EXPLORATION DISCOVERIES, NORANDA DISTRICT, QUEBEC
(Case History of a Mining Camp)

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Boldy, J., Exploration discoveries, Noranda district, Quebec (Case History of a Mining Camp); in Geophysics and Geochemistry in the Search for Metallic Ores; Peter J. Hood, editor; Geological Survey of Canada, Economic Geology Report 31, p. 593-603, 1979.

Abstract

This paper is a review of exploration discovery in the Noranda district over a 60-year period and illustrates the varied and interrelated role played by prospecting, geology, geophysics and geochemistry in the discovery of massive sulphide deposits.

Discovery case histories are examined and data compiled, showing the primary and contributory exploration methods which were successfully employed. To date, 19 sulphide deposits have been discovered in the Noranda district. Based on primary exploration methods, 4 resulted from surface prospecting, 8 from geological methods, 6 from geophysical surveys and 1 from the use of pathfinder lithogeochemistry. A valid set of prospecting criteria can be established and applied from these case histories.

Each case history is judged within its own time frame, and is characterized by a certain exploration methodology which cannot be divorced from the exploration philosophy prevailing at the time. For this reason, the discoveries are related to the Exploration Life Cycle of the district. The Cycle is divided into three phases: 1) The Early Discovery Years (1920-1935), dominated by prospecting discoveries, 2) The Middle Discovery Years (1935-1955), balanced between ground geophysical discoveries and those resulting from empirical geological methods, and 3) The Later Discovery Years (1955-1977), dominated by volcanogenic geological discoveries, airborne geophysical discoveries, and the utilization of pathfinder geochemistry as an exploration aid to locate blind ore deposits. Today, exploration in the Noranda district is one of diminishing return using currently available technology. It is proposed that an accelerated discovery rate can be achieved — particularly in the search for deeply buried, blind deposits — by further development and application of pathfinder lithogeochemistry, coupled with an appreciation of the role of volcanism in ore genesis.

Résumé

Ce rapport fait l'inventaire des découvertes dans le district de Noranda sur une période de 60 ans, et fait ressortir le rôle varié et mutuel de la prospection de la géologie, de la géophysique et de la géochimie dans la découverte des gisements de sulfures massifs.

On a étudié quelques cas particuliers relatifs à ces découvertes et compilé des données montrant ainsi les méthodes d'exploration primaire et secondaire qui avaient été employées avec succès. A ce jour, 19 gisements de sulfure ont été découverts dans le district de Noranda. Dans le cas des méthodes d'exploration primaire, 4 gisements ont été découverts au moyen de travaux de surface, 8 par des méthodes géologiques, 6 par des levés géophysiques et 1 à partir d'indicateurs géochimiques. On peut établir et appliquer un ensemble valable de critères de prospection à partir de ces cas particuliers.

Chaque cas est jugé dans le cadre de l'époque; il est caractérisé par une certaine méthodologie de l'exploration, inséparable de la philosophie de l'exploration à l'époque considérée. Pour cette raison, les découvertes font partie du cycle d'exploration du district de Noranda. Ce cycle est divisé en trois phases: 1) les premières années de la découverte (1920-1935), dominées par les découvertes par prospection, 2) les années intermédiaires de la découverte (1935-1955), avec un équilibre entre les découvertes dues à la prospection géophysique au sol et aux méthodes géologiques, et 3) les dernières années de découverte (1955-1977), dominées par les découvertes de gîtes volcaniques, celles faites par suite des levés géophysiques aéroportés et de levés géochimiques, où l'on utilise des indicateurs géochimiques pour localiser les gisements métallifères n'affleurant pas. Aujourd'hui, l'exploration dans le district de Noranda n'est plus rentable avec la technologie actuelle. Pour atteindre un taux de découverte élevé, on propose — particulièrement dans la recherche des gisements profonds et n'affleurant pas — de perfectionner les méthodes géochimiques où l'on utilise des "indicateurs" en tenant compte aussi du rôle du volcanisme dans la genèse du minerai.

INTRODUCTION

The Exploration '77 Symposium was a state-of-the-art review of the various geophysical and geochemical techniques employed in mineral exploration. Without doubt, technological aids have played a vital part in target definition and subsequent discovery, by detecting certain anomalous physical and/or chemical properties associated with metallic ores. However, as important as these disciplines are in modern exploration, the role of geology should not be underestimated or ignored. An appreciation of the geological environment under investigation is equally vital, in order to enhance the probabilities of discovery.

This paper is a personal geohistorical review of the history-of-the-art of massive sulphide exploration and discovery in the Noranda district over the past 60 years or so. It is a case history of a mining camp, viewed in the context of

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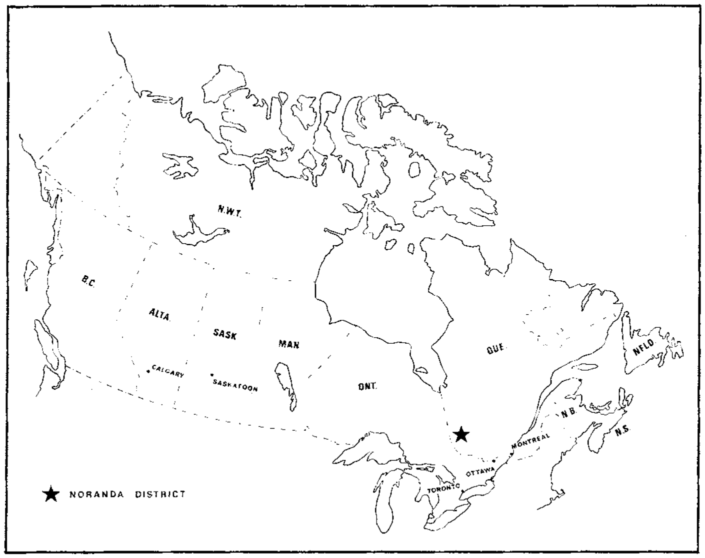

Figure 26.1. *Location of Noranda district, Quebec.*

certain significant exploration developments, which aided in establishing one of the world's premier base-metal mining districts located in the Abitibi region of northwestern Quebec (Fig. 26.1). Like all histories, it may be somewhat subjective. In any event, it attempts to bring out the interrelationship of the various exploration disciplines, each of which was successful in the context of its time, and each of which owes a debt to those of other disciplines, and to those who were earlier on the scene. It is the author's belief that exploration effectiveness will be increased by studying the exploration history of a mining district in depth, and in its entirety, particularly the evaluation and use of various prospecting criteria which led to discovery.

