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# GEOPHYSICAL AND GEOCHEMICAL METHODS USED IN THE DISCOVERY OF THE ISLAND COPPER DEPOSIT, VANCOUVER ISLAND, BRITISH COLUMBIA

**K.E. Witherly**
Utah Mines Ltd., Toronto, Ontario

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**Abstract**

*The Island Copper Mine of Utah Mines Ltd. is a large, low-grade copper-molybdenum deposit located 354 km northwest of Vancouver, B.C. The deposit lies in the Bonanza Volcanic formation of lower to mid-Jurassic age. The ore zones are in andesitic, pyroclastic rocks in the hanging wall and footwall of a quartz-feldspar porphyry dyke. At the commencement of production, ore reserves totalled 257 million tonnes averaging 0.52 per cent copper and 0.017 per cent molybdenum.*

*Exploration work on the deposit began in early 1966 when Utah Construction and Mining Co. (now Utah Mines Ltd.) optioned approximately 175 claims located on the north side of Rupert Inlet. Initial work consisted of geological mapping, soil geochemistry, ground magnetic and IP surveying. Considerable dependence was placed on the latter three tools due to the extensive overburden cover on the property. The geochemical and geophysical surveys produced an abundance of anomalies over the property.*

*During the first year of exploration, testing of geochemical and geophysical anomalies was done with a small company-owned diamond drill which could penetrate depths of up to 75 m under favourable conditions. Although copper and magnetite had a known association in the area, initial direct testing of the best magnetic anomalies located only subeconomic copper mineralization. The IP anomalies tested intersected some low-grade copper with pyrite, but more often just barren pyrite. It was observed from the initial testing that the total sulphide content of the anomalies tested was fairly constant, i.e. when the chalcopyrite picked up, the pyrite content dropped. This made anomaly discrimination based on amplitudes quite difficult.*

*In view of the poor resolution the geophysical anomalies provided, it was decided to test the copper soil geochemical anomalies before any more geophysical work would be done. The orebody was discovered as a result of testing one such geochemical anomaly with several shallow drillholes. Deeper drilling of the deposit was initiated soon after and the orebody was delineated a little more than two years later in the Spring of 1969. A VLF-EM survey over the deposit did not respond to the ore mineralization itself but did show up a number of significant structural features.*

*Although geophysics did not assist directly in the discovery of the Island Copper deposit, its contributions to the development of geological thinking in the area have been valuable. A large part of the recent interest in the northern part of Vancouver Island stemmed from a joint British Columbia Department of Mines/Geological Survey of Canada aeromagnetic survey flown in 1962. Examination of the geophysical data made subsequent to the discovery of Island Copper show that the geophysical results support and enhance information on structure, alteration and mineralization both in and around the orebody. Such information is not only of interest in its own right but as well provides a valuable data base to draw upon for exploration in similar geological environments.*

**Résumé**

*La mine de cuivre Island de l'Utah Mines Ltd. est formée d'un important gisement pauvre de cuivre-molybdène, 354 km au nord-ouest de Vancouver, en Colombie-Britannique. Le gisement repose dans la formation volcanique Bonanza du Jurassique inférieur et moyen. Les zones de minerai se trouvent dans des roches pyroclastiques à andésite dans la lèvre supérieure et la lèvre inférieure d'un dyke porphyrique de quartz-feldspath. Au début de la production, les réserves de minerai atteignaient 257 millions de tonnes d'une teneur en cuivre d'environ 0,52 pour cent et d'une teneur en molybdène d'environ 0,017 pour cent.*

*Les travaux d'exploration du gisement ont commencé au début de 1966, lorsque l'Utah Construction and Mining Co. (aujourd'hui l'Utah Mines Ltd.) a choisi environ 175 claims sur la rive nord de l'inlet Rupert. Les travaux préliminaires comprenaient la cartographie géologique, l'étude géochimique des sols, des levés magnétiques et des levés par méthode PP. On avait beaucoup misé sur les trois dernières méthodes, étant donnée la couche importante du terrain de couverture.*

*Au cours de la première année d'exploration, des vérifications d'anomalies géochimiques et géophysiques ont été effectuées à l'aide d'un petit foret au diamant que possédait la société; cet outil de forage pouvait atteindre des profondeurs de 75 m dans des conditions favorables.*

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*Les levés géochimiques et géophysiques ont révélé un grand nombre d'anomalies sur toute l'étendue du terrain. Bien que l'on ait su que, dans cette région, le cuivre et la magnétite étaient associés, la vérification directe initiale des meilleures anomalies magnétiques n'a indiqué qu'une minéralisation de cuivre non susceptible d'être exploitée de fa*ᵃ*on rentable.*

*Les anomalies vérifiées par la méthode PP ont livré un peu de cuivre pauvre contenant de la pyrite, mais surtout de la pyrite stérile. On a remarqué lors de la vérification initiale que le contenu total en sulfure des anomalies vérifiées était à peu près constant, c'est-à-dire que lorsque la chalcopyrite augmentait, la pyrite diminuait. Cette constation a rendu assez difficile la distinction des anomalies en fonction des amplitudes.*

*Compte tenu du faible pouvoir de résolution qu'avaient fourni les anomalies géophysiques, il fut décidé de vérifier les anomalies géochimiques des sols contenant du cuivre avant que d'autres travaux géophysiques ne soient entrepris. Le gisement en amas fut découvert à la suite de la vérification d'une telle anomalie géochimique au moyen de plusieurs trous de forage peu profonds. Le forage du gisement à plus grande profondeur fut entrepris peu de temps après, et le gisement en amas fut délimité un peu plus de deux ans plus tard, au printemps de 1969.*

*Un levé électromagnétique à très basse fréquence effectué sur l'ensemble du gisement n'a pas réagi à la minéralisation elle-même, mais a révélé un nombre important de particularités structurales.*

*Bien que la géophysique n'ait pas contribué directement à la découverte du gisement de cuivre Island, elle a influé grandement sur l'opinion que se font les géologues de la structure de la région. Une grande partie de l'intérêt manifesté dernièrement à ce sujet dans la partie nord de l'île Vancouver fait suite à un levé aéromagnétique effectué en 1962 par le ministère des Mines de la Colombie-Britannique et la Commission géologique du Canada. L'analyse des données géophysiques effectuées à la suite de la découverte de la mine de cuivre Island indique que les résultats d'ordre géophysique corroborent des renseignements sur la structure, l'altération et la minéralisation tant à l'intérieur qu'autour du gisement en amas. De tels renseignements ne sont pas seulement intéressants en eux-mêmes, mais ils fournissent également une base de données de valeur pour décider de travaux d'exploration dans des milieux géologiques semblables.*

## INTRODUCTION

The Island Copper (ISCU) deposit, controlled and operated by Utah Mines Ltd. (formerly Utah Construction and Mining), is located on the north shore of Rupert Inlet (50°36'N, 127°37'W) approximately 16 km south of Port Hardy on northern Vancouver Island (Fig. 32.1). The town of Port Hardy is 354 km northwest of Vancouver, B.C. and is serviced daily by scheduled flights from Vancouver. Port Hardy and the northern portion of Vancouver Island can also be reached by surface transportation using either public roads or a combination of provincial ferries and roads.

Elevations on the property range from sea level to 150 m. The area around the deposit is heavily timbered with spruce, hemlock and cedar. Glacial deposits with thicknesses of up to 75 m cover most of the area. Average annual precipitation at Port Hardy is 1900 mm, which includes an average of 600 mm of snow. The yearly temperature range is from -7°C minimum to 27°C maximum, with an annual mean of 8°C.

The orebody was discovered after more than four years of exploration activity that stemmed from the release of results of an aeromagnetic survey flown from July to September 1962 over the whole northern portion of Vancouver Island. This survey was a joint effort between the British Columbia Department of Mines and the Geological Survey of Canada. Release of the aeromagnetic survey results in 1963 stimulated considerable exploration interest in the area, with both companies and individuals participating in the follow-up. As part of their programs, a number of major mining companies, including Utah Mines Ltd., reconnoitered the Rupert Inlet area (Fig. 32.2), but found no encouraging evidence of economic mineralization. A small island, called Red Island, located slightly less than 2 km to the southeast of the present pit, was known to have good copper grades associated with abundant magnetite in volcanics. Prospectors at the time however, felt that the occurrence was only a high-grade pod and not part of a larger, mineralized system.

