gold Mining Company. The country in the neighbourhood of the veins of Quinua is Upper Cretaceous dolomite, limestone, red sandstone, and fossiliferous marl. Through the sedimentary rocks are intruded two andesite dykes. The auriferous quartz is distributed in pockets in the dolomite. This mine was in the early part of 1908 yielding about 250 ounces per month.

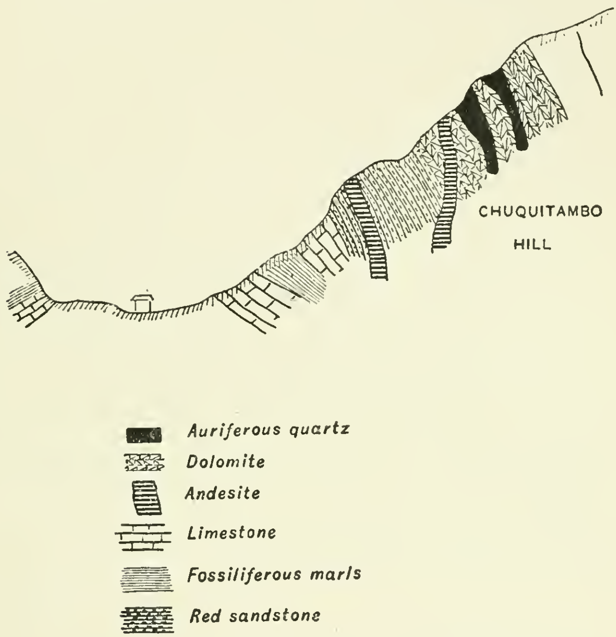

FIG. 209. SECTION THROUGH THE QUINUA MINE (*Laroza*).

In the Montana region the departments of Cuzco and Puno are the most productive. In this region gold occurs in the richer areas, as in that of Carabaya (north-west of Lake Titicaca), in quartz veins in Silurian slates. The principal mine now being worked is the Santo Domingo, owned by the Inca Gold Mining Company (Philadelphia). The gold of its veins is accompanied by pyrite and stibnite. The mine is situated on the eastern slope of the Andes, and may be reached only by a long and arduous mule journey. It has been highly productive for several years and for some time, though crushing with only a 10-stamp mill, was yielding £25,000 gold per month. In 1903 its output was 15,580 ounces gold.

Placer deposits are numerous in the province of Sandia (north of Titicaca and south-east of Carabaya). The tenor of the gravels of Aporona in this province has been estimated at 10d. per cubic yard. The sands of all the rivers of the Eastern Cordilleras contain gold, some of which is recovered by the native method of transforming the dry beds of the streams into rude sluices by paving the bottom with rough stones, the gold settling in the interstices between the stones during the floods of the wet season. By this method no less than 7,572 ounces gold were obtained in 1903. Modern hydraulic methods have been adopted in a few cases, as at the San Antonia de Poto mine (Sandia district), which yielded 2,666 ounces gold during 1903. The conglomerate gravels of the Poto are from 60 to 180 feet thick. The pay-streaks within the gravels are from 6 to 10 feet thick and carry perhaps 3½ to 4½ grains per cubic yard (·3 to ·4 gramme per cubic metre).[a] Dredging on a large scale was being inaugurated in 1907 on the Rio Inambari in the Carabaya province and on the boundary between Peru and Bolivia. The extensive placers of Pataz and Sandia, as well as those of the Rio Nusimiscato, were also attacked by modern methods. In the latter river the distribution of the gold is very irregular, no clearly-defined boundary existing between the overburden (*carga*) and the pay-streak (*venero*). The tenor of these gravels where examined varied from less than ½ grain to 4½ dwts. per cubic yard.[b] Large nuggets have in bygone years been found in the Peruvian gold-gravels. One from the Carabaya district weighed 1,503 ounces, and was forwarded to Spain for presentation to Charles V. (1517—1558).[c]

The following table indicates the varied sources of the gold of Peru, the year 1906 being selected :—

	Kg.
Gold in ingots, dust, &c.	966·108
,, from lead bars	12·671
,, ,, pyritous silver ores	16·513
,, ,, auriferous mattes	14·059
,, ,, various minerals	234·265
,, ,, ingot copper	3·730
	1,247·346

The gold yield of Peru during recent years is as follows :—

Year.	Fine Ounces.	Value, Sterling.
1903	34,667	£147,262
1904	19,335	82,134
1905	24,967	106,062
1906	40,091	170,355

[a] Malsch, Verh. des Deutsch. Wissen. Vereins. zu Santiago de Chile, IV, 1899, p. 339.

[b] Duenas, Bol. Cuerp. Ing. Min. de Peru, Lima, LIII, 1907.

[c] For detailed accounts of the geology and auriferous occurrences of Peru, see Boletin del Cuerpo de Ingenieros de Minas del Peru, Lima, 1902–1908.

VENEZUELA.

Gold is widely distributed throughout Venezuela, but it is only in the Yaruari district, in the basin of the river of that name, south of the Orinoco, that it occurs in appreciable quantity. Its existence has been noted from the west of Valencia in weathered gneiss;[a] from near Carupano, on the same mountain chain as that of northern Trinidad;[b] and from metamorphic schists in the neighbourhood of Caracas. The Yaruari river flows southward to join the Cuyuni, the main western tributary of the Essequibo in British Guiana. The possession of the Yaruari basin had long been a subject of dispute between Great Britain and Venezuela, but the question was settled in 1898 by an award in favour of Venezuela. The chief mine of the district is the famous El Callao, in its day one of the richest of the world's gold mines. It was possibly, indeed, a faint rumour of former workings on these mines that gave rise to the El Dorado legend of the early years of the sixteenth century. Between the Orinoco and the Amazon there lay the dominions of the golden emperor, "El Dorado," the last of the Incas. His was the gorgeous city of Mañoa situated on the shores of the beautiful lake of Parima. From 1536 to 1746, and especially in the earlier years of the period, numerous expeditions, commencing with that of George de Spires, were made in search of Mañoa by soldiers of fortune from all the principal European nations. Of the English, Sir Walter Raleigh alone need be mentioned. They all failed, it is true, in their quest, but they nevertheless rendered a lasting service to geographical science.

El Callao.—Gold was discovered, or more probably, re-discovered in the Yaruari district in 1849 by Dr. Plassard, or, according to other authorities, in 1856, by Friedrich Sommer, but it was not until 1865 and 1866 that the rich veins of Chile, Potosi, and El Callao were successively opened up.

The rocks of the region are ancient metamorphic schists associated with a gneiss that is intruded by granite and quartz-porphyry. The schists are talcose, micaceous, and amphibolitic. The whole series in Venezuelan Guiana, as indeed in the other Guianas, is intruded by basic rocks, mainly diabase and diorite. In the Nueva Providencia district, which contains nearly all the auriferous occurrences, the veins lie in the widely-developed diabasic member of the series. Though quartz veins are met with in great numbers in the schists, it is only where they are in close connection with the diabase

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[a] Wall, Q.J.G.S., XVI, 1860, p. 463.

[b] Ann. des Mines, I, 1852, p. 600.

that they become auriferous.[a] A much later intrusive diabase, north of the Yaruari river, is associated with a diallage rock that is probably a gabbro. The most productive lodes of the Yaruari were the Callao, Chile, Potosi, and Caratal. All except the Callao have a strike practically east and west. El Callao, however, swings to the north until it runs north and south across the Yaruari river. The Chile vein dips south about 55° and has a thickness of some 4 feet. At the outcrop its tenor was an ounce per ton, but at 200 feet in depth it had risen to 5 to 6 ounces per ton. On its hanging-wall and separated from it by only a few feet of country is a lode, or, more probably a bed, of red hornstone or jasperoid rock locally known as *porfido* or *piedra morada.* This rock contains pyrite. It is found in many places in the district and is everywhere regarded by prospectors as a favourable indication for gold veins.

El Callao lode ran, as already stated, almost north and south, and dipped west. Its thickness was only from 1 to 2 feet. The quartz was white and somewhat vitreous and contained much coarse lamelliform gold associated with a little pyrite. The country of the vein is termed "felstone" by Le Neve Foster.[b] A cursory inspection of specimens collected by him and now in the Museum of the Geological Society of London, indicates that the felstone is either a true felsite or a highly silicified sedimentary rock, probably the former, but in either case, a member of an ancient schistose complex. The felstone contains numerous crystals of pyrite.

In 1895 the El Callao mine was no longer able to pay expenses, and was closed down. It had a capital of £3,220,000, and had during its life milled 719,257 tons of quartz for a yield of 1,438,638 ounces gold.[c] Over one-third of the total production was distributed in dividends among the shareholders.

East of El Callao the Corinna lode is in decomposed schist. The Tigre and several other lodes to the south lie in diabase. Considerable secondary auriferous deposition, due to the decomposition of pyrite, has taken place in all these veins, in the vughs and cavities, which are often plated and are occasionally nearly filled with leafy gold. In nearly every case the gold of the Caratal district appears to have been originally associated with pyrite. In 1907 only one gold-mining company was working regularly in the Yaruari district.