NORANDA SULPHIDE DEPOSITS

The geological setting of the Noranda district deposits has been adequately covered in the literature, namely by Wilson (1941), Gilmour (1965), Dugas (1966), Sangster (1972), and Spence and de Rosen-Spence (1975). The bibliography which has been compiled, comprises principally broad concepts and selected references of case history technology. Detailed geological descriptions of the various deposits may be obtained by referring to these publications.

The term 'massive sulphides' refers to mineralization containing greater than 50 per cent sulphides composed of varying proportions of pyrite, pyrrhotite, sphalerite and chalcopyrite, with lesser amounts of galena, magnetite and other metallic minerals, not all of which are necessarily present in any one deposit. The massive sulphide component of a deposit consists of one or more lensoid masses which are essentially conformable with the host stratigraphy. Disseminated sulphides tend to flank the massive sulphides in the stratigraphic footwall, generally a more or less altered felsic volcanic unit. This alteration zone is often crudely pipelike in form. Disseminated sulphides also occur along the plane of ore-hosting rocks, generally a cherty-tuffaceous unit, a product of terminal felsic volcanism.

Although there are certain exceptions to the rule, deposits tend to be associated with the terminal phases of felsic pyroclastic volcanism. Most sulphide masses, with the exception of one or two of the larger deposits in the Noranda district, occur as fairly discrete bodies; the maximum dimensions are generally less than 400 m along the plane of the host rocks. By nature, these deposits have a variable response to geophysical and geochemical search techniques, being dependent in large part on their depth of burial below surface. It is vital therefore to have a proper understanding of the geology and geometry of these deposits, in order to obtain a sharper focus for target definition.

The Noranda district is the most prolific of Canadian Precambrian massive sulphide clusters, aggregating 114 million tons with an average grade of 2.14% copper, 1.37% zinc, 0.59 oz. silver, and 0.12 oz. gold per ton (Boldy, 1977). This tonnage is obtained from 19 deposits, 85 per cent of them located within (16 km) of the major Horne deposit. This tonnage is equivalent to 30 per cent of the (volcanogenic) base metal tonnage of the Abitibi area of northwest Quebec and northeast Ontario, and in total is equivalent to 20 per cent of Canada's Precambrian (volcanogenic) base metal tonnage. Currently, the Millenbach deposit remains in production, the Corbett and Macdonald deposits are under various stages of development, and the New Insco, Magusi River, and Mobrun deposits are considered as reserves for the future. Although primarily a base metal district, the Noranda area was a gold mining district in years past. Sixteen deposits have been mined out, aggregating 17 million tons, grading 0.16 oz. gold per ton.

EVALUATION DISCOVERY TECHNOLOGY

Reference to Table 26.1 and Figures 26.2 and 26.3, illustrate the discovery role played by prospecting, geology, geophysics and geochemistry in the Noranda district. The primary and contributory roles played by these disciplines have been examined and evaluated for all the various Noranda district deposits. Often a difficult decision had to be made when deciding which of several methods was the one primarily responsible for discovery. However, in order to understand the real significance of the various successful methodologies employed, the discoveries should be placed in their time frame, so that one can appreciate the interplay of ideas and their application during the course of an exploration program. Each case is governed by the following points:

(1) the available knowledge/data base for the period;

(2) the availability of applicable technological search tools;

(3) the prevalence and diffusion of new exploration concepts (often considered unorthodox at the time);

(4) the appropriate application of ideas and techniques and their proper execution in the field.

There is no doubt that some discoveries resulted from a complete and correct analysis of the evidence at hand, however, cases do exist where serendipity played an overly large part in discovery. Perhaps if the whole truth were known, most discoveries resulted when adequate preparation met opportunity, and was firmly grasped.

RELATIONSHIP OF DISCOVERY TECHNOLOGY TO EXPLORATION LIFE CYCLE AT NORANDA

Reference to Table 26.2 illustrates the relationship of discovery to the Exploration Life Cycle of the Noranda district. Exploration at Noranda may be conveniently divided into three phases, each roughly separated by a hiatus of about seven barren discovery years.

The Early Discovery Years (1920-1935)

As might be expected, prospecting discoveries dominated this period. Ed Horne staked the sulphide gossans near Osisko Lake in Rouyn Township in 1920, whilst intermittently prospecting the area for gold since 1911. In 1923, a drilling program was initiated which was successful in intersecting a major copper-gold zone beneath the pyritized

Table 26.1

Compilation of discovery technology, volcanogenic sulphide deposits, Noranda district, Quebec

		YEAR OF DISCOVERY	PROSPECTING	GEOLOGY					GEOPHYSICS					GEO-CHEMISTRY			DEPTH OF DEPOSIT FROM SURFACE
				MINERALIZATION	ALTERATION	LITHOLOGY - STRATIGRAPHY	STRUCTURE	OTHER	AERIAL EM	GROUND EM	GROUND MAG.	I.P.	GRAVITY	SOIL	LITHO-GEOCHEM	MERCURY PATHFINDER	
EARLY YEARS (1920-1935)	HORNE - UPPER 'H'	1923	P	X			X										SURFACE
	AMULET - UPPER 'A'	1925	P	X	X												SURFACE
	AMULET 'C'	1925	P	X		X											SURFACE
	OLD WAITE	1925	P	X	X												SURFACE
	ALDERMAC	1925	X	X	X						P						- 30'
	AMULET 'F'	1929		X	X	X		P									-125'
	HORNE - LOWER 'H' *	1931		P		X	X	X									-1300'
MIDDLE YEARS (1935-1955)	AMULET - LOWER 'A' *	1938		X	P	X											- 700'
	JOLIET	1940	X	P		X											- 25'
	MACDONALD	1944	X	X		X				P							- 25'
	QUEMONT	1945				X	X				P						-200'
	D'ELDONA	1947	X	P		X	X										-500'
	EAST WAITE	1949				X		P									-1300'
LATER YEARS (1955-1977)	MOBRUN	1956				X				P			X				- 30'
	VAUZE	1957				P	X										- 25'
	DUFAULT - NORBEC	1961				P	X										-1100'
	DELBRIDGE	1965		X		X						X				P	- 300'
	DUFAULT - MILLENBACH	1966				P	X	X								X	-2300'
	MAGUSI RIVER	1972				X			P								- 50'
	NEW INSCO	1973				X			P								- 50'
	DUFAULT - CORBETT	1974				P	X									X	-2300'

P = PRIMARY DISCOVERY METHOD

X = CONTRIBUTORY METHOD

* = SUBSEQUENT DISCOVERY

rhyolites. This discovery was to become the famous Horne mine, and with it, the Noranda organization was born (Roberts, 1956). It is interesting that within a year of its discovery, the property was surveyed using the spontaneous polarization (SP) technique, the first such geophysical survey conducted in Canada (Kelly, 1957). Although most of the ore lenses were discovered without reference to the SP results, the results did confirm the presence of a multiple series of sulphide lenses, some of which did not outcrop.