Soon after the release of the aeromagnetic data, Gordon Milbourne, a local prospector, ran a dip-needle survey over a localized magnetic high, situated just north of Rupert Inlet. Two years later, Milbourne returned to the area and located float and outcrops containing native copper and chalcopyrite, just west of Frances Lake (Fig. 32.2). Subsequent trenching revealed high-grade chalcopyrite in volcanic rocks.

Utah Mines Ltd., examined Milbourne's ground in October 1965, and concluded that the property warranted follow-up. After some preliminary exploration work in the Fall of 1965, Utah signed an agreement with Milbourne in January 1966.

Because outcrops on the property were very sparse, due to an extensive cover of glacial overburden, it was decided that an integrated geological, geochemical and geophysical approach should be used in evaluating the property. To facilitate this evaluation, a survey grid totalling 160 line km was established over the property. The lines were spaced 152 m apart with survey stations every 30.5 m. The lines were oriented N22°E, but local magnetic disturbances occasionally caused significant deflections in a surveyed line.

The choice of geochemical and geophysical parameters to be measured was based largely upon the initial test surveys done in 1965. Since only copper had been found in any significant amounts on the property, copper was the only element for which the soil samples were analyzed. Magnetic surveys were considered an important tool, due to the known affinity copper and magnetite showed in the area. Induced polarization was also felt to be useful, since considerable pyrite was found in association with the known copper mineralization.

Shallow drilling, with a company-owned X-ray machine, began early in 1966 to evaluate the mineralized area at the southwest end of Frances Lake. As geochemical and geophysical surveys progressed, the X-ray drill was used to test anomalies located elsewhere on the property. The initial criterion for drilling was that the anomalies be coincident

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with geochemical, magnetic and IP highs. On this premise, after some initial drilling north of Frances Lake, some interesting observations were made. Firstly, testing of the best magnetic anomalies encountered only low-grade copper mineralization; secondly, pyrite seemed ubiquitous in the area, with its distribution on a local scale being apparently unrelated to economic copper mineralization. Thus, primarily for these reasons, it was decided early in 1966 to give the geochemical anomalies the highest priority in the drilling program. Later that year, in the course of testing one such geochemical high located several kilometres to the southeast of the original prospect area, ore-grade mineralization was encountered in three of four X-ray holes.

Soon after these first shallow intercepts were confirmed with deeper drilling, the exploration tempo gradually built up, and by 1968 there were four large diamond-drill rigs working on the property. When drilling of the deposit was completed in May 1969, a total of 128 holes had been drilled for an aggregate length of over 35 000 m. The results of the drilling program outlined a deposit containing 240 million tonnes of copper and molybdenum ore, grading 0.52 per cent copper and 0.017 per cent molybdenum, extending from surface to a depth of 300 m, along a strike length of about 1700 m. Mill construction began in late 1969 and the first shipment of concentrates was made in December 1971. The current production from the mill is approximately 34 500 tonnes per day, and the current reserves (1976) are about 230 million tonnes.

## GEOLOGY OF NORTHERN VANCOUVER ISLAND AND THE ISLAND COPPER DEPOSIT

### *Regional Geology*

The rocks of Vancouver Island, north of Rupert and Holberg Inlets, are primarily volcanic and sedimentary units ranging in age from Upper Triassic to Lower Cretaceous (Muller et al., 1974). Intrusive rocks of early to middle Jurassic age intrude the central and upper portions of the North Island sequence and locally are associated with copper-molybdenum mineralization.

The Karmutsen Formation is the oldest rock unit in the area and constitutes the largest volume of the various units. Rocks of the Karmutsen are predominantly porphyritic and amygdaloidal basalt flows. The next oldest unit is the Quatsino Formation, which is generally a massive limestone with rare interbeds of tuffaceous material. Following the Quatsino Formation is the Parson Bay Formation. This is a transitional unit that separates the Quatsino Formation from the Bonanza Formation. The Parson Bay Formation is comprised of black calcareous siltstones, shales and limestones with shaly interbeds.

The Bonanza Formation is mid to lower Jurassic in age. The volcanic unit consists of bedded and massive tuffs, formational breccias and rare amygdaloidal and porphyritic flows. Porphyritic dykes and sills intrude the lower part of the unit. Unconformably over the Bonanza lie rocks of Lower Cretaceous age, consisting primarily of conglomerates, siltstones, sandstones and greywackes.

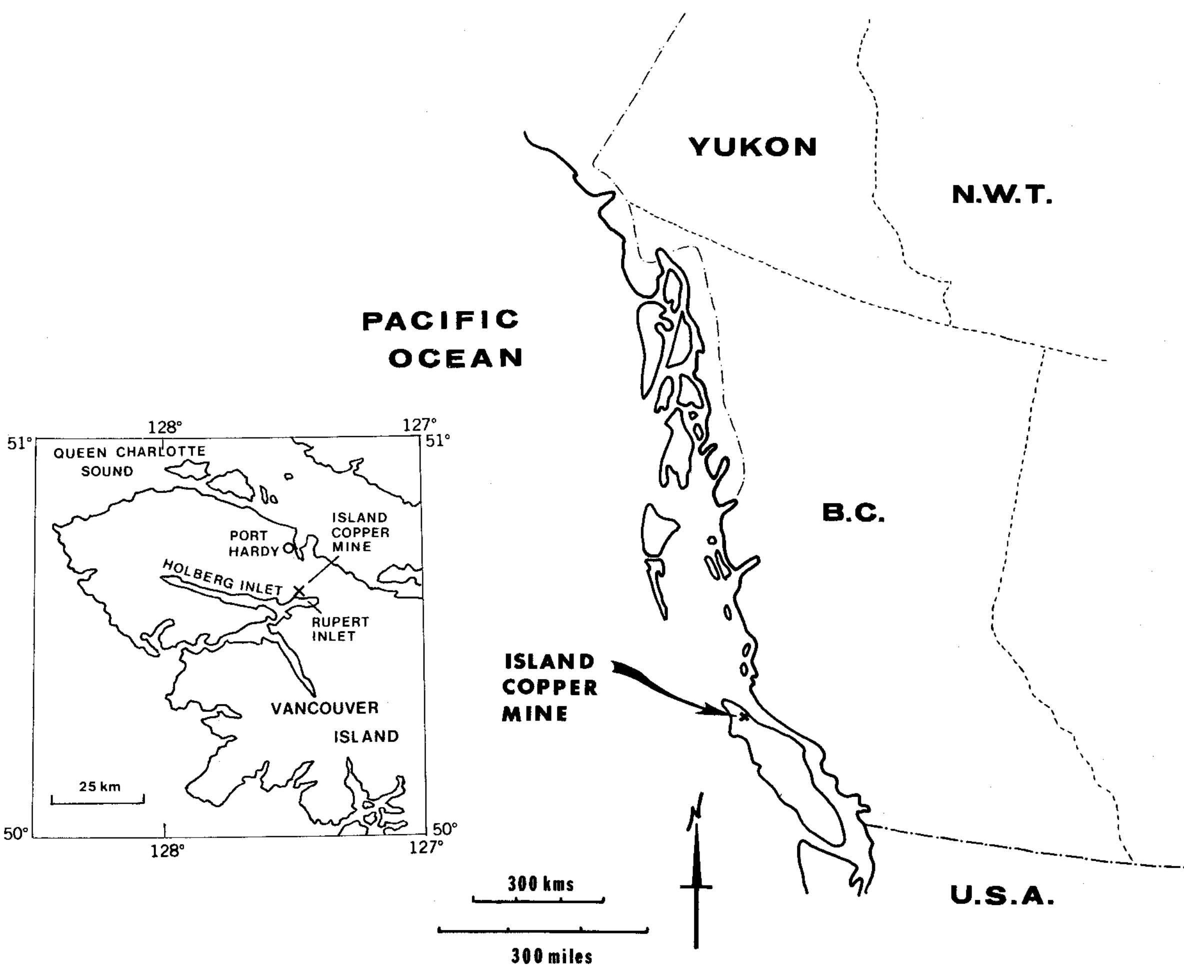


*Figure 32.1. Location map — Island Copper Mine, northern Vancouver Island, British Columbia.*