A considerable quantity of gold was also obtained from the placers of the Yaruari basin, especially in the *quebradas* (valleys)

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[a] Attwood and Bonney, Q.J.G.S., XXXV, 1879, p. 582.

[b] Q.J.G.S., XXV, 1869, p. 336.

[c] The writer has been unable to ascertain whether the last figures denote British ounces of 31·15 grammes or Spanish onzas of 28·75 grammes.

of the Tigre, Peru, Aguinaldo, &c. In these valleys the gold occurs both in the ordinary way on "bottoms," on *cascajo* or decomposed bed-rock, and also below laterites (*moco*), the latter being regarded as indicative of good pay-gravel. Dredging was attempted on the Yaruari river in 1899, but proved a failure.

The gold yield from Venezuela in recent years has been :—

Year.	Kg.	Ounces.	Value, Sterling.
1900	600	19,290	£63,904
1901	842	27,070	89,151
1902	653‡	20,994	89,076
1903	451	15,000	61,602
1904	262*‡	8,423*	30,708*
1905	621	19,965	60,163†

* Second half-year only.
† Includes £1,428 value of gold ore exported.
‡ Fine ounces.

Several discrepancies will be noted in the foregoing table, which is nevertheless compiled from official sources.

BRITISH GUIANA.

The geology of British Guiana is, in its broader aspects, extremely simple. For 50 to 70 miles from the coast the country is covered with interbedded clays, sands, and silts of recent or Pleistocene origin. Further in the interior, in the few spots where outcrops of bed-rock are obtainable, Archæan metamorphic rocks, varying in character from aplite-gneiss to hornblende-schist, are exposed. The foliated rocks are intersected by belts of granitite and by masses of true granite. In other parts the gneissose rocks give place to wide areas of porphyries, porphyrites, and felsites. Overlying the Archæan rocks in some regions is a great development of unfossiliferous sandstone and conglomerate of unknown age. Both the Archæan rocks and the sandstones are penetrated by dykes and sills of diabase. In places, as at Roraima, the diabase appears to have been developed as laccoliths. Elsewhere it has flowed over the Archæan rocks.[a] Gold is found widely diffused in the districts occupied by the Archæan rocks, but only in payable quantities where certain conditions prevail. The chief of these appears to be the intrusion of basic igneous rocks. The basic rocks are of two periods ; the earlier belonging to the gneissose formation

[a] "Gold, &c., of British Guiana," Georgetown, 1903, p. 4.

and probably originally gabbro and diabase, but now converted to quartz-diorite, epidiorite, amphibolite, and hornblende-schist, while the later igneous rock is an unaltered diabase.

The former type of rocks yields the Groete Creek goldfield; parts of the Cuyuni goldfields; the Puruni field; and that of the upper Mazaruni. Gold appears to be diffused through the mass of rock and to be set free during its weathering and degradation. Some of the British Guiana rocks contain sufficient gold disseminated through their bulk to account for economically valuable placers.[a]

Where the Archæan rocks are traversed by dykes of the later diabase, gold is not infrequently found in the decomposition products, especially in the vicinity of the junction of gneiss and diabase. Where the diabase dykes traverse a district already intersected by intrusions of quartz porphyry, felsite, and allied rocks, the junctions are frequently rich in gold, and from their degradation products many rich placers have been derived. The auriferous deposits occur most frequently where the dykes of diabase are small and numerous.

A third locus of gold, at times of economic importance, is in highly mineralised acid rocks, such as the aplite of Omai. In many places there occur pegmatite veins that gradually pass into quartz veins in lateral extension, but these are almost always barren.

The fineness of the placer gold of British Guiana gold varies from 914 in the Potaro to 932 in the Puruni district. The alluvial gravels, except at Omai, where a hydraulic plant was erected, and at various spots where dredging has been attempted, are worked by simple methods of sluicing.

The alluvial gold of British Guiana is found in the gravels of the existing streams. Ordinarily, the pay-streak is only from 2 to 3 feet thick, while the overburden is from 4 to 7 feet, but may reach in a few cases 20 feet in thickness. The pay-streak rests on clay or on decomposed bed-rock. As a rule the amount of pay-gravel in the smaller streams is insignificant. The extensive use of hydraulicing installations is thus precluded. Most of the gold-washing is therefore done with the "tom" or sluice by small parties of independent negro gold-washers, locally termed "pork-knockers." Gravel containing less than 2 dwts. per cubic yard cannot be worked at a profit with "toms" and negro labour. With sluices, however, gravels of a somewhat lower tenor (1 to 1½ dwts. per cubic yard) may be treated.[b]

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[a] Harrison, Rep. Inst. Mines, Brit. Guiana, 1906.

[b] Powell, Trans. Inst. Min. Met., VIII, 1900, p. 354.

Only one large hydraulicing company has carried on operations in British Guiana, viz., the Demerara Exploration Company, working at Omai on the Essequibo river. This company commenced work in July, 1902, but by 1907 had exhausted its sluicing ground and had ceased operations in that direction. In 1904, the company placed on Gilt Creek, near Omai, a small dredge that had been working with indifferent success on the Barima river. Its operation proving successful, a larger dredge with 5 cubic feet buckets was placed in commission in June, 1906. So far as they are available the total returns of this company from sluicing and dredging appear to have been :—

July, 1902	to March, 1903	..	..	2,250 crude ozs.
1903	1904	..	..	4,392 fine ozs.
1904	1905	..	..	12,683 ,, ,,
1905	1906	..	..	12,651 ,, ,,
1906	1907	..	..	948* ,, ,,

* From the large dredge alone and for eight months only.

Dredging at Omai has been largely hindered by buried logs and trees. The fineness of the alluvial gold ranges from 882 to 960.[a]

On the Conawaruk river a large dredge was erected and commenced work in January, 1907. The costs of working were estimated at £69 per week, and the returns were at the rate of £150 per week. To June 30th, 1907, it had produced 612½ ounces gold.

Gold-quartz veins have never, up to the present, contributed materially to the gold output of British Guiana. As early as 1863, however, a small quartz vein was opened up at Wariri, on the Cuyuni river, but was abandoned before it had reached the producing stage. In 1892-3 a remarkable boom, based on a single rich pocket of vein quartz, took place in Demerara. The boom collapsed as soon as the pocket was worked out, a matter of only a few days to the 20-head stamp battery that had been erected to treat it. The first serious gold-quartz mining was at the Kaniamapoo mines, some distance up the Demerara river, and east of Omai. The quartz was of very low tenor. The initial crushings yielded at the rate of 2½ dwts. per ton or 480 ounces in all. The mine was soon abandoned. A Huntington mill was also in operation at the Aparpoo mine, 5 miles further north.

The Barima mine at Arakaka Creek, in the north-west portion of the colony, produced in 1896-7, 8,017½ ounces gold from 9,500 tons quartz, an average of 16·88 dwts. per ton, before exhausting the ore-shoot on which it was working. Its veins lie in a decomposed

[a] Lungwitz, Zeit. für prakt. Geol., 1900, p. 213.

diabase. Mining appears to have been abandoned in subsequent years owing to lack of ore developed. The mine was, however, reopened in 1907. The veins of the region vary greatly within themselves in size and in value. The oxidised zone reaches on an average a depth of 100 feet. At this depth the ore-bodies are usually impoverished, but the tenor of the ore as a rule rises slightly on passing into the sulphide zone.

The most promising mine in British Guiana in 1908 was the Peters mine, situated on the right bank of the Puruni river. Its veins lie in solid hornblende-schist. Milling commenced with a 15-stamp mill in September, 1905, and by the end of June, 1906, 8,278 ounces gold had been obtained from quartz of a tenor of 15 dwts. per ton. In 1906-7 a further 9,500 ounces were recovered from 12,621 tons ore. Its workings had in 1908 reached a depth of 300 feet.

An interesting occurrence is that of Omai, Essequibo river. The surface rock here is a diabase which is associated with aplite and granitite. At a depth of 964 feet borings through the acid rocks came upon epidiorite. The Archæan rocks of the country are apparently intruded by this mass or stock of aplitic granite. After its intrusion there was a succession of outbursts of diabase, and the latter rock is now developed both above and below the aplite. The interest of the occurrence lies in the fact that the aplite is auriferous, selected specimens assaying as high as 15 dwts. per ton. The aplite further carries in depth a great deal of pyrites, and the gold found is probably to be associated with that mineral. Small quartz veins, which are exceedingly numerous in the aplite, are slightly auriferous.[a] During 1904-5, ninety per cent. of the total yield of the company, or more than 22,600 ounces gold, was obtained by sluicing the highly decomposed aplite. It was worked out in benches to 150 feet, to which depth the aplite was freely decomposed. The gold was free and often well crystallized, and there was no pyritous residue in the wash. The acidic rock is therefore the primary source of much of the alluvial gold of Omai.[b] The only occurrences readily comparable with that of Omai are those of Berezovsk, in the Urals, and of Gallinazo, Colombia.