By 1925, other gossans were discovered (8 km) to the northwest of the Horne mine. These were the Amulet Upper A and Amulet C deposits in Dufresnoy Township, and the Old Waite deposit (2.4 km) to the northwest in Duprat Township.

The first geophysical discovery of the period was made in 1925 in a location (16 km) to the west of the Horne mine in Beauchastel Township. There, a simple dip-needle magnetic survey led to the discovery of the Aldermac deposit which

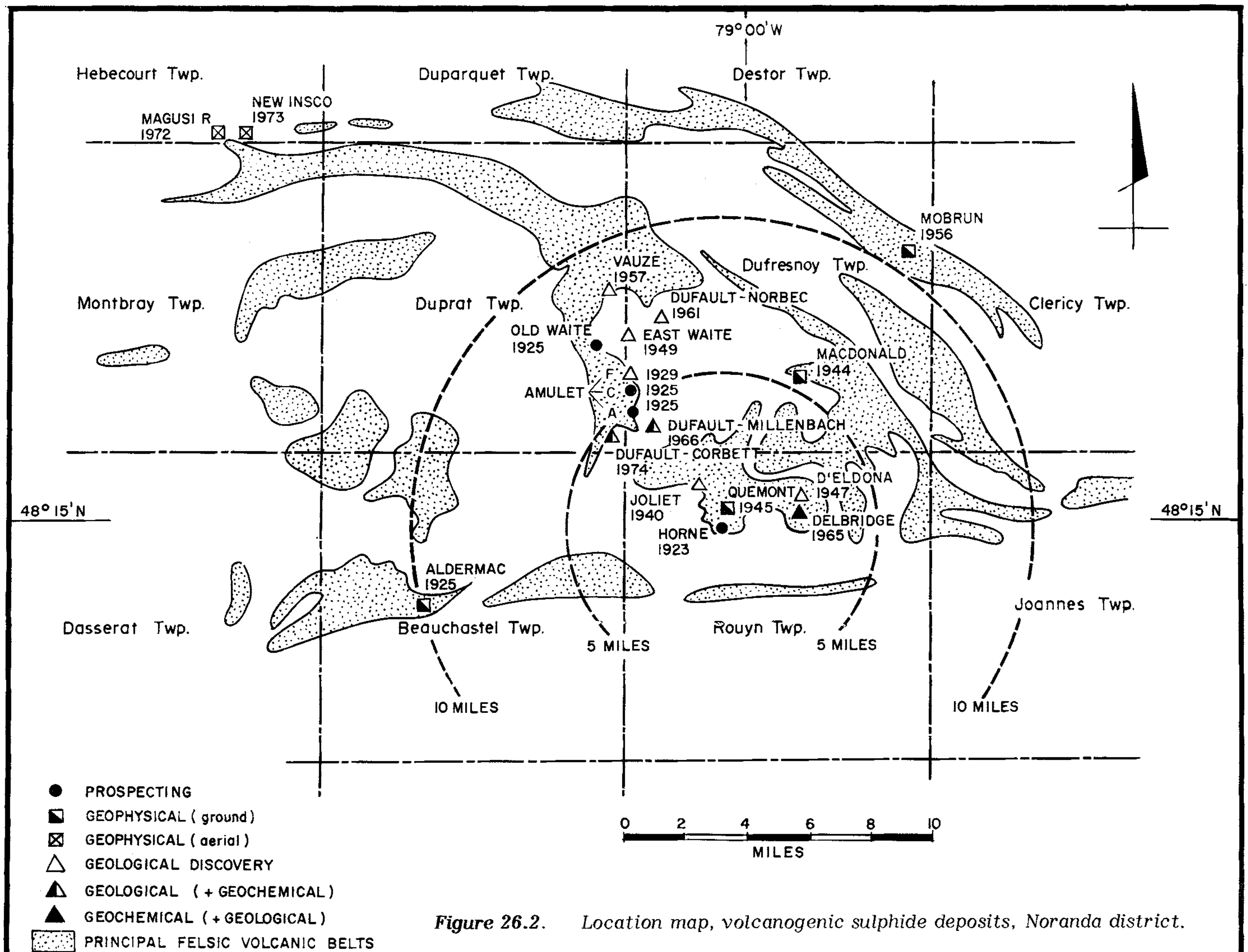

Figure 26.2. *Location map, volcanogenic sulphide deposits, Noranda district.*

was located under low ground, about 100 m north of mineralized and altered felsic volcanics. The alteration (cordierite-hornfels) was recognized to be similar to that associated with the Amulet Upper A and Amulet C deposits.

In 1929, a drill program based on geological interpretations intersected the Amulet F deposit, which was located 1.6 km to the north of the Amulet C deposit. Mineralized and altered felsic volcanic outcrops existed to the west of this discovery, and the drilling had intersected massive sulphides at a shallow depth, on the downdip extension of the (Amulet) rhyolite-andesite contact.

The period closes in 1931 with the discovery of the large Lower H deposit in the Horne mine during the course of underground development. It was noted at the time that the massive sulphide lenses in the mine area were located in a major fault wedge, within which the felsic volcanics were brecciated, sericitized and silicified. This specific structural setting was considered vital for the location and formation of this major ore deposit (Price, 1948).

The Middle Discovery Years (1935-1955)

This period is characterized by the empirical phase of geological exploration, where certain associations of lithology, mineralization, alteration and structure known to be favourable for ore deposition, were traced and investigated by drilling. Emphasis was placed in locating "favourable" fault or fold-controlled structures, within which mineralizing solutions rising from depth could replace physically or chemically receptive lithologies.