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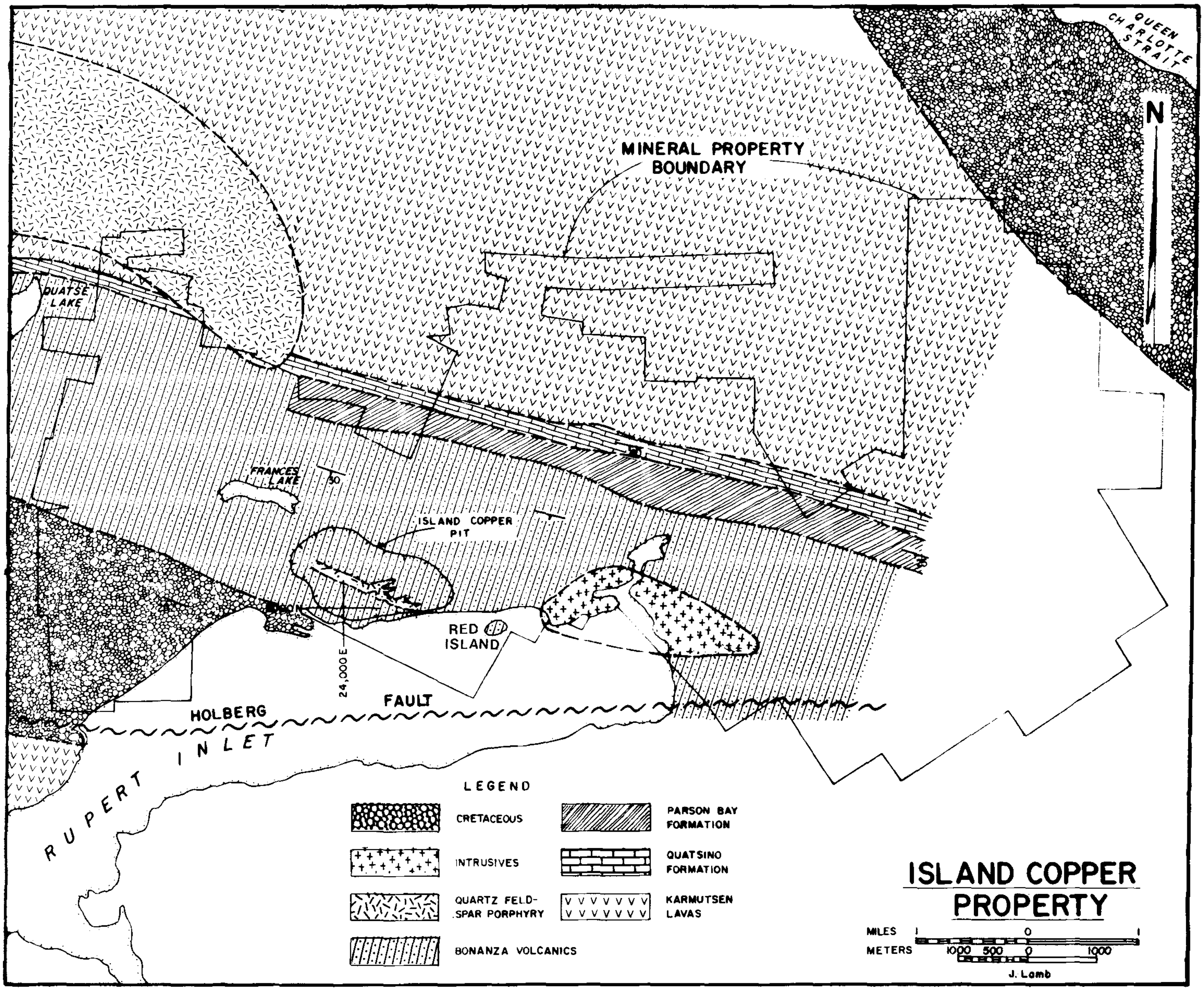


***Figure 32.2.*** *Regional geology of Island Copper Mine (after Cargill et al., 1976).*

A northwest-trending zone of intrusive stocks extends from the east end of Rupert Inlet to the Queen Charlotte Sound in a zone about 56 km long and up to 6.5 km wide. The stocks range in composition from diorite to quartz monzonite.

Quartz-feldspar porphyry dykes occur along the southern edge of the zone of stocks. These dykes tend to be quite small, usually less than 30 m wide and 150 m long. Felsic dykes and sills occur around the margins of some of the intrusive stocks. They are generally a few metres wide and less than 100 m long and cut through rocks of the Karmutsen, Quatsino and Bonanza formations. Andesite dykes which cut the Karmutsen, Quatsino and Parson Bay formations are apparently feeders to Bonanza-age volcanism.

### *Geology and Mineralogy of the Island Copper Deposit*

The geology on the north side of Rupert Inlet is a representative section of the rocks just discussed in the regional setting. The rocks increase in age going northeasterly from the shoreline and dip at approximately 30° to the south. The regional strike is about N70°W, with several other prominent northwesterly and northeasterly trends superimposed on the regional strike. A small granodiorite stock lies at the east end of Rupert Inlet (Fig. 32.2). The mineralized quartz-feldspar-porphyry dyke at ISCU is 4 km to the northwest from this stock along a N70°W bearing. the ISCU dyke lies in the upper part of the Bonanza Formation and dips to the northeast approximately normal to the bedding of the Bonanza rocks. Several kilometres to the northwest of the ISCU dyke lies another granodiorite body of larger proportions than the one at the east end of Rupert Inlet. This intrusive body outcrops lower in the geological section and lies predominantly in the Karmutsen Formation.

The ISCU deposit lies in the upper portion of the Bonanza Volcanic Formation. The deposit is localized in and adjacent to a quartz-feldspar-porphyry dyke that strikes at N70°W, and dips at about 60° to the northeast (Fig. 32.3). The dyke at the pre-mining bedrock surface has a strike

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length of slightly over a kilometre and an irregular width that varies from 180 m to less than 20 m. The dyke is granodiorite in composition, the same as the stock at the east end of Rupert Inlet. These two bodies are believed to be genetically of the same origin.

Several periods and directions of faulting are apparent in the vicinity of the deposit. The most prominent structure adjacent to the deposit is the End Creek fault (Fig. 32.3), which dips steeply to the south on the southwest side of the dyke. This fault is believed to be post-mineralization and has an unknown magnitude and direction of offset. The End Creek fault has a width of approximately 60 m and has a strike that has been mapped and inferred for a length of several kilometres. A second major fault zone strikes N65°E, roughly through the centre of the deposit (Fig. 32.3). As with the End Creek fault, this structure has a steep dip and possesses an unknown amount of offset.

Two major stages of metamorphism have been recognized at ISCU (Cargill et al., 1976). The first stage is called the contact metamorphic stage, which occurred when the dyke initially intruded the volcanic pile. The major alteration minerals formed in the host rocks at this time were biotite, chlorite and epidote, in a direction moving away from the dyke. After this initial alteration occurred, the hydrothermal system around the dyke changed as the dyke cooled. As a result of further heating, a second stage of alteration – the wall rock stage, took place. The characteristic minerals formed during this stage were chlorite, sericite, pyrophyllite, dumortierite and a rusty-orange dolomite. This last alteration sequence affected both the quartz-feldspar-porphyry dyke as well as the surrounding volcanic rocks.