In 1907 about 80 per cent. of the gold yield of British Guiana was produced by individual miners and small parties. From 1884 to the end (June 30th) of the fiscal year 1899-1900 the total output

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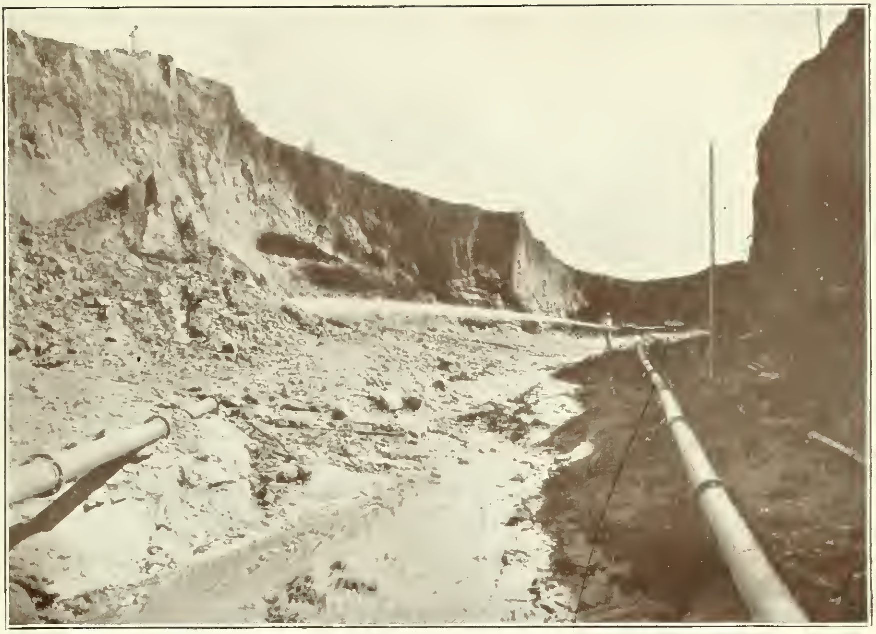
[a] Lungwitz, Zeit. für prakt. Geol., 1900, p. 213; Harrison, Govt. Reports, Georgetown, 1900, p. 10; Id., ib., 1905, p. 52.

[b] Linck, *in verb.*



Decomposed Aplite Dyke, sluiced for Gold.

General View

The open-cut made by sluicing away the aplite may be seen traversing the ridge in the middle background.

OMAI, BRITISH GUIANA.

of the colony had been 1,250,469 crude ounces. Since the latter year there have been produced :—

Year.	Crude Ounces.	Value, Sterling
1900–1	114,102	£409,968
1901–2	101,332	369,450
1902–3	104,527	381,080
1903–4	90,336	329,350
1904–5	95,864	349,504
1905–6	94,363	334,202
1906–7	85,505	303,542*

* Estimated.

DUTCH GUIANA (Surinam).

Gold in Surinam is entirely derived from placer-mining of comparatively recent development, for though it had long been known that gold occurred in the hinterland, it was only after the sugar-cane industry had ceased to be profitable that attention was turned towards the minerals of the country. The first gold-deposits of consequence were found in 1885-6 on the Lawa river, a tributary of the Marowyn, which separates Dutch from French Guiana. These proved very rich for a time, and led to the establishment of permanent workings on both the Dutch and French sides of the river. Speaking generally, the placer deposits of Dutch Guiana lie in the east and south-east of the colony. The " bottom " of the placers is almost everywhere a stiff clay. The gravel is treated in " long-toms " or in sluice boxes. The gold is often coarse, and nuggets are not rare. Of the latter the heaviest recorded weighed 530 ounces (16·5 kilos).[a] The gravels are often highly ferruginous, in which case the gold is often coated with iron oxides, necessitating considerable care in the treatment by amalgamation of the concentrates obtained by washing. The large nugget above-mentioned was thus coated, and nearly escaped observation. Labour is scarce, ineffective, and expensive. With it the gravel, to be profitable, must be sufficiently rich to return at least 2 dwts. per day per labourer. Du Bois, however, estimates that a yield of 3s. 4d. (2 florins) per man per day would cover all working expenses. This sum would require gravel of a tenor of about 45 grains per cubic yard.

[a] Granger, Trans. Amer. Inst. M.E., XXVI, 1896, p. 516; Hennecke, Zeitsch. Berg-Hütt. und Sal., XLVI, 1898, p. 252; Du Bois, " Geologisch-bergmännische Skizzen aus Surinam," Freiberg i. S., 1901, pp. 1–112.

In 1896 the six principal placers had yielded a little over a million sterling, divided as follows :—

Barnett's	£600,000
Green's	200,000
Mueller and De Jong's	100,000
Solomon's	100,000
Montana	50,000
Savanna	30,000

In 1897 the principal producing rivers with their yields were :—

Surinam	13,974 ounces.
Saramacca	4,356 ,,
Marowyn	2,456 ,,
Lawa	1,479 ,,

The gold-gravels here, as in the other Guianas, are often concealed beneath a lateritic surface layer. The gold, moreover, is occasionally disseminated through the more impure laterite. The average fineness of Dutch Guiana placer gold is 926. Dredging methods have recently been tried, but no information as to their success or otherwise is available.

The rocks of Dutch Guiana, as indicated on the geological sketch-map accompanying the treatise by Du Bois, already cited, are mainly crystalline schists, phyllites, and ancient sedimentary rocks, with which are associated extensive exposures of granite, gneiss, and diabase. Search for gold-quartz veins is a matter of extreme difficulty in the dense tangled forests of Guiana, but veins of a fairly high tenor have, nevertheless, been found. These occur in the crystalline schists and phyllites, especially where the metamorphic rocks have been intruded by igneous dykes. Yet quartz veins in intrusive diabase or diorite or in granite have so far been found to be either barren or to be too poor to be profitably worked. The gold-quartz veins of the neighbourhood of the De Jong and Guyana-Goud placer deposits lie in phyllites. The country is highly weathered ; the veins traversing it carry an oxidised zone to depths of about 100 feet. The average width of the veins is from 1 to 3 feet. The gold is finely disseminated through the quartz and is associated with auriferous pyrite, which often impregnates in addition the walls of the vein.

The progress of mining in Dutch Guiana has been greatly hindered by the lack of transport facilities. A railway to the gold-fields was in course of construction in 1907.[a]

[a] Middelburg, Min. Jour., April 4, 1908, p. 407.

The total gold production of Dutch Guiana from 1879 to 1900 inclusive was 536,220·2 ounces (16,678·716 kg.). Since 1900 there have been produced the following :—

Year.	Kg.	Ounces.	Value, Sterling.
1901	753	24,209	£85,949
1902	587	18,872	67,085
1903	682	21,926	77,918
1904	882	25,784	91,548
1905	1,071	34,883	116,848
1906	1,188	38,194	129,611*
1907	1,085	34,882	118.373*

* Estimated.

FRENCH GUIANA (CAYENNE).

The general geology of French Guiana, as of the other Guianas, may be briefly outlined as a complex of Archæan and metamorphic rocks lying in the hinterland, with Tertiary or more recent sedimentary rocks nearer the coast. Only minor modifications of the foregoing statement are necessary. Devonian limestones outcrop not far from Cayenne, and Silurian slates are known in the Mana valley. The ancient metamorphic rocks comprise gneiss, talc-schist, mica-schist, amphibolite, slate, &c. These are intruded by granite and pegmatite, and also by diabase and diorite, the latter also occurring in flows.[a]

The quartz veins of French Guiana are met with in the older schists and also in the diorites, forming often, as is also the case with quartz veins in similar rocks on the Ankobra river, West Africa, bars or falls in the courses of the rivers. The veins vary in width from a few inches to several feet. Their quartz is ordinarily milky-white in colour, but when rich it assumes a bluish tint. Pyrite and mispickel are abundant. Levat concludes that the majority of these veins are barren, and that it is only in the neighbourhood of diorites and diabase (as at Adieu-Vat) that they become auriferous. The diorites and diabases of French Guiana are often highly impregnated with pyrites, and in such cases are themselves auriferous. The proportion of pyrites present may reach 5 per cent. of the total weight of the rock. The auriferous content of these basic rocks as determined by Levat,[b] varied from 1 to 1½ dwts. per ton, and depended, as a

[a] Levat, Revue Scientifique, Ser. 4, IX, 1898, p. 705; Id., Ann. des Mines, Ser. 9, XIII, 1898, p. 386; Pelatan, "Les Richesses Minérales des Colonies françaises," Paris, 1902, p. 42.

[b] Loc. cit., p. 415.

rule, on the amount of pyrites present. A sample of diorite from Maripa yielded the exceptionally high return of 15 dwts. gold per ton, but in this case free gold was noted in the rock prior to assay. Granitic intrusions on the other hand appear to be barren. Similar diorites to the foregoing occur in all the Guianas, from the famous El Callao mine in Venezuela in the west to the Carsavéne fields in the Disputed Territory, north of the Amazon, in the east—a total distance of some 650 miles. It therefore becomes obvious that we are here dealing with a single petrological province, in which the intrusion of basic rocks is genetically connected with auriferous impregnation. The subject has been dealt with at length in an earlier section of this volume, and will not be further pursued in this place.