In 1938, after a period of exploration stagnation, the Amulet Lower A deposit was discovered 210 m beneath the surface outcrop of the smaller Amulet Upper A deposit. The two deposits were physically separated but were linked by a common alteration pipe of cordierite-anthophyllite which had pierced the favourable (Amulet) rhyolite-andesite contact. This contact hosted the Amulet C deposits to the north. In 1940, the Joliet deposit (copper-bearing siliceous flux ore) was discovered 1.6 km to the northwest of the Horne mine, where disseminated sulphides had been previously noted in sheared rhyolitic rocks. The deposit subcropped beneath shallow overburden.

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Two major geophysical discoveries were made in 1944-1945. The first of these was the Macdonald deposit located in Dufresnoy Township 8 km to the northeast of the Horne mine. A subsurface conductor was defined by ground EM in an area containing scattered base metal bearing sulphide occurrences along a rhyolite-granodiorite contact. It was the first ground EM survey to be successful in locating a massive sulphide deposit in the Noranda district. The deposit occurred under 8 m of overburden.

The major geophysical discovery however, was that of the Quemont deposit, discovered in 1945. This property lies adjacent to the Horne mine, generally north of the Horne Creek fault, which up to then was thought to be the bounding structure for the emplacement of ore in this sector of the mining district. Much surface and underground exploration had been done without success during the previous 20 years. The successful geophysical technique utilized was a ground magnetic survey which outlined several magnetic anomalies. These were systematically drilled by Mining Corporation. Massive sulphides were found to be associated with one of the magnetic anomalies located along the north shore of Osisko Lake. This major discovery was a classic example of the importance of target definition and location.

In 1947, following the excitement generated by the Quemont discovery, empirical geological investigations continued. One of these resulted in the discovery of the D'Eldona deposit, 4 km to the east of the Quemont mine. Here, weakly disseminated pyritic sulphides had been noted on surface close to a northeasterly-trending diabase dyke (a continuation of the dyke that passes near the Horne mine), which cuts through a sequence of porphyritic rhyolites, not unlike those rhyolites that hosted the Quemont deposit 4 km to the west. A subsequent drilling program at this location resulted in the discovery of a pyrite-sphalerite lens 150 m below surface.

The final episode in this period occurred in 1949 with the discovery of the East Waite deposit, in a step-out hole, following the third deepening of an assessment drillhole which had been originally started in 1938. This deposit is located in Dufresnoy Township, 1.2 km to the northeast of the Old Waite deposit which had been discovered in 1925. The new deposit was down-dip from surface and occurred on the same lithological contact as that of the Old Waite deposit. This contact had been recognized in the assessment drillhole. The deposit was located 400 m below surface, and was underlain by a classic alteration pipe; in addition, the deposit appeared to be associated with a domal structure on the upper surface of the (Waite) rhyolite, and its position was masked by 0.4 km thickness of (Amulet) andesite, in part intruded by diorite. This discovery was to have an important influence on geological thinking in the district.

Following the geophysical and geological developments at the close of this period, probably one of the earliest attempts to utilize lithogeochemical methods in prospecting in the Amulet area was carried out by Riddell (1950). The investigation involved the determination of trace amounts of copper and zinc peripheral to the Amulet deposits, some of which outcropped, and were associated with cordierite-anthophyllite alteration pipes. Although it is not known whether or not this technique led to any discovery it did outline a broad, anomalous zone, and could be related to one or two of the deposits.

The Later Discovery Years (1955–1977)

With the continued use of ground EM systems which had been successfully employed in many massive sulphide districts, much time and effort were expended conducting EM surveys in the Noranda district. One such survey (truck-mounted EM) was initiated by Rio Tinto and was conducted