There are three associated breccia phases identified with the deposit: (1) pyrophyllite; (2) marginal; and (3) Yellow Dog breccia. The pyrophyllite breccia lies over the top of the dyke in a hood-like fashion at the northwest end of the deposit and extends over 1100 m in a northwesterly direction. The breccia fragments originate both from the dyke and from highly altered volcanic rocks. The marginal breccias lie on both sides of the dyke in a sheet-like fashion and extend down-dip to a considerable depth. Composition varies from predominantly volcanic fragments, away from the dyke, to almost totally quartz-feldspar-porphyry fragments, adjacent to the dyke. The Yellow Dog breccia derives its name from the rusty-brown colour of veinlets of ferroandolomite. The Yellow Dog breccia cuts through the middle of the deposit and has north and northeast trends. The fragments are primarily highly altered volcanic rocks with quartz and carbonate vein fillings.

The ore minerals at Island Copper are chalcopyrite and molybdenite. The orebody is composed of a hanging wall zone and a footwall zone around the quartz-feldspar porphyry dyke. The ore zone, on both sides of the dyke, is about 60 m to 180 m wide and 1700 m long, extending to over 300 m below the surface. The bulk of the ore is found in the volcanic rocks adjacent to the dyke, although some parts of the dyke are mineralized. Most of the chalcopyrite occurs in veinlets on slip surfaces and occasionally as disseminations. Molybdenite occurs primarily on slip surfaces, but occasionally in quartz veinlets.

Other prominent minerals are pyrite and magnetite. Pyrite is two to three times more abundant than chalcopyrite in the ore zone and is also locally abundant in the alteration halo around the dyke. The mode of occurrence for pyrite is disseminations and fracture fillings. Magnetite occurs in both the volcanic rocks and in the dyke. In the volcanic rocks the magnetite is found as small disseminations and with chlorite pseudomorphs of mafic minerals. There appears to be very little primary magnetite in the Bonanza volcanics themselves; therefore, the bulk of the magnetite is believed either to have been introduced, or more likely, altered from original iron-rich minerals. Recent magnetic susceptibility studies confirm in a qualitative way, the affinity between magnetite and chalcopyrite in the area (J. Flemming, pers. comm., 1977).

## GEOPHYSICAL SURVEYS OF THE ISLAND COPPER DEPOSIT

### *Aeromagnetic Survey*

The Federal/Provincial aeromagnetic survey was flown on north-south lines with a nominal 800 m (0.5 mile) line spacing. The total magnetic field was recorded at a mean elevation of 305 m above the ground surface. Results were diurnally corrected and compiled on 1:63 360 scale topographic maps (Anonymous, 1964) with a 10 gamma minimum contour interval. The major feature of the aeromagnetic survey contours north of Holberg and Rupert Inlets (see Fig. 32.4) is a northwesterly-trending magnetic high which correlates closely with the line of Jurassic stocks discussed in the Regional Geology portion of this report. The strongest magnetic responses occur along the edges of the stocks in contact with the Karmutsen rocks. Some skarn highs also appear over the Quatsino Limestone Formation, but these are generally small. The smaller stocks are generally homogeneous, low amplitude highs on the airborne data. Some of the larger stocks however, show considerable magnetic zoning inside their boundaries. At the far southeasterly end of the major axis of the magnetic high and offset slightly to the southwest, lies a small, isolated high. The ISCU deposit underlies the southern part of this magnetic anomaly.

The aeromagnetic contours around the ISCU deposit (Fig. 32.4) show a prominent anomaly centred just northwest of the pit. The anomaly as defined by the 4000 gamma contour is shaped like a lopsided arrow head, with the southern side drooped down over the top of the deposit. The peak values of the zone lie roughly parallel to the north shore of Frances Lake and extend some distance to the west and east. The complete anomaly is approximately 6 km long, striking N65°W, with a width varying from 1 km to 1.5 km. A smaller high dominates the southeast portion of the overall feature and is situated at the edge of Rupert Inlet. Several kilometres north of the ISCU high lies a larger but somewhat less intense anomaly. This correlates with a granodiorite stock that straddles the Karmutsen and Quatsino formations. A third and much weaker high occurs at the east end of Rupert Inlet and correlates with the southeast edge of the granodiorite stock mapped in the area.

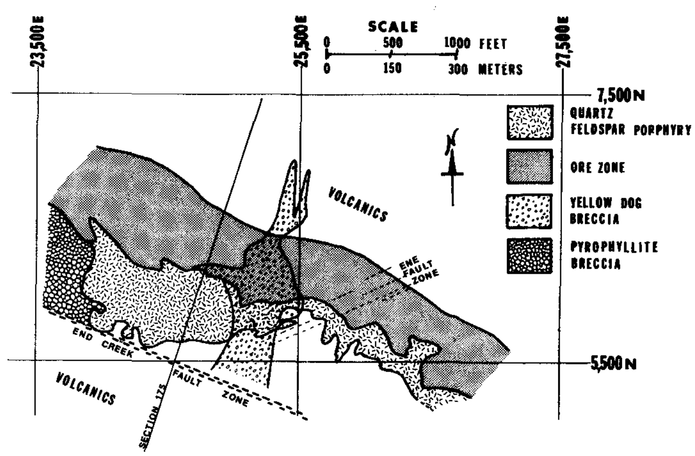


***Figure 32.3.*** *Pit geology.*

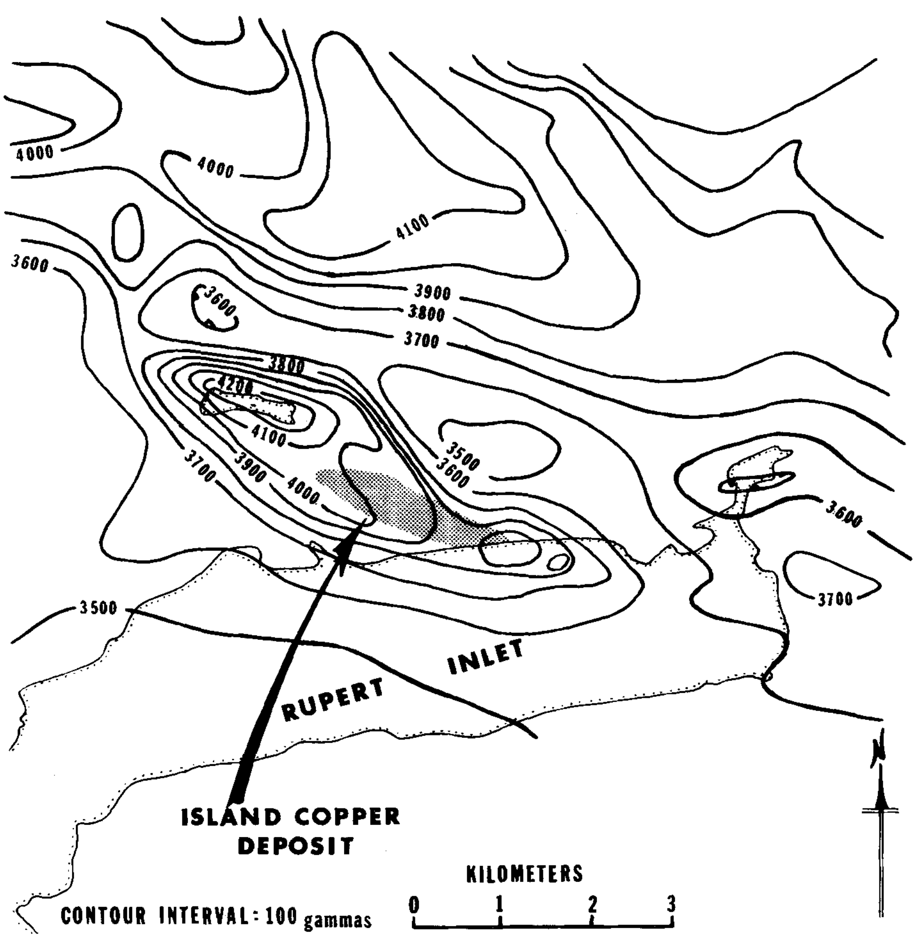


***Figure 32.4.*** *Aeromagnetic survey over the Island Copper mine area (from Aeromagnetic Map 1734G, Geol. Surv. Can.).*

### *Ground Magnetic Surveys*

The ground magnetic surveys were carried out along the 160 km of survey grid by several two-man crews who took both magnetic readings and obtained soil samples. To extend the survey data, 50 stations were observed over Frances Lake using an aluminum boat, so as to better define the anomaly immediately north of the lake. The instruments used were a Jalander fluxgate and an Askania Gfz torsion magnetometer – both are vertical field instruments with repeatable sensitivities of about ± 20 gammas and ± 5 gammas respectively. The normal diurnal corrections were applied to the readings and the results plotted and contoured on 1:2400 scale base maps. A background level of 1000 gammas was selected to reference the local magnetic variations against.