Only one gold-quartz mine in French Guiana has attained any measure of success. It belongs to La Société Anonyme de St. Elie, operating at Adieu-Vat on the Sinnamari river. Its veins are in greatly weathered dioritic rock, the zone of weathering extending to a depth of 80 feet. The veins are from 2½ to 4 feet in thickness and are of high tenor, ranging from 2½ to 3 ounces per ton over several thousand tons. Work was commenced at Adieu-Vat about 1878, and in 1885 a small 20-head stamp mill was erected and treated some 2,500 tons of 2-ounce stone, leaving from 6 to 30 dwts. gold per ton in the tailings. The ore-shoot soon gave out, and operations then ceased. In 1890 the mine was re-opened for a short time, when 10 tons of 7¼-ounce stone were extracted. The mine was being worked again in 1905. With a capital of £160,000 La Société Anonyme de St. Elie had paid in dividends to its shareholders no less than £191,724 between the years 1878 and 1898.

In the Disputed Territory the bed-rock of the rich placers is amphibolite and amphibolite gneiss, through which are intruded diorites that are sometimes porphyritic and are often epidotised. The diorites contain veins of quartz and thin intrusions of pegmatite (granulite), the latter carrying, as accessory minerals, garnet and hornblende. Both the quartz and the granulitic veins are auriferous, but the gold is always intimately associated with the quartz even in the granulites.[a]

Nearly all the gold of French Guiana is derived from its placer deposits. The earliest discovery of alluvial gold appears to have been made in 1853 by a Brazilian prospector, who had settled on the upper waters of the Approuague river. The auriferous gravels occur along the present valley bottoms and are of comparatively recent origin. The richest placers are found distributed along the course of the diabasic and dioritic intrusions through the

[a] Levat, loc. cit., p. 437.

country, and also along folds produced in the quartzose schist by the basic intrusions. All streams radiating from such areas are likely to contain gold. These conditions are fulfilled in the case of the St. Elie, Dieu-Merci, Élysée, Pas-Trop-Tôt, Lawa, and other placers.

A vast extent of the lower country is covered with a lateritic deposit (*roche à ravets*), which is occasionally auriferous. Samples of this rock yielded on assay to Levat tenors of 1½ to 4½ dwts. per ton, with two exceptionally high assays of 11·6 dwts. and 2⅓ ounces per ton respectively. It was in such a ferruginous rock that the largest nugget found in the colony was obtained. It weighed 530 ounces, and was coated with iron oxide. Levat compares these lateritic deposits with the jacutinga and canga of Brazil, but there is no real analogy except in the high percentage of ferruginous matter. On the other hand, an analogy between the older rocks of the two countries is sound.

With native labour and under favourable conditions a gold content of at least 1½ dwts. per cubic yard (3 grammes per cubic metre) is required in order to return a profit. A party of 12 workers, of whom four are diggers, will not treat more than 6 to 8 cubic yards per diem. The gold is ordinarily somewhat coarse, and nuggets of ⅓ to 1½ ounces are by no means rare.

Since the only traffic routes of the country lie along the waterways, it is only near these that placers have been discovered. Taking the placer districts of the colony in order from west to east, the first is the Marowyn (Maroni), the boundary river between Dutch and French Guiana. It was to one of its main tributaries, 140 miles from its mouth, that the great Lawa rush took place in 1889. The ownership of the Lawa territory was long in dispute between France and Holland, but was finally awarded to the latter country. It still remains one of the richest placers in the Guianas. Next to the east is the Mana district, worked since 1879. Then follow in order, the Sinnamari, Kourou, Comté, Approuague, Oyapok, and finally, the Carsavéne district, on the river of that name, and in the disputed Franco-Brazilian territory north of the Amazon.[a] The placers of the last were extraordinarily rich, the two discoverers, after only two months' work, obtaining in 1893 nearly 10,000 ounces (300 kg.) gold. The news of this yield naturally caused a rush, in which many thousands participated. In 1907 the yield from the district was inconsiderable.

Until 1905 all the alluvial gold recovered had been obtained by crude methods of sluicing, but in that year a small dredge was

[a] Katzer, Oesterr. Zeit. für Berg- und Hütt., 1897, p. 295; Id., Zeit. für prakt. Geol., V, 1897, p. 422.

erected on the Courcibo river, a tributary of the Sinnamari. For some time it gave good returns, but was eventually sunk during a flood. Two dredges were in operation in 1907 on the Élysée placer on the Lezard river, a left tributary of the Mana. The Lezard valley is here from 100 to 400 yards wide. The bed-rock lies at a depth of some 12 to 16 feet. Heavy black sand is very abundant, sometimes forming 10 per cent. of the wash. Assays of the black sand showed gold tenors of from 1½ to 15 ounces gold per ton.[a]

From 1868 to 1899 inclusive the officially estimated gold-yield of French Guiana, based solely on the amount of duty paid (8 per cent.), was 1,920,608 ounces (59,739 kg.) worth £7,168,680. For obvious reasons, not all the gold produced is declared for duty, and to the foregoing figures at least a third is to be added, making the total production of the colony for the 32 years stated worth about 10 millions sterling. Since 1899 the following returns have been declared :—

Year.	Crude Kg.	Crude Ounces.	Value, Sterling.
1900	2,170	69,765	£285,360
1901	4,021	129,275	434,320
1902	4,645	149,337	501,760
1903	4,325	139,049	468,376
1904	3,437	110,500	371,200
1905	3,568	114,711	385,440
1906	3,503	112,621	378,400

BRAZIL.

The chief auriferous region of Brazil extends from Bahia in the north to Goyaz in the south. Gold-bearing districts of minor importance are met with in the States of Matto Grosso, Rio Grande do Sul, Sao Paulo, Paraná, Ceara, Pará, and Maranhao. The gold deposits of the Disputed Territory north of the Amazon have already been mentioned under French Guiana.

Placer Deposits.—In Matto Grosso gold has long been worked in the lateritic ferruginous conglomerate of the Cuyaba district, but these deposits are now on the point of exhaustion. Gold-quartz veins traverse the slates of the district, but are not of high tenor. Nevertheless, their denudation and that of the ferruginous conglomerate has furnished gold to the rivers, and principally to the

[a] Delvaux, Eng. Min. Jour., March 2, 1907, p. 421 ; Id., Bull. Soc. des Ingenieurs Civ. de France, Feb., 1908.

Coxipo-de-Ouro, which flows into the Cuyaba.[a] The gravels of this river, after having been worked for many years by native methods, were attacked in 1902 by dredging, with apparently successful results.[b] The workable portions of the river vary from 80 to 200 feet in width with a thickness of 2 to 25 feet, and have a total length of 40 to 100 miles. All the pay-gravel is in the present river bed. No boulders occur in the wash. Both gold and diamonds are saved. The value of the wash treated is about 3¼d. per cubic yard. The gold is fine, and is worth about £4 per ounce. Dredging conditions are on the whole very favourable.[c]

Elsewhere in Brazil dredging ground is known to occur on the Piracicaba river, which flows from near São Paulo into the Rio Tiete, a tributary of the Paraná. In the province of Minas Geraes dredges are in operation on the Rio das Mortes and the Ribierao do Carmo.

The date of the first discovery of gold in Brazil is doubtful. The discovery has been credited to a *paulista* (half-breed) named Antonio Rodriguez Arzaõ, who is believed to have washed gold in 1693 in the Caethe district. Other authorities ascribe the first discovery to another *paulista*, Antonio Dias, working in the placer deposits in Minas Geraes near the town now known as Ouro Preto. The date of his discovery is believed to be 1699. In 1718 the Cuyaba placers, or, rather, those of the Coxipo-de-Ouro river, flowing into the Cuyaba, in the Matto Grosso region, became known. Six years later similar auriferous deposits were found in the region now forming the State of Goyaz, to the east of Matto Grosso. The royalty imposed by the Crown of Portugal was one-fifth, and was the same, therefore, as the *quinto* paid to Spain in the case of Mexico, Panama, and the northern Spanish colonies of South America. In 1817 the Baron von Eschwege, a Prussian savant engaged by the Governor of Brazil to improve mining and metallurgical methods in Brazil, opened up the mines of Passagem, near Marianna, after the most approved methods then in vogue, at the same time erecting the first gold-milling stamps worked in Brazil. Previous to that year the methods of mining and milling were crude in the extreme, the quartz crushed by hand being laboriously washed by the batea. Indeed, the washing in the batea has survived to the present day, but is employed only on free-milling ores with coarse gold.[d]

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[a] Evans, Q.J.G.S., L, 1894, p. 102.

[b] Eng. Min. Jour., March 2, 1907, p. 419.

[c] Booth, Min. Jour., May 9, 1908, p. 562.

[d] For a complete bibliography of Brazilian mineral deposits to 1903, see Branner, Archiv. Mus. Nacion., Rio de Janeiro, XII, 1903.