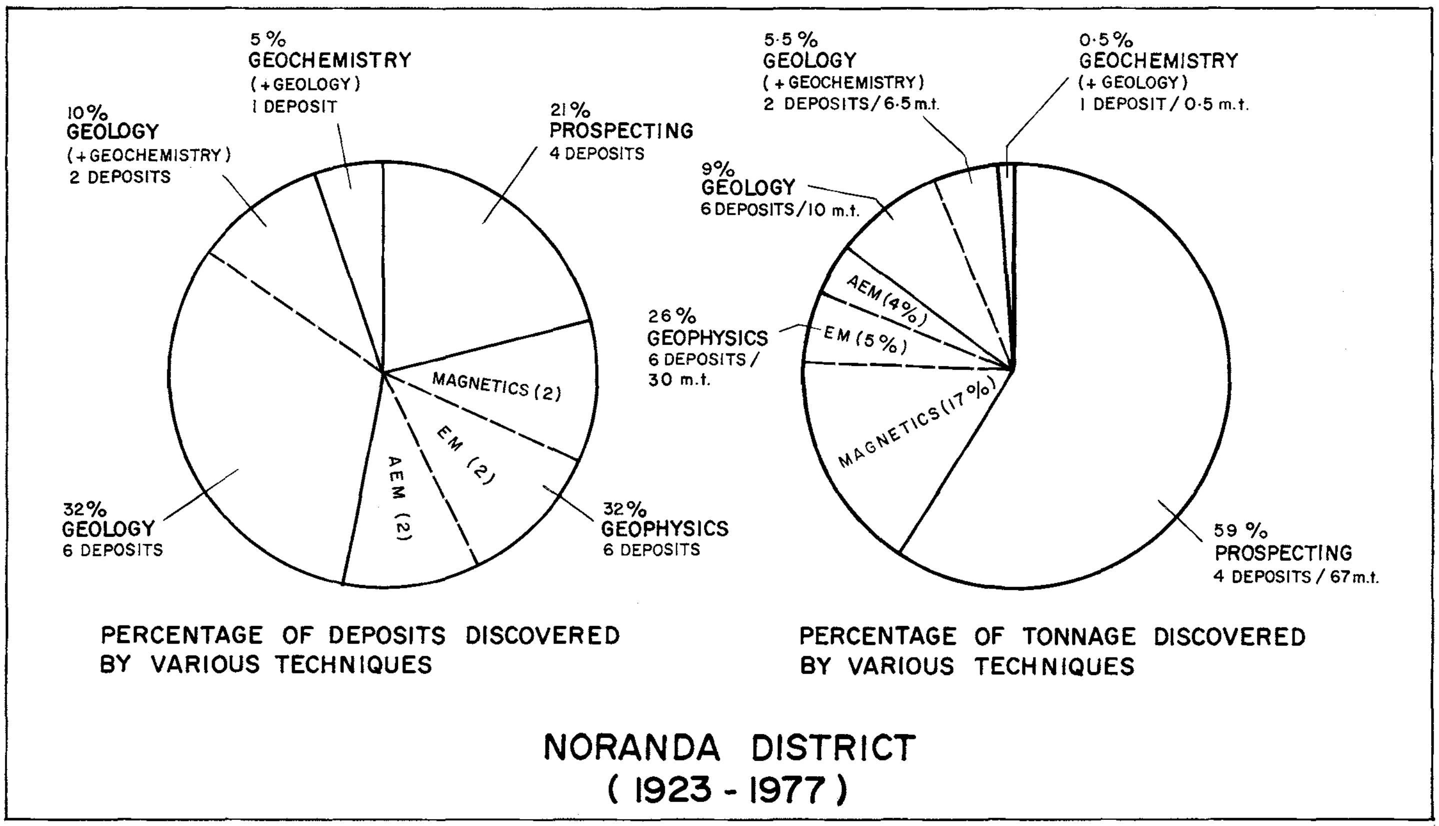

Figure 26.3. *Percentage of deposits and tonnage discovered by various prospecting techniques in the Noranda district.*

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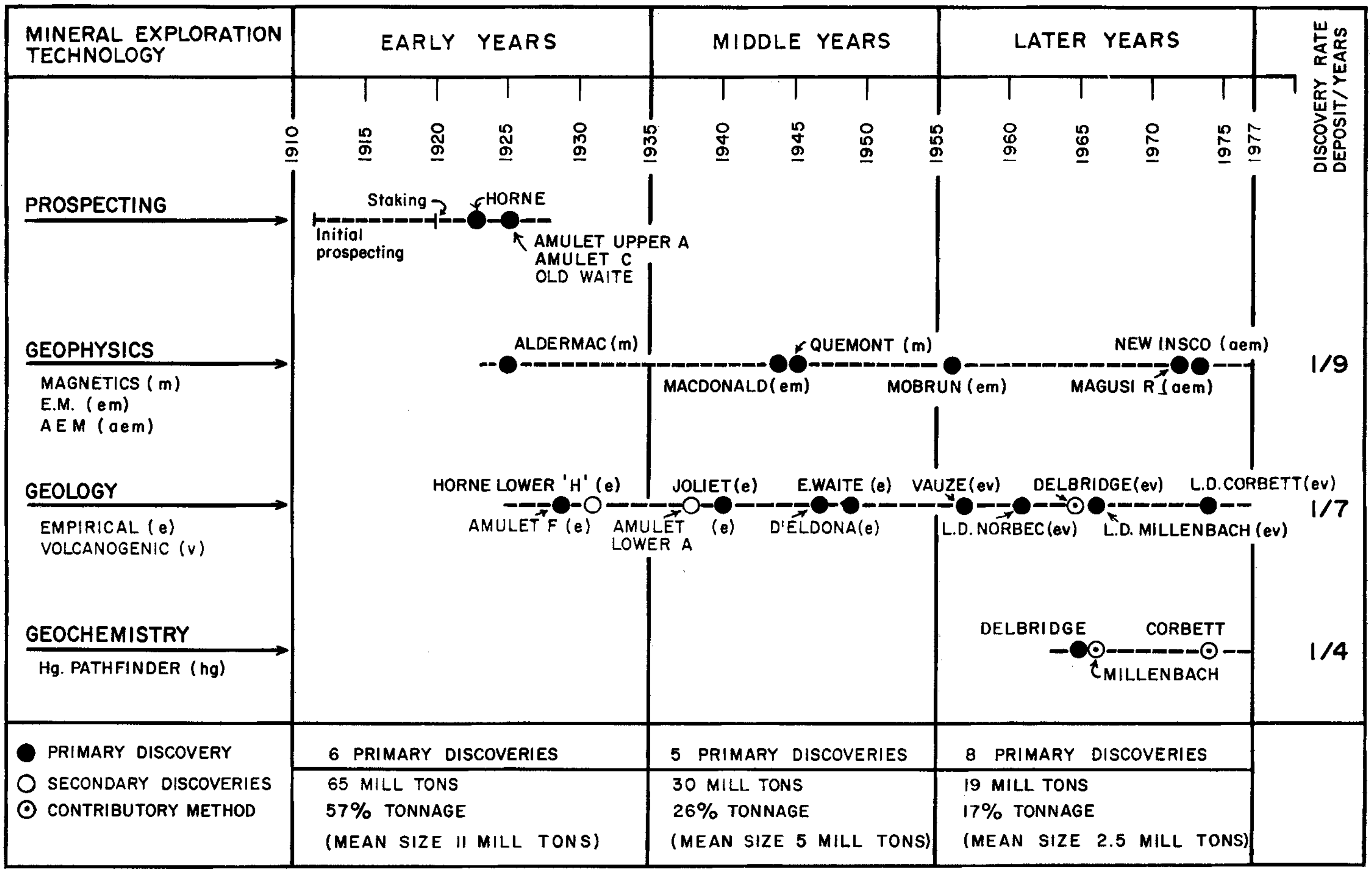
Table 26.2

Relationship of mineral exploration technology to the exploration life cycle of the Noranda district, Quebec



along road networks known to be underlain by felsic volcanics. This resulted in the discovery of the Mobrun deposit in northeast Dufresnoy Township in 1956, located 17.7 km to the northeast of the Horne mine (Siegel et al., 1957). In addition, a gravity survey helped confirm the presence of a massive sulphide deposit prior to drill investigation of the anomaly, and a tonnage estimate was made from the gravity results by Goetz (1958). An airborne EM test survey, carried out over this deposit later, has been described by Paterson (1961). Sixteen years were to elapse between this discovery and others made by geophysical methods.