The ground magnetic survey resolved the aeromagnetic anomaly observed over the ISCU deposit into two distinct zones of positive magnetic anomalies (Fig. 32.5). The largest and most continuous of the two zones lies several kilometres to the northwest of the orebody. This zone is called the Frances Lake Zone, having a strike of N73°W, a length of 2.8 km and an irregular width that averages about 300 m inside the 2500 gamma contour. The magnetic relief along the Frances Lake Zone is locally 4000 gammas above background, with the most intense portion just northwest of the lake. This is the area that Milbourne originally investigated with a dip-needle instrument. The other zone of positive magnetic anomalies is called the Pit Zone. This zone is roughly parallel to the Frances Lake Zone, but is offset about 700 m to the southwest with an overlapping stagger of 1400 m. The Pit Zone strikes at N65°W and has an observed length of 3.3 km. Observed length is a significant qualification since the southeast end of the zone ends at the shoreline. Red Island is located on the same southeast trend at a distance of 1.2 km from the shoreline (Fig. 32.2). On the aeromagnetic map (Fig. 32.4) the extension of the Pit Zone to include Red Island is apparent so the total length of the zone, both on land and underwater, is almost 5 km. The Pit Zone's width as defined by the 2500 gamma contour is variable but is generally slightly less than 700 m (Fig. 32.6). Four major anomalies stand out in the zone, of which the two central highs are located directly over the orebody. A third high lies off the northwest end of the deposit and the fourth high is a partially defined zone lying along 1100 m of shoreline.

Even though the Frances Lake and Pit Zones are spatially quite close to each other, there are several differences in their magnetic expressions. In a semi-quantitative sense, the differences can be listed as:

1. The Frances Lake Zone is quite continuous in appearance; it is not broken-up like the Pit Zone.
2. An examination of the anomaly frequencies over the two zones shows the magnetic sources in the Frances Lake Zone are very near surface, while in the Pit Zone, particularly at its northwest end, the bulk of the causative magnetic body is located at a substantial depth. The anomaly over the northwest end of the pit has a source depth based on the half-width rule (Riddell, 1966) of about 215 m.

With regard to the first point of difference, corroborating information was obtained from a detailed magnetic susceptibility mapping program on core and outcrop in the pit at various bench levels. The instrument used was a small, hand portable magnetic susceptibility meter model PP-2A, manufactured by Elliot Geophysical Company, Tucson. The survey results in general substantiated the interpretation of the surface magnetic data in that the distribution of magnetite around the orebody was found to be quite irregular. Drilling of the Frances Lake and Pit Zones both before and after the exploration phase substantiated the second observation – early testing of the Frances Lake Zone encountered magnetite at a shallow depth, while more recent drilling at the northwest end of the pit found the percentage of magnetite to increase sharply 240 m below the pre-mining surface (vs 215 m based on the half-width rule).

Although there are apparent differences between the Frances Lake and the Pit Zones, there is also evidence from the magnetic data suggesting that the two zones are closely related in origin and may at one time, have been a more or less continuous feature. Support for this hypothesis comes in part from the geometrical relationships between the magnetic highs and lows around the deposit. The lows of particular interest are two magnetic troughs that trend N15°E; one commences from the southeast end of the Frances Lake Zone and strikes to the northeast and the other commences 1400 m to the northwest of the Pit Zone and extends to the southwest (Fig. 32.5). The separation between

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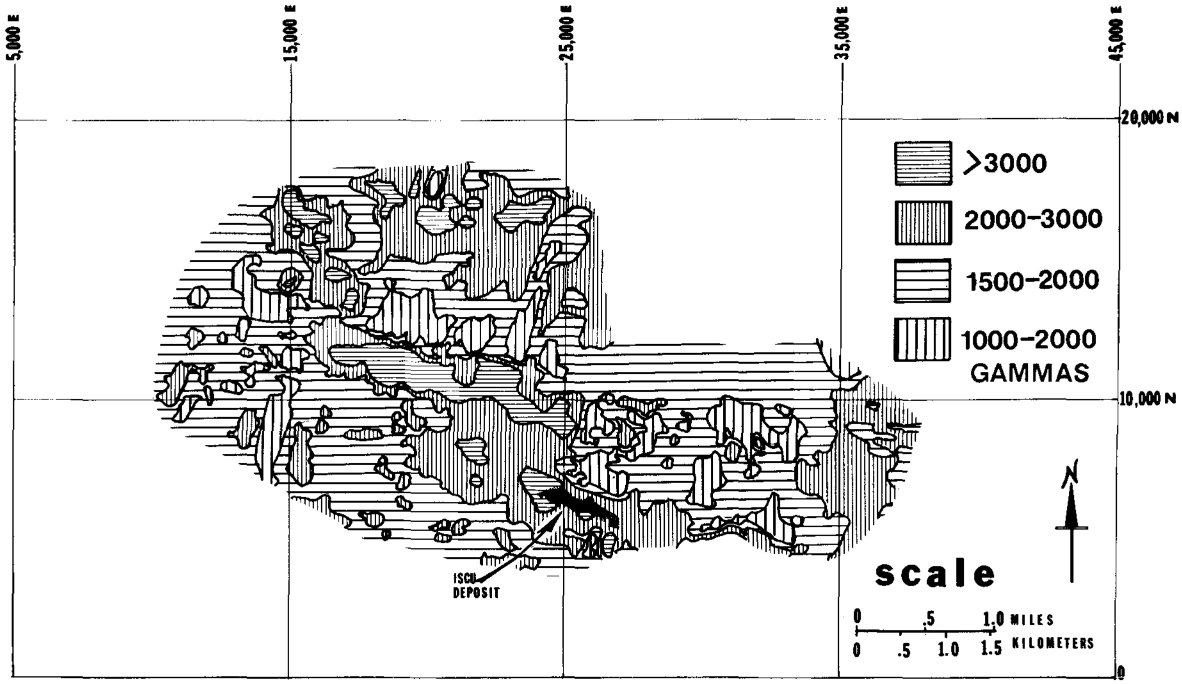


*Figure 32.5.* *Regional ground magnetic survey.*

the troughs on a northwest-southeast line is about 1400 m and the displacement on a northeast-southwest line is about 730 m. These figures are almost identical to the displacement and offset values between the Frances Lake Zone and the Pit Zone. The conclusion then is that the two zones of magnetic high might well have originally formed together along the same structural trend but that post-mineralization faulting has displaced the zones in a right lateral sense to the present positions. The origin of the magnetic lows is not certain, but they are probably due to the presence of a major fault that was once active, resulting in the local destruction or remobilization of magnetite. One other prominent N15°E magnetic trend is a line normal to the southeast end of the Frances Lake Zone. If this lineament is carried to the southwest, it lines up with the Yellow Dog breccia in the pit, which, in turn separates the two magnetic highs in the deposit.

Other magnetic features of interest include the End Creek fault which lies on the southern flank of the Pit Zone. This structure appears in profile form on a number of lines as a positive peak with a distinctive negative on the south side. The amplitudes of the positive and negative varies considerably from line to line but the pattern indicates local removal of magnetite along the fault zone with some remobilization to the footwall side. This signature lies on the south side of the larger magnetic highs caused by deeper sources from within the deposit. Another area of interest is around the two highs located in the northern and northwestern portion of the survey area. The anomaly in the northwest part of the grid appears to be an extension of the west end of the Frances Lake Zone. Interestingly, the northwest zone commences with a dog-leg from the Frances Lake Zone at a bearing of N29°W. The northern part of the outlined anomaly lies adjacent to a granodiorite stock mapped off the northwestern corner of the survey grid. The northern anomaly correlates with a mapped diorite stock and the magnetic response seems to be due to the presence of original magnetite in the rock.