Rio Grande do Sul.—The Rio Grande do Sul is the most southerly department or state of Brazil. Its auriferous deposits lie in two formations : (*a*) in veins in metamorphic chloritic schists, and (*b*) in syenites. The former are in the western portion of the Sierra do Herval, south-west of Porto Alegre, the capital of the department. The metamorphic schists are associated with gneiss and with fine and coarse porphyries. The veins of the second class, in syenites, are grouped more particularly in the neighbourhood of Lavras, at the head of the Camacuam river and 37 miles north of the railway station of Bagé. The matrix of the auriferous veins is quartz, but gold also occurs in impregnations in the decomposed syenite.[a]

Mining has been carried on since 1835 or earlier, the first-discovered gold-quartz veins being situated at San Antonio de Lavras. These were originally worked by Brazilians, then by an English company, by which they were eventually abandoned. In 1898, three European companies, one English and two Belgian, resumed work in the vicinity of Lavras. The gold occurs mainly in small stringers and stockworks of veinlets in a syenite, that near the veins is decomposed for distances of 6 feet or less from the walls. The gold generally occurs in pockets and is associated with galena, pyrite, and blende. Of these, galena is locally considered the best indication of richness, but the pyrite is also auriferous and may reach tenors of 16 to 23 ounces gold per ton of concentrates. At São Sepe, north-north-east of Lavras and 22 miles north-west of Caeapava, numerous quartz veins exist over an area of 50 square miles. In one place a workable gold-quartz vein traverses the granite and the metamorphic rocks, close to their contact with coal-bearing beds ; coal being mined in this case not more than 1,000 yards away from the vein. It is indeed used to drive a small 5-head stamp mill. The São Sepe quartz veins vary in thickness from 1½ to 6½ feet. The gold is sometimes visible, and, as at Lavras, is found in pockets.

Near the village of Dom Pedrito, west of Bagé, and near the Uruguayan frontier, unimportant auriferous veins were worked for a short time in 1887. Within 3 miles of the Barcellos veins similar auriferous veins are known.

The most important copper deposits of Rio Grando do Sul, viz., those of Camacuam, near the river of that name, contain small quantities of gold (perhaps 4 dwts. per ton). The auriferous belt of this department is continued south into Uruguay.

Minas Geraes.—Few mines or deposits of economic value exist in Brazil beyond the boundaries of the Minas Geraes State,

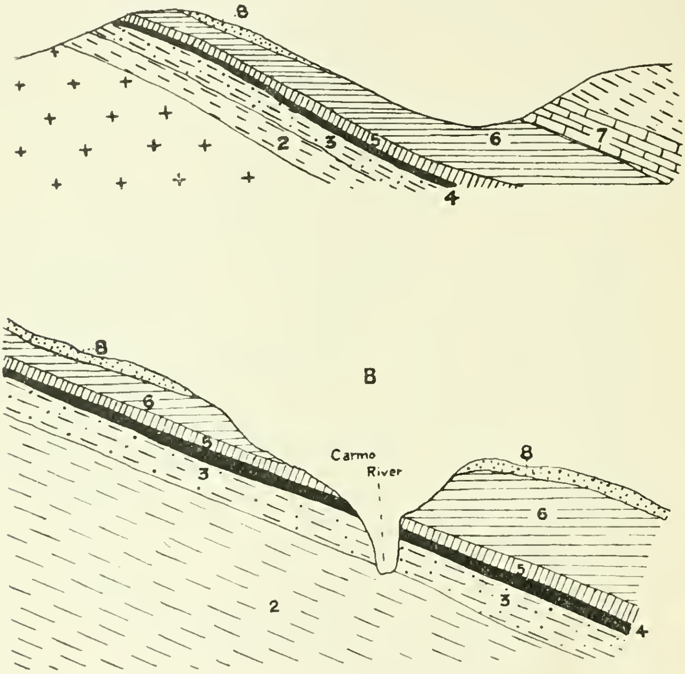
[a] Scott, Trans. Inst. M.E., XXV, 1903, p. 510.

which lies to the north-north-west of Rio de Janeiro. The goldfield proper is some 80 miles long by 60 miles broad, lying at an average altitude of some 4,000 feet above sea-level, and attaining a maximum of 6,410 feet. The auriferous deposits lie along the Sierra do Espinhaço, a range of mountains running north and south to the

FIG. 210. MAP OF AURIFEROUS PORTION OF MINAS GERAES PROVINCE, BRAZIL (*Scott*).

Sierra do Itacambira and the Sierra da Mantiquiera respectively. The centre of this district is about 200 miles distant from Rio de Janeiro, with which it is connected by railway.

The oldest rocks of the region are apparently gneisses and granites, having an extensive development along the base of the Sierra do Espinhaço, from Ouro Preto northward to beyond Cocaes. These rocks are generally much decomposed, and may in such cases be occasionally auriferous. Derby[a] has described extensive old workings in an extremely decomposed gneiss in the Campanha and São Gonzalo districts, 50 to 60 miles south-west of São Joao del Rei. These mines are now deserted and appear to have attained their greatest productiveness about 1818. The rock is a dark, highly micaceous, schistose gneiss, with many thin seams of quartzite that in places form beds quite a yard in thickness. True quartz veins do occur, but these are nearly always barren. Minor exceptions



Figs. 211 and 212. *A.* Section through Ouro Preto Mountain. *B.* Section through Passagem Mine (*Scott*).

1. Granite or Gneiss. 2. Micaceous and Talcose schists. 3. Schistose quartzite. 4. Auriferous Quartz Lode. 5. Argillaceous schist. 6. Itabirite. 7. Limestone. 8. Canga or Iron-ore conglomerate.

to this rule are, however, known. The valuable portion of the gneissose rock, and in general the host of the gold, is that which contains the above-mentioned quartzose bands or beds, particularly when these are ferruginous. Derby states that the average tenor of the whole mass at its principal gold occurrence was some $3\frac{3}{4}$ grains gold per ton. Magnetite, together with a few grains of pyrite, occurs in the heavy residues left on washing, and it is concluded that the gold was

[a] Amer. Jour. Sci., XXVIII, 1884, p. 443.

originally in intimate association with the latter, especially in view of the similar relations subsisting between gold and pyrite in the central and northern portions of Minas Geraes in the auriferous schists, quartzites, and itabirite (hæmatite-mica-schist) series. In former days these deposits were worked after the same manner as placers. A company formed in 1884 to work the São Gonzalo deposits by hydraulicing met with indifferent success.

Overlying the fundamental granites and gneisses of the province of Minas Geraes is a series of micaceous and talcose schists of possible Huronian age.[a] These are the characteristic gold-bearing rocks of Brazil. They are not themselves auriferous, but are traversed by auriferous quartz veins. The schists are generally very much decomposed, and are, therefore, readily affected by stream waters, the action of which results in the formation of deep ravines. Associated with the micaceous members of the series are schistose quartzites, made up mainly of quartz and mica, and carrying, in the neighbourhood of Ouro Preto, gold-quartz veins. Argillaceous schists also occur in the same districts, and are traversed by quartz veins that are occasionally auriferous. In places these schists become chloritic.[b]

Of the schistose rocks of Minas Geraes the micaceous hæmatite-quartzite is perhaps the best known. It is commonly known as *itabirite*, and is essentially a mixture of specular iron-ore and magnetite containing a variable amount of quartz. While generally decidedly schistose it may also be found either solidly compacted or, on the other hand, loosely granular. With the itabirite are associated thin beds (1 to 8 inches thick) of sandy micaceous and limonitic iron-ore containing yellowish talc and earthy oxides of manganese. These beds are generally friable, and appear to be a decomposition product of itabirite. The rock is locally known as *jacutinga*. The itabirite is occasionally auriferous, but the jacutinga is generally so. The two most important mines in this formation are Gongo Socco and Maquiné. Dolomitic and siliceous limestones rest on the itabirite and jacutinga at Ouro Preto, Gongo Socco, &c., and contain no auriferous veins. Overlying the calcareous members of the series come great thicknesses of micaceous schist. These are often auriferous and have been largely worked in former days.

The primary gold-deposits of Minas Geraes may be separated into four divisions : contact lodes, lodes in the schists, lodes in the quartzites, and jacutinga lines in itabirite. The first have been

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[a] Wappaeus, "Geographia Physica do Brazil," Rio de Janeiro, 1884, pp. 44–59.

[b] Scott, Trans. Amer. Inst. M.E., XXXIII, 1903, p. 406, *et seq.*; from which excellent account many of the details here given are derived.

worked since the earliest days of vein-mining in Brazil. They have furnished the important mines of Vellosa, Pelluçias, Tassara, Passagem, and Morro Santa Anna. Of these only the two last are still being worked. These contact lodes are lenticular masses of quartz interstratified between the itabirites and the underlying quartzites or between the itabirite and argillaceous schist. The lenses are much longer in dip than in strike, but vary between 30 and 300 feet with a thickness of 3 to 50 feet. The Passagem lode[a] lies between mica-schist and itabirite and is parallel to the stratification. The lode varies in thickness between 6 and 50 feet. Its vein filling is quartz, tourmaline, and arsenopyrite, with lesser quantities of pyrite and pyrrhotite. Near the footwall, where arsenopyrite and tourmaline abound, the tenor of the ore may reach 6½ ounces per ton. A notable feature in this vein is the presence of zircon and monazite of contemporaneous deposition with the ore. Tourmaline is also present in the country beyond the lode. Andalusite crystals deposited in the lode-fissure are largely altered to or replaced by sericite, rutile, arsenopyrite, and pyrite. The whole association is considered by Hussak to indicate an igneous intrusion, but the foregoing association is quite within the powers of formation of highly-heated aqueous solutions.[b] In the Passagem and similar lodes the gold is, as a rule, unevenly distributed throughout the quartz, the tenor varying from 1½ dwts. to 7 ounces per ton. The higher tenors occur only in the presence of arsenical pyrites. Nevertheless, the results obtained from large quantities of quartz at Passagem vary little from year to year. The Morro Santa Anna mines are of considerable antiquity, and are shown by Mawe on his route-map[c] as mines of some importance. Morro Santa Anna lies east of Ouro Preto and 4 miles north of Passagem. In geological and mineralogical characteristics its lode closely resembles that of Passagem.