The period commenced with a consolidation of empirical geological knowledge gained over the previous 30 years from the efforts of earlier workers. However, major advances in geological thinking were made in Australia in 1953 (King, 1965; 1976), and in Europe (Oftedahl, 1958), with the advancement of new concepts of ore genesis. After studies on the Broken Hill deposit in Australia, Haddon King, a Consolidated Zinc Corporation geologist, came to the conclusion that certain sulphide deposits should be considered as an integral part of their lithological environment. His ideas may be briefly paraphrased as follows: "The (sedimentary) concept in mineral exploration.....promises to lift ideas of ore occurrence out of the realm of miracles and put it, for the first time, where it belongs--in the scheme of natural events. In this view, ore occurrences should become not only understandable--perhaps even predictable." A similar viewpoint was developed in Canada during the course of investigations in the Bathurst camp in New Brunswick in the mid 1950s (Stanton, 1959; Cheriton, 1960; Miller, 1960; Sullivan, 1968).

Approximately concurrent with these developments in ideas of ore genesis, certain Noranda-based Consolidated Zinc geologists, namely Edwards, Gilmour and Spence, were also developing ideas that the massive sulphide deposits in Noranda were probably contemporaneous with their volcanic host rocks. Furthermore, they believed that major ore controls could be related to particular time – stratigraphic periods of felsic volcanism – and that localizing (volcanic) structures would be found associated with certain phases of felsic (eruptive) volcanism. In addition, they believed that the hydrothermal mineralizers, a terminal product of volcanism, would precipitate metals during the waning stages of a particular volcanic cycle, not unlike that of hotsprings and fumeroles (Gilmour, 1965; Spence, 1967; Spence and de Rosen-Spence, 1975).

The discovery of the Vauze deposit in 1957 by Consolidated Zinc Corporation, 2.4 km northwest of the East Waite deposit resulted from a revolutionary interpretation of existing data. Although of modest proportions, it was the first to be discovered using empirical methods, coupled to embryonic volcanogenic concepts. This discovery opened up a large subsurface area known to be underlain by the favourable (Waite) rhyolite, but covered by an extensive sequence of (Amulet) andesite.

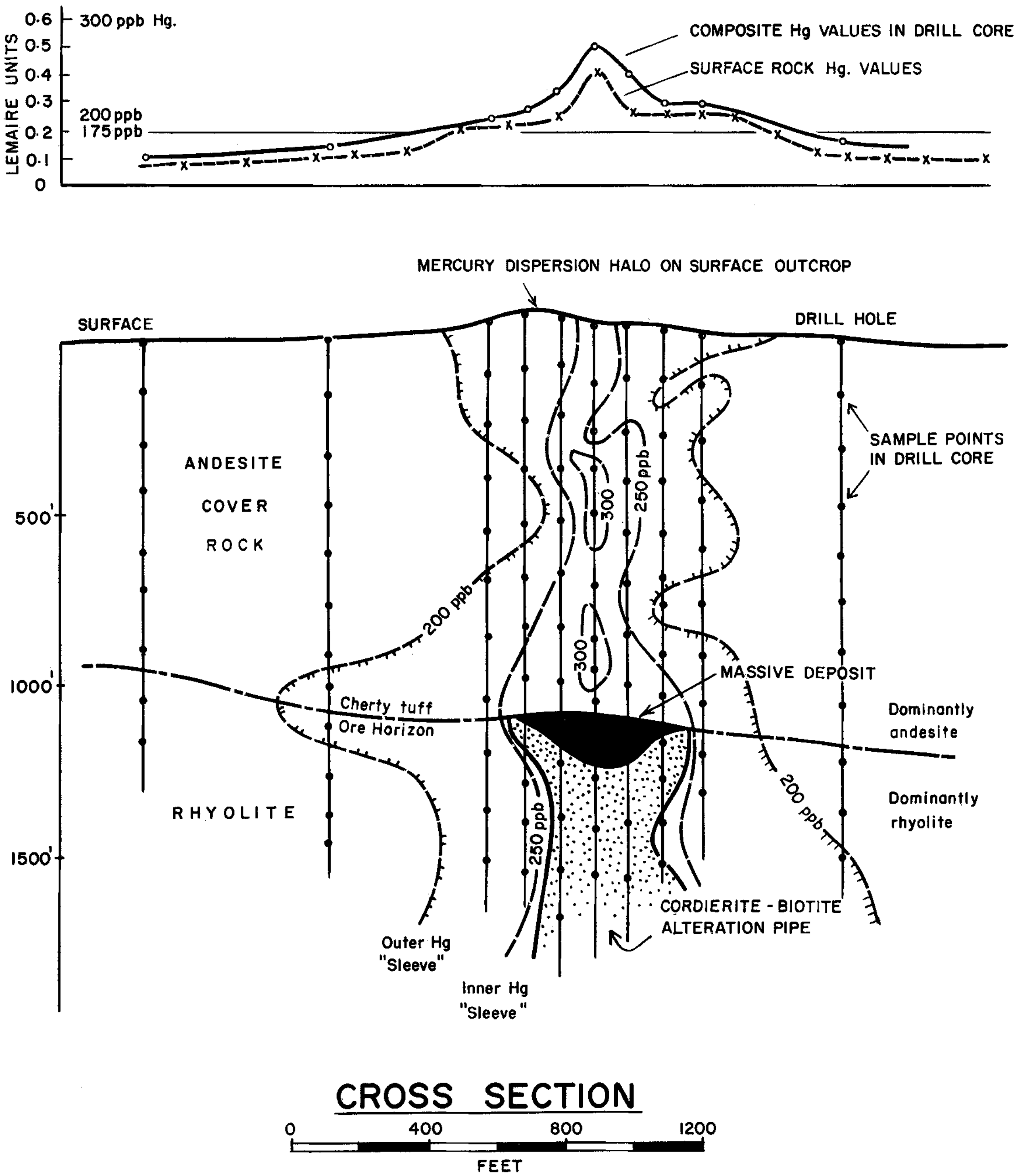


Figure 26.4. *Section — Relationship of mercury dispersion halo to a blind massive sulphide deposit, Noranda district.*

Much painstaking analysis of data was undertaken by various companies, based on interpreting drilling information, particular emphasis being placed on determining the subsurface configuration of the Waite rhyolite using isopachs and structural contour plotting of this felsic unit. This unit fortuitously dipped at a gentle angle, and combined with repetition of stratigraphy due to faulting, was within reach of surface exploratory drillholes. In addition, it was noted that the deposits in this sector of the district tended to occur along trends of 070° and 350° relative to the location of the East Waite deposit. In 1961, after a long barren period, hole 124 drilled by Lake Dufault Mines discovered the Norbec deposit in Dufresnoy Township, 2 km northeast of the East Waite, at a depth of 335 m. This discovery marked a turning point in the fortunes of Lake Dufault Mines.