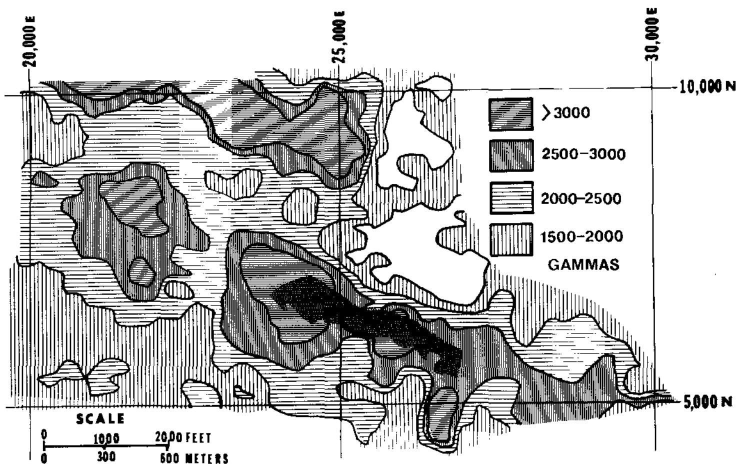


*Figure 32.6.* *Pit area ground magnetic survey.*

### *Induced Polarization Survey*

The equipment used for all the induced polarization (IP) exploration work carried out on the ISCU property was a Hewitt 100 time-domain IP system. This unit is a physically-linked transmitter-receiver system with a rated output of 800 watts. The receiver integration periods are similar to the Newmont standard (Dolan, 1967) and in comparison field tests, the conversion factor between the two systems was about 1:1. The Wenner electrode array was used except for the last survey over the orebody when the pole-dipole array was utilized. A regional survey along the logging roads used dipoles of 152 m and 183 m spacing while the pole-dipole work used a potential electrode spacing of 61 m with N=1 and N=2 separations. The extremely damp conditions on the property, especially during the winter months, caused the IP equipment to malfunction a number of times which was partly the reason why the IP method was not utilized more in the initial exploration stage.

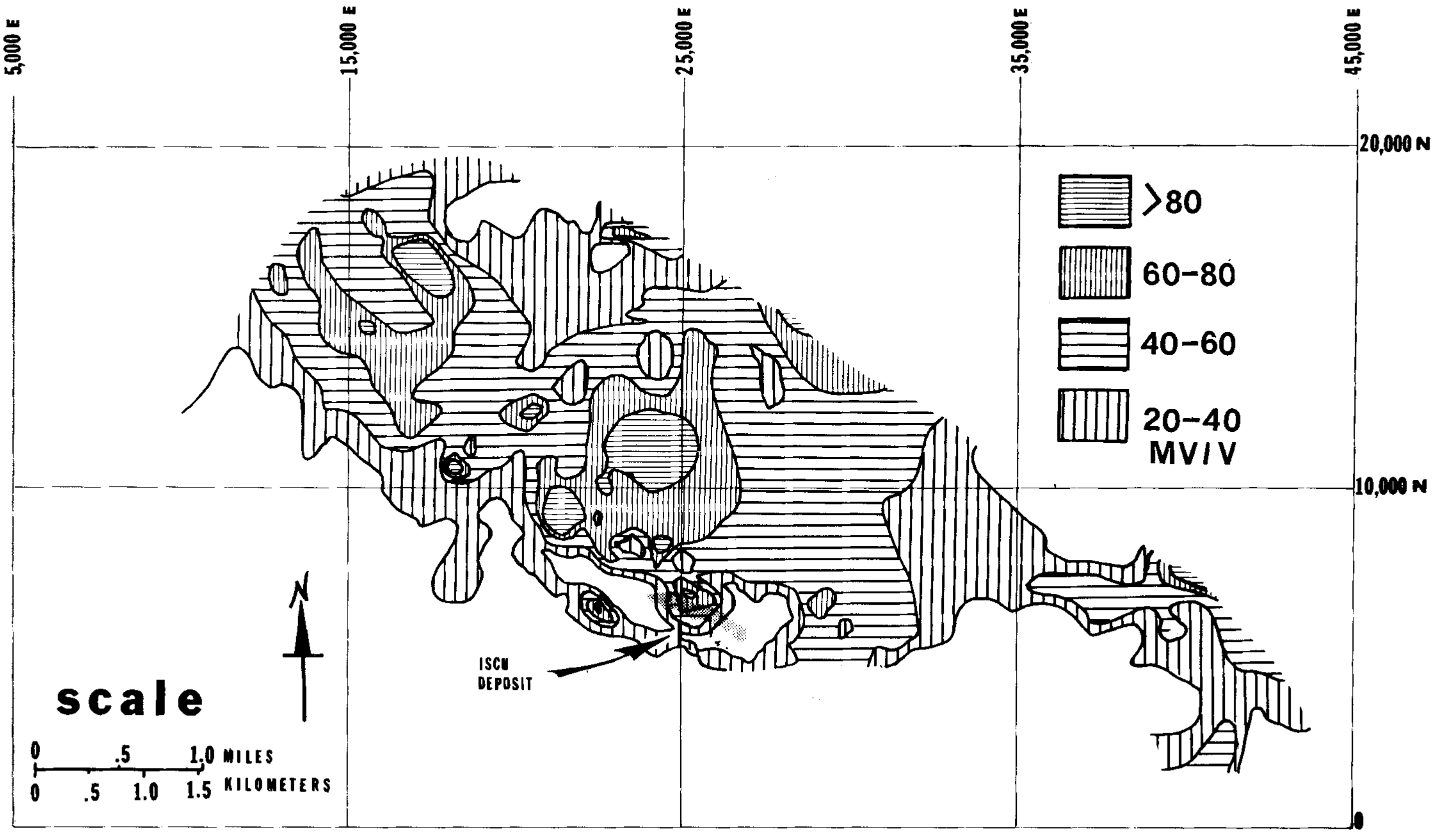


*Figure 32.7.* *Regional IP survey.*

The induced polarization technique was used initially to investigate specific areas of geological and geochemical interest around the west end of Frances Lake. Numerous anomalies were obtained and it was found by subsequent drilling that the best IP highs were due mostly to pyrite. Although this information was useful in an indirect manner, in that it could help outline zones of alteration, the magnetic and geochemical survey results provided much less expensive and more diagnostic means by which to locate copper mineralization. Largely for this reason, little IP work was done during 1966 and once the deposit was found, only the immediate area of the deposit was surveyed using IP.

In 1968, as part of a program to evaluate the remaining ground held by Utah Mines Ltd. around the deposit, a regional IP survey was conducted utilizing the extensive system of logging roads on the property. The results of this survey (Fig. 32.7) shows a large zone of anomalous chargeability as outlined by the 40 ms contour trending at N70°W across the property. The zone has an observed length of 6.4 km and a width of about 2 km. The anomaly ends 1500 m past the southeast end of the pit and is open to the northwest. There are several clusters of intense highs (>80 mv/v) within the overall zone. These clusters vary in size, but there appear to be at least four pairs with the members aligned at about N50°E ± 10°. Interestingly, these pairs of IP highs all straddle anomalous magnetic zones. The Frances Lake Zone is straddled by two such pairs and the magnetic high in the northwestern corner of the property is almost encircled by an IP high, open only to the northwest.

The resistivity results provide little in the way of unique diagnostic information, either on the structure or mineralization in a regional context. The dominant feature is a northwesterly-trending break running roughly across the property, as indicated by the 500 ohm-metre contour. Northeast of the break, resistivities are generally greater than 500 ohm-metres, while to the southwest of the contour, they tend to be less than 500 ohm-metres. This corresponds roughly to the contact between the Bonanza-Parson's Bay formations to the southwest and the Quatsino-Karmutsen formations to the northwest.