The Passagem and Morro Santa Anna mines are the property of the Ouro Preto Company. The former lies about 4½ miles east of Ouro Preto (the ancient Villa Rica). It was worked, as has already been mentioned, in 1817 by the Prussian engineer, Baron von Eschwege. From April, 1884, to December, 1900, this mine treated 617,129 tons ore for a yield of 220,661 ounces gold, or an average of 7·1 dwts. per ton. In 1907 quartz to the amount of 72,703 tons was treated, yielding 24,500 ounces crude gold worth £97,872, or a yield per ton of 26s. 11d. Costs of treatment were 22s. 11½d.

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[a] Hussak, Zeit. für prakt. Geol., 1898, p. 345.

[b] Lindgren, Trans. Amer. Inst. M.E., XXX, 1901, p. 556.

[c] "Travels in the Interior of Brazil," 1828, p. 194.

per ton. In 1906, the tonnage, yield, and costs were all slightly higher.

Lodes in the schists furnish the greater number of the mines worked at the present time in Minas Geraes. Broadly speaking, they consist of lenticular shoots of quartz intercalated in the country. In depth, they have, as at Morro Velho, considerable persistence. The quartz contains, in addition to gold, varying quantities of

Fig. 213. Plan of Passagem Mine, Minas Geraes, Brazil.

pyrite and pyrrhotite, together with carbonates of lime, magnesia, and iron. Of this type of lode the Morro Velho is the most important example. It is situated in the north-west of the auriferous district and a few miles south-east of Bello Horizonte. It is owned by the St. John del Rey Company, one of the best-known and the longest established of English gold-mining companies. The company was formed in 1830 with a capital of £165,000 to work a lode near São Joao d'el Rei. This mine was abandoned in 1834, and in the same year the company commenced work on the present Morro Velho mine. From 1834 to 1867 mining was conducted after native methods, with the result that a serious cave occurred in the latter year, leading to the temporary abandonment of the mine. During this period the mine had produced 28·5 tons gold of a probable value of some £3,163,500, and had paid in dividends £896,000 on a paid-up capital of £135,000. Mining was resumed in 1874, but a second extensive cave occurred in 1886. From 1875 to 1884 the total value of the gold extracted was £5,500,000, while £556,000 had been distributed as dividends. In 1901 the value of the ore being crushed was £2. 6s. 6½d. per ton. There were crushed 140,855 tons for a yield of 99,197 ounces bullion worth £327,663. For the year 1907 there were treated 151,454 long tons of ore for a yield of gold worth £324,882, and a net profit of £70,840 was made. The average profit of the six preceding years had been £58,747.

The country rock is everywhere a highly sheared calc-schist, that, on account of the development of micaceous and chloritic material, has generally been described as a mica-schist. The dominant carbonate is that of lime. The vein-filling of Morro Velho contains 30 to 40 per cent. sulphides, 30 to 40 per cent. carbonates, and 20 to 30 per cent. quartz. Pyrrhotite is the principal sulphide, followed by pyrite, arsenopyrite, and chalcopyrite. Galena and blende are rare. The gangue is quartz with siderite, dolomite, and calcite, the proportion of the carbonate present diminishing in the order given. Beautiful crystals of albite felspar are common in the vughs and cavities of the Morro Velho lode. Albite also occurs in the quartz. Graphite is met with. The ore is very irregular in its gold content. Pure quartz is seldom auriferous, nor are the sulphides, except in the case of arsenical pyrites. The richest ore is a mixture of quartz, dolomite, and siderite, with arsenical pyrites and pyrrhotite. The enclosing walls of the lode, though often highly pyritous, rarely carry more than 2 to 3 dwts. gold per ton, and that only at the contact. The proportion of pyrrhotite in the ore is on an average 28·5 per cent. The bullion obtained is 790 to 810 fine. The quartz-body or chimney of Morro Velho has a horizontal length of 600 feet with an average cross-section of 45 feet. It has been followed for more than a mile on the dip and for 3,100 feet vertically.

The Rapasos and Cuyabá mines in the vicinity of Morro Velho are also the property of the St. John del Rey Company. They present the same character of country and lode as does Morro Velho. At Rapasos the itabirites are highly charged with magnetite. They are further traversed by diabase dykes, that appear to have a genetic connection with auriferous deposition.[a] The Cuyabá

[a] Berg, Zeit. für prakt. Geol., X, 1902. p. 83.

(Continued below.)

Panoramic View of Morro-Velho Mine, St. John D'el Rey Company, Minas Geraes, Brazil.

workings are on a bedded deposit of pyrites of a tenor of 3 to 4 dwts. per ton.

The São Bento mine lies a few miles south-west of Santa Barbara. Its lode is intercalated in micaceous schists. The lode-matter is a siliceous and micaceous iron-ore. The lode is some 40 feet in width, but of this only 1½ to 8½ feet, of a tenor of 2 dwts. to 1 ounce per ton, is worth working. In the oxidised zones the gold lay in a ferruginous granular quartz that was replaced in depth by quartz carrying pyrite and arsenopyrite. The Santa Quiteria mines in the immediate neighbourhood show features similar to those of São Bento.

The Taria mine, a short distance south of Morro Velho, is working a quartz-chimney similar to that of Morro Velho. It also lies intercalated in mica-schist. The chimney is about 160 feet in horizontal length, and varies between 6 and 33 feet in thickness. The gold is associated mainly with pyrites.

The lodes of the third type, viz., those in quartzites, are now of no importance, and all have long been abandoned. The Catta Branca appears to have been the most important.

Of lines or bands in jacutinga, representing the fourth type, the most famous has been the Gongo Socco, situated 16 miles west of Santa Barbara. It was first worked by an English company in 1820, and it was its great success, coupled with the fact that Latin America had succeeded in throwing off the Spanish yoke, that appears to have directed the flow of British capital towards South American mines in the fourth decade of the nineteenth century. The gold of Gongo Socco was found in a band of jacutinga that never attained a greater thickness than 7 inches. In its wider parts the central portions were composed of laminated masses of gold weighing from a few pennyweights to many ounces. In 1830 a miner is said to have extracted a single capful that contained 300 ounces of gold. Some two-thirds of the gold obtained was exceedingly coarse and in the form of solid masses, plates, and threads. The whole of the adjacent itabirite carried gold. The richer quartz was crushed by hand and washed in the batea, the poorer was put through crude native stamp-mills. The jacutinga on analysis contained no less than 97 per cent. ferric oxide. The mine was exhausted about 1846. It had then reached a depth of 420 feet. The English company had paid £90,000 for the mine, and despite the crude methods of mining and treatment then in vogue had recovered between 1826 and 1839 no less than £1,300,000 gold. From 1826 to 1856 the total yield had been 414,317 ounces (12,837 kg.) gold.[a]

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[a] Scott, loc. cit., p. 422.

The Maquiné mine near Morro Santa Anna was also in a jacutinga band. Its history is similar to that of Gongo Socco, for it was abandoned when its workings had reached a depth of 700 feet on the dip. Its period of greatest production was 1867-8, when 2½ tons gold were extracted and dividends of 100 per cent. were paid. The average value of the ore was ½-ounce per ton. This successful mine was also the property of an English company.

A third productive mine in jacutinga was the Itabira, near the town of Itabira do Matto Dentro. Its workings dated from the middle of the eighteenth century.

Near the town of Paracatu on the north-west frontier of Minas Geraes, surface deposits of gold occur in decomposed mica-schists, lateritic conglomerate, and surface soil, the first being the richest. No auriferous veins or igneous dykes are known in the vicinity. These deposits were highly productive from 1745 to 1825. It is estimated that their annual yield for this period was 31,065 ounces.[a] A few *faiscedores* still eke out a scanty living from the rivers in the neighbourhood of Ouro Preto by batea-washing, but the native placer industry of Brazil is insignificant.

The gold product of Brazil, which is indeed almost entirely derived from the Minas Geraes department, has been in the twentieth century :—

Year.	Kg.	Crude Ounces.	Value, Sterling.
1901	4,012	128,986	£535,000
1902	3,971	127,667	432,706
1903	4,302	138,309	468,591
1904	3,871	124,452	418,309
1905	3,879	124,710	420,128
1906	4,548	146,218	485,794

URUGUAY.

Little information concerning the gold mines of Uruguay is available. The earliest discovery was made in 1842 at Cuñapirú in Tacuarembo, in the north of the republic, and these mines have been worked spasmodically since 1867. The production during 1900 was only 2,568 ounces. The general geological features of the auriferous area resemble closely those of the Rio Grande do Sul province in Brazil. The country of the veins is composed of talcose and chloritic slates, penetrated by diorite dykes. The gold-quartz veins are small, but near the outcrops carry gold to the extent of

[a] Pearson, Trans. Inst. M.E., XXXI, 1906, p. 258.