Geochemical literature regarding the use of mercury as a pathfinder to discover blind sulphide deposits (Fursov, 1958; Ozerova, 1959; Hawkes and Williston, 1962) came to the attention of Falconbridge Exploration in 1963. In addition, previously published data on geochemical investigations of the East Tintic district, Utah (Lovering et al., 1948), revealed that meaningful information could be obtained by analyzing the trace element content of fractures uprake from blind deposits.

Analysis by Falconbridge of surface and drill core samples taken around the recently discovered Norbec deposit using a simple S-1 Lemaire detector, revealed easily detectable anomalous amounts of mercury in the 150-300 ppb range. A distinct primary dispersion halo was found to exist

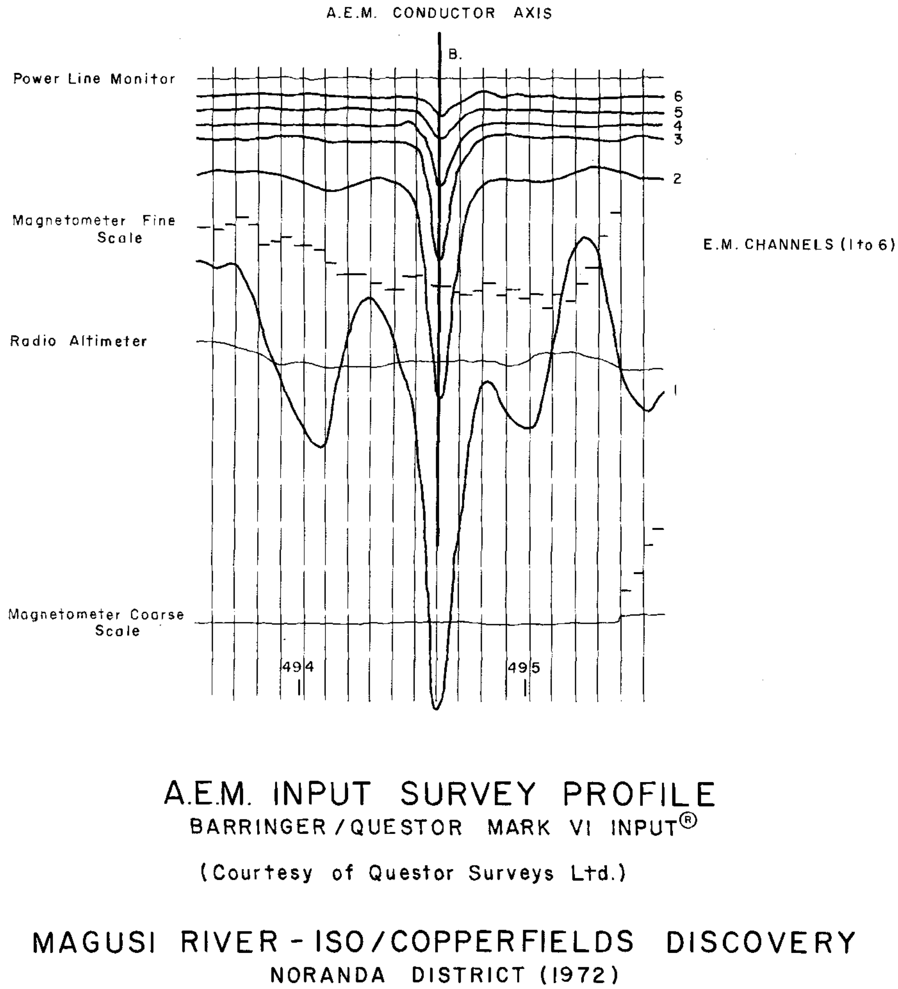


Figure 26.5. *AEM Input survey profile, Magusi River district, Noranda district.*

in cover rock above the deposit encompassing an area 460 by 210 m. The surface halo covered an area approximately four times the area of the underlying alteration pipe which is characteristic of this type of deposit (Fig. 26.4).

The detailed lithogeochemical investigation of the Norbec deposit and other blind deposits in the district was carried out over the following two years. It was found that the mercury was confined to a minute meshwork of fractures (i.e. grid-type alteration in Noranda terminology), suggestive that the leakage of mercury had indeed occurred from below, leaving an easily detectable three-dimensional imprint in the surrounding lithologies. In addition, the largest and highest amplitude mercury anomalies (300-1200 ppb) tended to be associated with massive sulphide deposits that contained appreciable amounts of zinc, silver or telluride mineralization. The application of this practical tool helped focus attention on certain areas which were considered prospective for deeply buried, blind sulphide deposits (Boldy, 1963).

An appreciation of the significance of mercury as a geochemical pathfinder coupled with a realization of the importance of volcanic stratigraphy in ore localization, resulted in Falconbridge discovering the Delbridge deposit in 1965; this deposit is 4 km east of the Horne – Quemont complex, and 0.4 km south of the old D'Eldona workings. It was the first deposit to be discovered using pathfinder lithogeochemistry in the Noranda area. In addition, frequency-domain IP surveys were utilized in defining weakly-disseminated pyritic mineralization occurring in the stratigraphic footwall of the blind deposit, which was subsequently found to be located 90 m below surface, and extended to a depth of 350 m from surface. IP surveys have been proven to be a useful exploration tool for massive sulphides (Hallof, 1960; Hendrick and Fountain, 1971).

In 1966, and more recently in 1974, the Millenbach and Corbett deposits were discovered by Lake Dufault Mines, in an area approximately 2 km distant from the Amulet A deposit. Both these new discoveries occurred at depths of about 700 m below surface. The discoveries were made using a variety of empirical (lithology, stratigraphy, and structural) information, particularly a deciphering of the structural setting, based on a fairly immense data bank gathered over the years from previous drilling programs. Pathfinder geochemistry (mercury and certain other elements) was a contributory aid at the Millenbach and also at the Corbett deposits. In the latter area, the leakage anomalies were horizontally offset in plan-view, which added complications to ready interpretation at that time.