The results shown in Figure 32.8 (chargeability) and Figure 32.9 (resistivity) are the N=1 data from the detailed pole-dipole survey over the deposit. The chargeability results around the deposit show two bands of high straddling the dyke and the pyrophyllite breccia cap on a more or less continuous basis, with the high on the north side of the dyke being much more intense and extensive than the zone on the south side. This difference is felt to be probably due in part to vertical movement along the End Creek Fault which has removed most of the pyritized wall rock on the southwest side of the dyke.

It is apparent from Figure 32.8 that there are several pairs of chargeability highs straddling the orebody and the pyrophyllite cap in a similar fashion to those already noted in the regional results. The pairs of anomalies around the deposit are noticeably smaller in area and somewhat less in amplitude than the pairs around Frances Lake and in the northwest corner of the property, but they show the same northeasterly alignment and similar straddling of magnetic highs.

Besides the major zone of anomalous IP, a second anomalous zone is noted in Figure 32.7 at the far southeastern corner of the survey. This anomaly is adjacent to the granodiorite stock at the east end of the Inlet, and could be considered a continuation of the main chargeability zone, interrupted by Rupert Inlet.

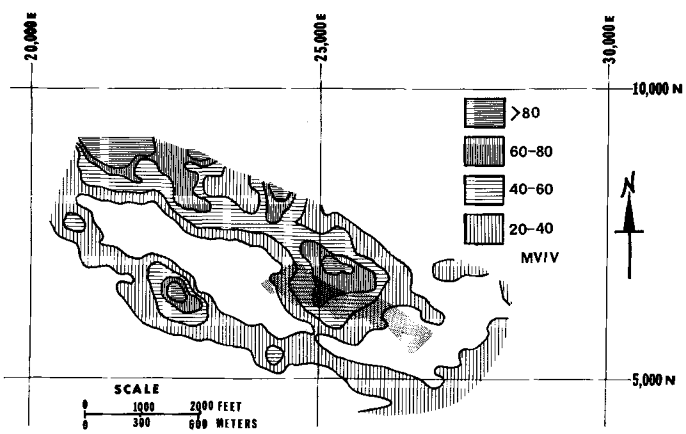


*Figure 32.8.* Pit area IP survey.

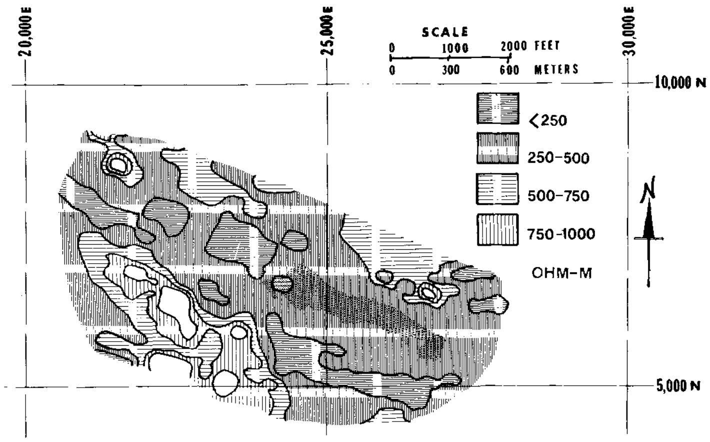


*Figure 32.9.* Pit area resistivity survey.

In assessing the IP results, consideration must be given to the unknown dilution effects caused by the large variations in overburden thickness around the deposit. The chargeability anomalies on the ISCU property are felt to be due to a combination of sulphide and non-sulphide responses. Pyrite is present both in the ore and in the adjacent rocks as noted earlier. Together with chalcopyrite, sulphides in the pit total about 5 per cent combined, whereas pyrite reaches 15 per cent locally north of the deposit. Alteration clays around the deposit also appear to make a significant contribution to the observed chargeability response. Interestingly, the pyrophyllite breccia contains a small but significant amount of finely disseminated pyrite. On the IP results, however, the breccia cap stands out as a pronounced chargeability low. Some graphitic material is found in sediments north of Frances Lake, however the sediments are spatially quite restricted and are not believed to have contributed significantly to the overall IP picture.

The regional sulphide zoning as indicated by the IP results with respect to the magnetite in and around the deposit, appears to be an interesting variation of the pyrite-shell-IP-donut pattern sometimes suggested for the Southwest United States-type porphyry copper deposits. Geologically, the mineralization at ISCU appears to have been emplaced when an extensive zone of sulphides was first introduced along a northwesterly grain. This was followed by the alteration of some of the sulphide iron to magnetite. At about the same time, faulting (probably) disrupted the original northwesterly zone of weakness and some sulphides were selectively redistributed along northeasterly structures. Later, post-mineral faulting then further dislocated the sulphide distributions to their present position.

Around the pit area, the resistivity results (Fig. 32.9) were a little more diagnostic than those obtained in the regional survey. A portion of the End Creek Fault correlated with a resistivity low on its hanging wall side. Northwest and slightly southwest of this low, a pronounced zone of high resistivity shows up with a low on its northeastern side. The pyrophyllite breccia cap extending from the northwestern end of the dyke is located between the resistivity ridge and trough and where the cap apparently ends, so does the ridge-trough resistivity feature. The character over the deposit itself is quite uniform, with the resistivity values ranging from 200 to 300 ohm-m.

A typical cross-section through the deposit is shown in Figure 32.10. This figure presents the magnetic, geochemical, chargeability and resistivity profiles across the orebody and quartz feldspar porphyry dyke, and illustrates the spatial relationship of the ore with the geophysical and geochemical data.

### *VLF-EM Survey*

In the early drilling around the southwestern corner of Frances Lake, some massive copper mineralization was found in a near-surface vein system. To try to assist in the detection of such mineralization, a limited VLF-EM survey was run over the area. A Geonics EM-16 receiver was employed with the Jim Creek (Seattle), Washington station (48°12'N, 121°55'W) being used as the transmitter. This transmitter provided a good alignment with respect to the regional geological strike on the property. After some initial positive results over mineralization around Frances Lake, it was decided to conduct a survey over the newly found orebody using the EM-16. Although the overburden generally had a fairly high resistivity, there were many poor surface conductors (swamps, beaver ponds, etc.) where the EM-16 could be expected to respond. The VLF-EM results are presented in Figure 32.11 and because of their low amplitude character, little in the way of quantitative information was gained from the results at the time of the survey. Subsequent examination of the data showed that several sets of conductors axes could be correlated with legitimate structural and lithological features. Three of the most distinct sets of crossovers were adjacent to magnetic highs and two of the three conductor axes straddled the orebody. One other major conductor axis picked out the edge of the Bonanza volcanic-Cretaceous sediment contact west of the pit. This contact can be traced for a distance of almost 2 km, based on the EM-16 results. Most of the survey was carried out along grid lines 152 m apart with survey stations every 30.5 m. This type of coverage although likely too coarse for massive sulphide detection, gave satisfactory results in mapping major structures.

## GEOCHEMICAL SURVEY OF THE ISLAND COPPER DEPOSIT

The geochemical survey of the ISCU property was carried out in conjunction with the ground magnetic survey during the first half of 1966. Soil samples were taken every 30.5 m along lines that were 152 m apart (the same distance used in the magnetic survey). A total of 4203 samples were collected along 160 km of grid.

The area around the ISCU deposit has a variable cover of glacial till, peat and moss which ranges in thickness from less than one metre to over 75 m. The soil samples were taken with a mattock in areas where the organic cover was thin and with a 1.2 m long auger where the cover was thicker. The B soil horizon was sampled wherever possible. In all, however, 22 per cent of the stations could not be sampled due to excessive organic cover, lakes or lack of soil development over bedrock.