3 ounces per ton. Hitherto, the tenor has been found to diminish rapidly at depths as shallow as 20 to 35 feet. It is, therefore, locally believed that when a vein shows no gold at the outcrop it is useless to sink on it in the hope of finding ore-shoots. Much of the gold is free, but auriferous pyrite and chalcopyrite are also found. The principal mines are those of São Gregorio and Cuñapirú. In addition to the small gold-quartz veins great barren reefs with quartz of a glassy or chalcedonic aspect are known to traverse the auriferous areas.[a] At Cuñapirú, in 1907, there were treated 18,028 metric tons quartz for a yield of 117·917 kg. (3,667 ounces) gold, or a little more than 4 dwts. per ton. This amount probably represents the total yield of the republic.

ARGENTINA.

The gold districts of the Argentine Republic, with the exception of those in Tierra del Fuego (described with the Chilian occurrences of that region), are situated on the western slopes of the Andes. The best known are those of the Sierra de Famatina in the Rioja Province, somewhat north of the 30th parallel of south latitude. As far back as 1824 an English company (the Famatina Mining Company) commenced work there, but eventually succumbed to the difficulties engendered by the geographical and political conditions obtaining. The region is barren, and there is neither animal nor vegetable life, while water is obtainable only by the melting of snow or ice. The veins are essentially cupriferous but contain also gold and silver. According to Bodenbender[b] the veins are probably to be associated in origin with neighbouring andesites. So precipitous are the mountains that the mines can be worked on an extensive modern scale only by aerial tramways. These have been erected by the Argentine Government and converge mainly on Chilecito at the head of the railway line. The Famatina mines are primarily copper mines containing from 8 to 10 dwts. gold per ton. A successful commencement was made in 1908 in the smelting of these ores. Gold is also found in Argentina in the provinces of San Luis, San Juan, Tucuman, Catamarca, Salta, and Jujuy. Dredging in the northern rivers has not hitherto been successful, and better results are expected from the eastern portion of Tierra del Fuego, which lies within Argentine jurisdiction.

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[a] Fuchs and De Launay, "Traité de Gîtes Mineraux," Paris, 1898, p. 910; Scott, Trans. Amer. Inst. M.E., XXV, 1903, p. 516; Bodenbender, "El Oro," Cordoba, 1902, p. 41.

[b] "El Oro," Cordoba, 1902, p. 41.

Auriferous quartz veins occur in the Archæan rocks in gneiss and crystalline schists with granite and diorite in the Sierra de Cordoba (Candelaria mines), in the San Luis, Tucuman, and Catamarca provinces ; in Silurian or Devonian limestone in the province of San Juan (Gualilan Guachi) ;[a] and in slates of similar age in the province of Jujuy and possibly associated with acid plutonic rocks. Alluvial auriferous deposits occur in the Jujuy province ; at Famatina ; and, as already stated, in the eastern portion of Tierra del Fuego.

Among the more recently reported auriferous fields are those of the Neuquen territory, and near Chosmalal at the head of the Neuquen river in the Cordilleras. The auriferous area is said to be large. It has, however, been worked for many years by the Chilians using primitive methods of ground-sluicing.[b]

CHILE.

The auriferous veins of Chile have been broadly divided by Möricke [c] into two main classes : (*a*) Auriferous veins proper, that are worked entirely for their gold, as, Guanaco in the province of Antofagasta ; Inca de Oro, Cachiyuyo, and Jesus Maria in the province of Atacama ; Talca, Andacollo, and Los Sauces, in the province of Coquimbo ; Mina Chivato in the province of Talca ; &c. ; and (*b*) auriferous copper deposits in which the gold is subordinate in value to the baser metal, *e.g.*, Remelinos and Ojancos in the province of Atacama ; Tamaya and La Higuera in the province of Coquimbo ; Las Condes and Peralillo in the province of Santiago, &c. The deposition of gold in the case of the first group appears to be closely connected with the acid eruptive rocks of the Chilean coast ranges, a connection which may, indeed, be traced with a few breaks from the far north of Chili to and beyond Valdivia in the south. The connection is, however, more or less continuous and obvious from Taltal to some distance south of Concepçion. Near Valdivia gold-quartz veins occur in mica-schist. At Lake Villa Rica, north-east of Valdivia, the Spaniards worked a rich gold mine whose veins apparently lay in granite.

Three Chilean goldfields lie on or a little to the south of the 25th parallel of south latitude. These are the Paranao, 42 miles north of the seaport of Taltal ; Guanaco, 80 miles north-east of Taltal ; and the Sierra Overa, 63 miles south-west of Taltal. The Guanaco

[a] Bodenbender, loc. cit.

[b] For a detailed description of the metalliferous occurrences of the Argentine Republic, see Hoskold, "Official Report on Mines, &c., of the Argentine Republic," Buenos Ayres, 1904.

[c] Berichte der Naturfor. Gesell., Freiburg i. B., X, 1898, p. 152.

field lies in the barren waterless Atacama desert, perhaps the most arid in the world. Its mines are situated at an altitude of more than 9,000 feet above sea-level, and are confined, with the exception of a rich chimney in a small hill 3 miles away, to two small hills (Guanaco and Guanacito) rising abruptly from the desert level. No other gold veins are known to exist within a radius of 50 miles. The mines were discovered in 1885. The country of the gold veins is liparite (quartz-trachyte).[a] The rock is normally greatly decomposed, but in its original state was apparently a brownish somewhat porphyritic rock with glassy modifications (perlitic pitchstones). The gold occurs as very fine particles strewn throughout the mass of the rock, which is now almost completely silicified. Even when the rock has a tenor of hundreds of ounces gold per ton, the gold itself is rarely visible. Gold of secondary origin occurs in fissures, in cleavage planes in kaolinite, as fine grains in cellular rock, and as brilliant spangles on barytes crystals. The last are occasionally covered by a thin layer of clear crystallized quartz, through which the gold may be seen. After the general silicification of the country, barytes has been deposited in fissures, as also has scorodite (hydrous ferrous arseniate). In depth tetrahedrite is found, and its oxidation gives rise near the surface to copper silicates and copper carbonates. The average fineness of the gold is 944.

The ore-bodies of Guanaco have no definite shape, the nearest approach to regularity being assumed by the bodies locally termed *mantos*—oval, flattened lenses of quartz, pink or grey in colour, and themselves disposed through the country without any indication of system. The deposits appear to have little permanence in depth, the rich deposits that have hitherto been found lying less than 120 feet from the surface.[b] According to Möricke the primary source of the free gold is the liparite itself, and not, as might naturally have been expected, siliceous solutions containing gold resulting from the oxidation of auriferous pyrite or other sulphides.

The Sierra Overa gold region, 63 miles south-west of Taltal, and 5,600 feet above sea-level, differs from that of Guanaco inasmuch as its gold lies in highly ferruginous banded crystalline quartz veins in diorite. To depths of at least 300 feet the ore is free-milling with little or no pyrite. The gold occurs fairly evenly distributed through the quartz, and also is occasionally found impregnating the country beside the veins. The last vary in width from a few inches to 3 feet. One vein, 8 feet in width had, at a depth of 300 feet, an

[a] Kaiser, Verh. naturh. Verein. Preuss. Rheinl., LVI, 1899, p. 31; Möricke, loc. cit. sup.

[b] Loram, Trans. Amer. Inst. M.E., XXIX, 1899, p. 489.

assay value of nearly £13 per ton. The Sierra Overa field was discovered only in 1893, and its subsequent progress has been considerably retarded by the absence of water and the difficulties of access.[a]

The district of Andacollo is the richest and most important, from the point of view of gold production, in Chile. It is situated about 40 miles south-west of the port of Coquimbo, and lies on the flanks of a barren mountain chain some 3,250 feet above sea-level. Its placers have been worked since the days of the Incas, and from them the early Spanish adventurers also obtained great quantities of gold. Even at the present day a considerable amount of alluvial gold is recovered by the inhabitants, but the principal modern source of the gold of Andacollo lies in its gold-quartz veins, that, like the irregular quartz bodies of Guanaco, traverse liparite or quartz-porphyry. For the most part, the veins of Andacollo are true gold-quartz veins, but auriferous pyrites-veins are also known. Pyrite is scattered throughout the rock-mass, as also is chalcopyrite, but the latter is not abundant.

The ores of Canutillo, north of Taltal and 15 miles south of Freirina, in the Atacama province, were mined by the Incas between 1430 and 1470. In 1535 the country fell into the hands of the *conquistadores*, and the gold mines were worked with great profit for some time. Mining, however, ceased until 1700, when the rich oxidised zones were opened up. After a century these in turn were exhausted, and, with the political troubles of the early years of the nineteenth century, the mines were again abandoned, not to be re-opened until the advent of an American company in 1896. The country is augite-diorite, intrusive through hornblende-schist. The age of the intrusive rock is probably lower Tertiary. The veins exist only in the diorite, and in no case pass out into the schists. They vary in width from a few inches to 10 feet. In the upper levels the gold is free. In the sulphide zone it is associated with pyrite and arsenopyrite.[b]

The La Higuera mines in the province of Coquimbo are working on gold-copper veins. Next to the Tamaya mines, they are the most important of the auriferous copper-pyrites workings in Chile. The country here, as at Tamaya, is a quartz-bearing gabbro-diorite, associated with a normal quartz-diorite. The gold-copper veins of La Higuera occur in the latter variety of diorite. Both at La Higuera and at Tamaya the veins are characterised by the presence of tourmaline. Similar gold-copper ores occur at Remelinos in the Copiapo department of the province of Atacama, where the country

[a] Loram, loc. cit., p. 493.