After a sixteen year lapse since the previous successful geophysical discovery, an airborne Input EM survey conducted in 1972 by Questor Surveys on behalf of the Quebec Department of Natural Resources, (re) discovered a strong, isolated, magnetic conductor in Hebecourt township, 34 km northwest of the Horne mine (Fig. 26.5). This airborne EM system has been described by Lazenby (1973). This anomaly had been previously drilled with inconclusive results. Following a correct analysis of the geophysical data, drilling by the Iso-Copperfields group discovered the Magusi River deposit (Jones, 1973). A case history study was carried out by the McPhar group using various geophysical methods (Fountain, 1972). In 1973, a detailed Dighem AEM survey located the adjoining New Insco deposit (Fraser, 1974) on ground that had been previously acquired with stratigraphic concepts in mind.

It is interesting to note that the use of AEM surveys, which is a standard survey technique today, found two deposits after a period of almost 60 years of active exploration. If this tool had been available years earlier, perhaps up to half of the deposits discovered to date could have been located using this exploration tool.

Reference to Table 26.3 illustrates the tonnage and grade figures of the various volcanogenic sulphide deposits discovered to date in the Noranda district. At current metal prices the gross value of the volcanogenic sulphide deposits is in excess of $6 billion.

CONCLUSIONS

The Noranda district can be considered to have reached a mature stage of exploration development over the past sixty years. This is due in part to Nature's bounty, and in part to a certain tenacity and approach to exploration by those active on the local scene. The diffusion of ideas on theories of ore genesis, international in scope, coupled with the use of various technological aids, have all had an impact on

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Table 26.3

Tonnage-grade data, volcanogenic sulphide deposits, Noranda district

Deposit	Status	Size (M/Tons)	% Cu	% Zn	oz. Ag	oz. Au
Horne	Past producer	60.26	2.20	--	0.40	0.17
Quemont	Past producer	16.35	1.20	1.80	0.54	0.12
Amulet A	Past producer	5.30	5.12	5.50	1.40	0.04
Magusi	Prospect	4.11	1.20	3.60	0.90	0.03
Norbec	Past producer	4.00	2.80	4.71	1.40	0.03
Joliet	Past producer	3.70	1.12	--	0.25	0.01
Millenbach	Producer	3.58	3.69	4.73	1.72	0.03
Macdonald	Inactive producer	3.25	0.07	4.77	0.63	0.02
Mobrun	Prospect	3.00	0.62	2.30	0.60	0.05
Corbett	Active development	2.93	2.92	1.98	0.59	0.03
Aldermac	Past producer	2.07	1.48	--	0.20	0.01
E. Waite	Past producer	1.50	4.13	3.30	0.90	0.05
O. Waite	Past producer	1.25	4.70	3.00	0.60	0.03
New Insco	Prospect	1.15	2.11	--	0.50	0.03
Amulet C	Past producer	0.60	2.12	8.50	2.00	0.02
Delbridge	Past producer	0.40	0.55	8.60	2.00	0.07
Vauze	Past producer	0.37	2.94	1.00	0.80	0.02
Amulet F	Past producer	0.28	3.54	3.40	0.10	0.02
D'Eldona	Past producer	0.10	0.30	5.00	0.76	0.12
		114.20	2.14	1.37	0.59	0.12

Note: 1-Grade and tonnage figures include production and reserves.

2-District metal content:

Copper	2,455,000 tons
Zinc	1,542,000 tons
Silver	67,378,000 ounces
Gold	13,704,000 ounces

discovery, irrespective of the disciplines employed and the companies involved in discovery. No single person or company can afford to be too smug about their achievements. In return, many ideas and concepts advanced and developed by those who explored the Noranda district over a period of many years, saw these concepts develop into valid prospecting guidelines, and become of use to others engaged in volcanogenic massive sulphide exploration within the Noranda district, and elsewhere in the Precambrian Shield. Today, the use of the term Noranda-type i.e. a volcanogenic massive sulphide deposit, is firmly established in the geological literature (Gilmour, 1976).

The Early Discovery Years (1920-1935) were dominated by prospecting discoveries with geophysics and geology playing a minor role. The Middle Discovery Years (1935-1955) demonstrated the value of ground EM and magnetic surveys, coupled to the development and use of empirical geological methods. The Later Discovery Years (1955-1977) commenced with the development of volcanogenic concepts and coupled to a strong empirical base, resulted in a string of discoveries. During this period, well-designed ground EM and airborne EM systems still continued to discover ore in the peripheral areas of the district. In addition, the advent of the use of mercury geochemistry as a pathfinder to ore, helped focus attention on certain prospective areas and was successfully employed in targeting deeply buried blind deposits.

The review of various case histories of discovery illustrates the depth and scope of successful exploration technology applied over the years in the Noranda district. Currently, blind ore discoveries will probably continue to be made between 300 m and 900 m below surface. Deep ore search however, is difficult and expensive, and requires a long-term, adequate drilling budget. Today, we are faced with the problem of diminishing return using currently available technological search tools. However, an accelerated discovery rate will reward those who have an appreciation of the role of volcanism in ore genesis, coupled to the continued development and use of lithogeochemical pathfinder techniques. The presence of ghost mining districts is a reminder to all explorationists of what may lie ahead if we fail to meet the challenge. In any event, the development of successful exploration technology in the Noranda district can be considered a monument to the spirit of human endeavour, in this most heart-breaking of pursuits – the quest for ore!

ACKNOWLEDGMENTS

I am indebted to innumerable explorationists, especially to those who actively explored the Noranda district over a period of many years. Amongst the many, I would like to acknowledge the aid of several who helped compile the list on Discovery Technology. They are W. Bancroft, Bud Hogg, Peter Price, and Roger Pemberton – Noranda Mines Ltd.; Colin Spence – Rio Tinto Canadian Exploration; Hugh Squair – Selco Mining Corporation; Stan Charteris and Gordon Walker – Falconbridge Nickel; George Archibald and Bert Sakrison – New Insco Mines Ltd.; Mike Knuckey – Lake Dufault Division – Falconbridge Copper; Hugh Jones – Geophysical Engineering Ltd.; and E. Hart – Geological Consultant. In addition, an appreciation is extended to W.G. Robinson and D.H. Brown, and the late A.S. Dadson, with whom I had the pleasure of having many shared experiences in the Noranda district whilst in the employ of Falconbridge between 1962-1968.

The writer acknowledges the permission of the senior management of Gulf Minerals Canada Limited to publish this historical review. However, he assumes responsibility for the text and for any conclusions reached in the article.

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