[b] Idem, Trans. Amer. Inst. M.E., XXXV, 1905, p. 696.

is hornblende-biotite-granite and quartz-diorite. Free gold occasionally occurs in the Remelinos veins. The Las Condes mines, south of Santiago, are the highest of the Chilean mines, lying at an altitude above sea-level of 13,000 feet. They are found in a granite that has been intruded by an aphanitic andesite,[a] the ore-bodies being situated near the intrusive contacts. Together with quartz and tourmaline there occur in the veins auriferous copper ores, hæmatite, anatase, titanite, and zircon. According to Domeyko[b] molybdenite also is found. Another tourmaline-bearing copper-gold region is that of Peralillo, north-west of Santiago, the country of which is quartz-diorite. For northern Chile, therefore, the association of vein tourmaline with auriferous copper sulphides is on the whole highly characteristic. Yet, Möricke could find in the mines of Jesus Maria, Ojancos, Cachiyuyo, and Inca de Oro (Atacama province) no trace of tourmaline, although the veins of these mines are in the same country (quartz-diorite) as the foregoing tourmaline-bearing veins. Cachiyuyo and Inca de Oro mines are very old and have been extensively worked. They are, however, rather gold-quartz mines with a little copper sulphide than gold-copper mines. In addition the Cachiyuyo vein carries a considerable quantity of specular iron ore.

The general relations of the Chilean quartz-diorites to the andesites and liparites of the Cordilleras are not very clear, but they nevertheless recall very forcibly the orogenic relations of the Californian granodiorites to the Nevada andesites. Tourmaline occurs in each case in the veins of the older rocks. On the whole, there is perhaps reasonable ground for assuming that the Chilean area is a southern analogue of the Californian province.

The placer deposits of Chile are numerous and have long been worked in a primitive fashion, which is now gradually giving place to modern methods of sluicing and dredging. The alluvial gold produced in Chile in 1903 amounted to 13,561 ounces (421,817 kg.) fine gold worth £57,606 (768,078 pesos).

The gold of Chilean placers is fairly coarse, and nuggets of 6 and 22 ounces have been found in recent years. Many placers, as at Loica, Melipilla, &c., have been covered by clay. The gold of the fine sands of Carelmapu in southern Chile has been concentrated on the ocean beaches until they sometimes contain as much as 9 to 30 dwts. per cubic yard (10 to 35 parts per million). These auriferous deposits have been proved to depths of 26 feet. Similar marine placers occur at Cucao, and at Chacao passage near the island of Chiloe.[c]

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[a] Stelzner, Zeit. für prakt. Geol., 1897, p. 41.
[b] "Mineralojia," Santiago, 1879, p. 437.
[c] Cortes, Bol. Soc. Naç. Min., 3, XV, 1903, p. 49.

River placers of some extent and value occur at Quilacoya, 25 miles north of Concepçion ; at Marga Marga ; and at Catapilco. An attempt was made to work the last in 1903 by hydraulicing, but the enterprise failed from lack of water. It is believed that the placers of Loica, Yalé, Caxuto, and Andacollo would yield profitable returns with modern methods.

Tierra del Fuego.—In Tierra del Fuego and the regions that lie adjacent to the Magellan Straits, partly in Chile and partly in Argentina, gold deposits have been known for many years. The first washings were made in the valley of the Rio de las Minas, near Punta Arenas. Towards the end of 1880 gold was discovered on the south coast of Tierra del Fuego, near Ushuaia (Argentina), and also on the islands of Navarin and Lennox (Chile). In 1881 one Señor Ponce de Leon (a name of happy omen) commenced gold-washing on the Baquedano, an affluent of the Rio del Oro, in the northern portion of the island. Soon after were discovered the placers of the Rio Oscar, which, like the Rio del Oro, flows northward to Magellan Straits. These placers were worked for several years by individual washers, generally with profitable results. In 1900 more than 500 gold-washers were busily employed.

On the Rio de las Minas, near Punta Arenas, attention was first directed to the valley gravels, but was soon turned to the more accessible older high-level river terraces when these were found to be as rich or richer in gold. Elsewhere on the mainland south of Punta Arenas, auriferous alluvials have been worked in the Tres Brazos and Agua Fresca streams. The marine black-sand placers of the north coast of the Magellan Straits at one time attracted considerable attention, perhaps more than was merited by their intrinsic value. The gold is very sparsely distributed through the beach sands, and the deposits have in recent years been abandoned. Similar marine placers occur on the Atlantic seaboard of southern Argentina, immediately north of Cape Virgenes and of the eastern entrance to the Magellan Straits.

On Tierra del Fuego itself the principal auriferous streams are the del Oro, Oscar, Side, Chico, Verde, Paravich, Progreso, Banco, &c. North of San Sebastian Bay at El Paramo (Argentina) are marine placers similar in character to those already mentioned as existing on the coasts of the mainland. Many of the islands off the south coast of Tierra del Fuego carry, or have carried, placer deposits of notable value. The principal of these islands are Nueva, Navarin, Loff, Agustin, Picton, Barneveld, Lennox, &c. On the last mentioned a nugget of 4 ounces (124 grammes) was found. A suction dredge was erected on the beach of this island in 1908, and it was estimated that $1\frac{1}{2}$ million cubic yards of gravel worth 1s. 3d. per yard were available for treatment.[a]

The material of which the placer deposits of Tierra del Fuego is very largely composed is fluvio-glacial, *i.e.*, morainic debris that has been re-sorted by running water. Pebbles of mica-schist containing auriferous pyrite have been found near Punta Arenas and also on the island of Santa Magdalena in the Magellan Straits. Since similar schists contain the auriferous veins of Cañete, Carahue, Valdivia, &c., in southern Chile, it may be conjectured that the alluvial gold of Tierra del Fuego has been derived from veins and impregnations in such rocks. Fairly large nuggets have from time to time been found in Tierra del Fuego, the largest on record weighing 19 ounces (590 grammes) and coming from the Santa Maria stream.[b] Nevertheless, the gold is, on the whole, fine and flaky rather than coarse. It is occasionally found crystallized in distorted octahedra and rhombic dodecahedra, and is often, and especially when flaky, coated with iron oxides. The gold is from 850 to 920 fine. Magnetite and titanite grains are abundant in the wash.

In 1902 a small dredging boom took place in Tierra del Fuego, and by the summer of 1907-1908 no less than a dozen dredges were at work on the various rivers flowing to the Atlantic seaboard and into the Magellan Straits. The dredging season lasts only for the summer months—from October to April or May, though a dredge on the Rio Oscar is reported to have worked all the year round with an average recovery of 35 ounces gold per week. A dredge on the Rio del Oro is also stated to have recovered 130 ounces per week.[c] In 1903 there were produced in Chilean Tierra del Fuego, 4,412 ounces (137·25 kg.) fine gold worth £18,743 ; in 1904, 170·182 kg. ; and in 1905, 143·563 kg.

The relative production of vein-gold of the various Chilean provinces in 1903 is shown below :—

	Kg. Fine Gold.	Ounces.
Antofagasta	92·502	2,969
Atacama	156·105	5,011
Coquimbo	33·565	1,077
Aconcagua, Valparaiso, and Santiago ..	42·909	1,377
Talca	3·602	115

[a] Curle and Richardson, Min. Sci. Press, June 27, 1908, p. 880.

[b] Brain, "Lavaderos de Oro de Tierra del Fuego," Bol. Soc. Nac. de Min., Chile, 3, XVII, 1905, p. 71 ; Pohlmann, Verh. Deutsch. Wiss. Ver. zu Santiago de Chile, IV, 1900, p. 307.

[c] Milward, Cons. Reps., 1907.

According to Herrman[a] the gold production to 1900 has been :—

	Kg. Fine Gold.	Fine Ounces.
16th century (56 years)	76,000	2,443,400
17th ,, ...	35,000	1,125,250
18th	92,000	2,957,800
19th	122,792	3,947,762[b]
In the 20th century the yield has been:		
1901	637	20,480
1902	762	24,498
1903	220	7,073
1904	910	29,256
1905	731	23,501
1906	1,427	45,886
Grand total to end of 1906..	330,479	10,624,906[c]

[a] "La Produccion en Chile de los Metales i Minerales, etc.," Santiago de Chile, 1903.

[b] Cortes, however (loc. cit. sup.), places the total value of the gold yield of Chile at £100,000,000, more than double the estimate of Herrman.

[c] For further detailed information regarding Chile, the student may consult: Cortes, "La Industria del Oro en Chile," Santiago de Chile, 1890; San Roman, "Minéria i Metallurjica de Chile," Santiago de Chile, 1894; Yunge, "Estadistica Minera de Chile," Santiago de Chile, 1905.

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