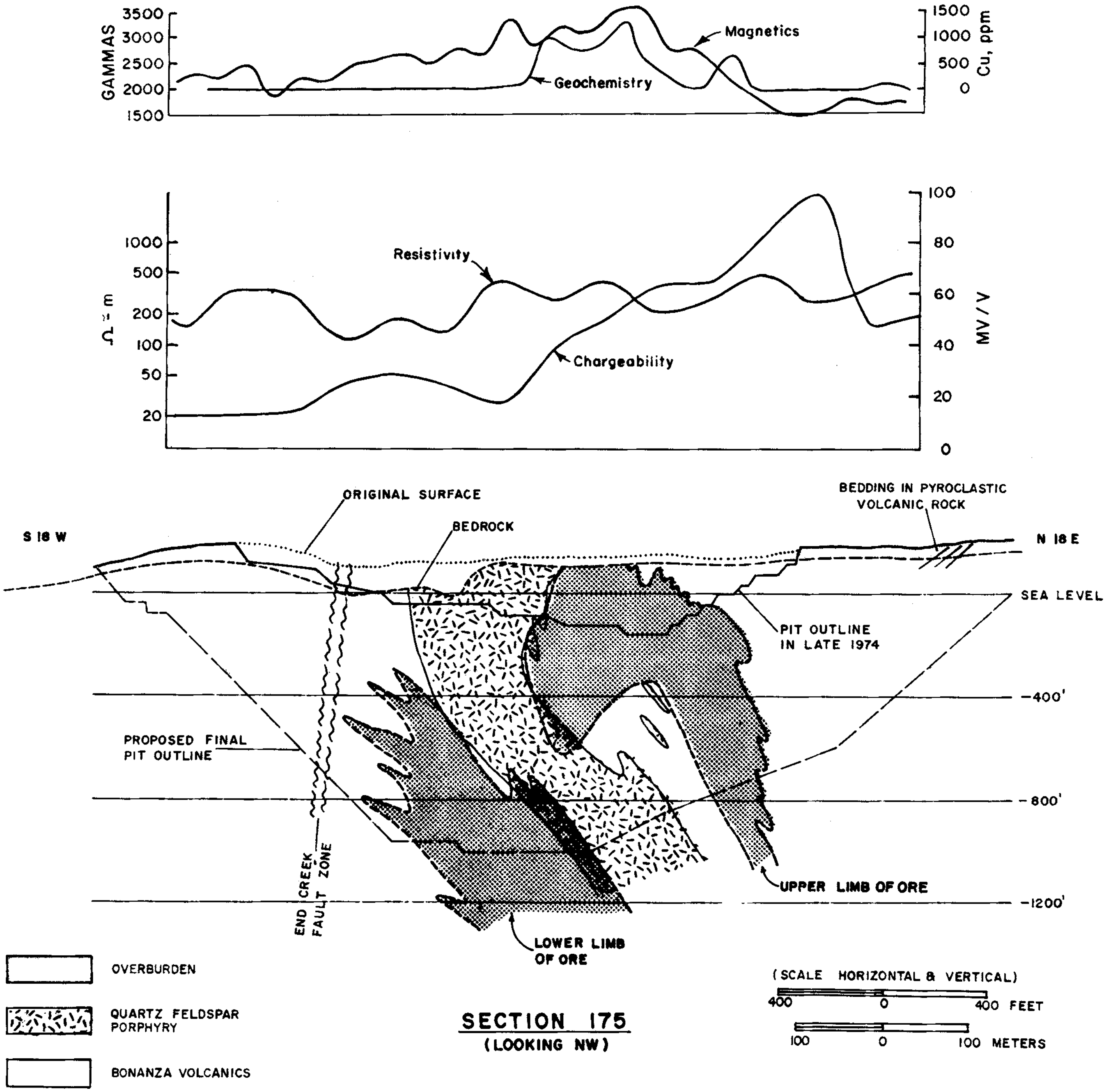


***Figure 32.10.*** *Cross-section 175; showing geochemical, ground magnetic, IP and resistivity profiles.*

The soil samples were first dried, ground and then sieved through an 80 mesh screen. The residues were then analyzed spectrographically for total copper content in parts per million (ppm). In order to assist in interpreting the geochemical results, some statistical treatment of the data was applied. A semilogarithmic frequency distribution histogram of the geochemical data is presented in Figure 32.12. Based partly on the statistical analysis of the geochemical, but more on empirical results derived from the drilling, an anomalous threshold of 100 ppm was decided upon. Values between 100 to 200 ppm were considered slightly anomalous, between 200 to 500 ppm were anomalous and above 500 ppm were considered significantly anomalous.

Several large anomalous zones were identified inside the survey block (Fig. 32.13), the largest being a N75°W trending zone located roughly in the west central portion of the property (approximately 10 000W to 15 000N, 10 000E, to 25 000E). The zone is composed of a number of discrete anomalies linked together by an envelop of above-background values. The zone terminates quite abruptly to the east but splits into a number of small parallel-trending zones in the west. Several relatively discrete geochemical anomalies with approximately N70°W trends were found to lie south of Frances Lake (Fig. 32.2), one at the southwest end of the lake centred at 9460N, 18 700E and the other several kilometres to the southeast centred at 6720N, 24 450E.

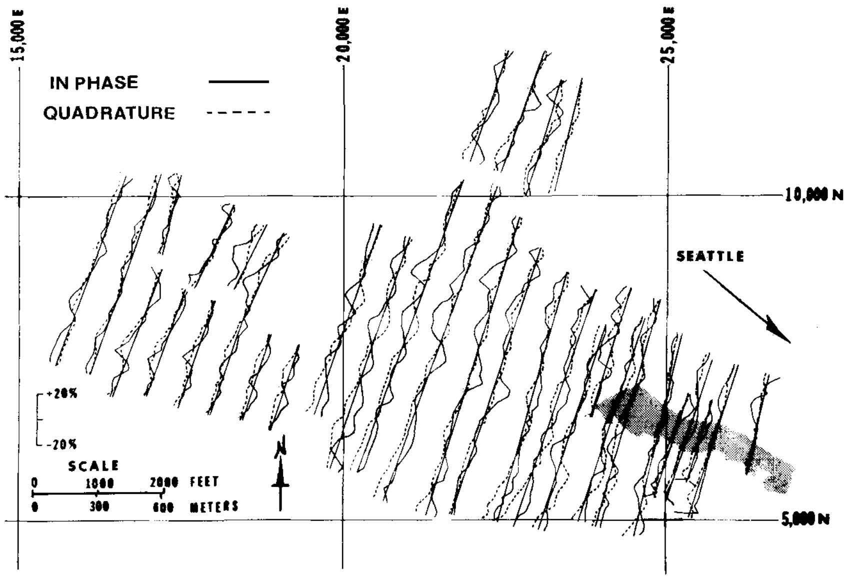


*Figure 32.11.* VLF-EM survey.

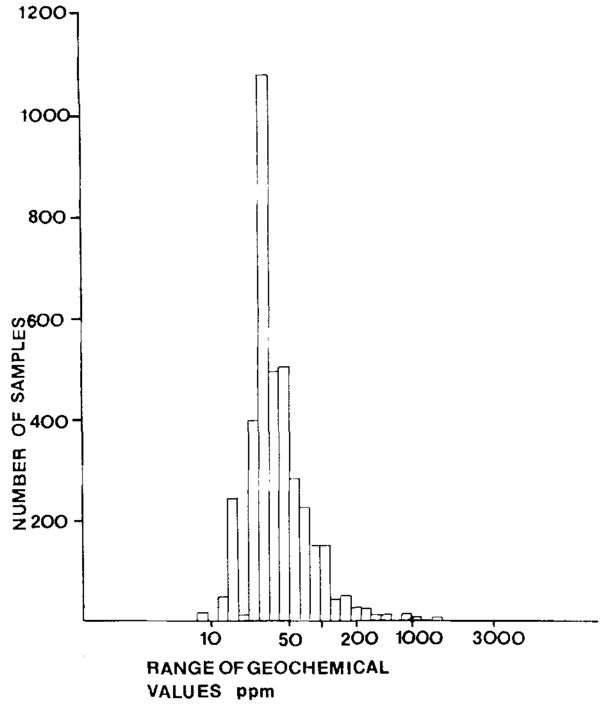


*Figure 32.12.* Histogram of copper geochemical data.

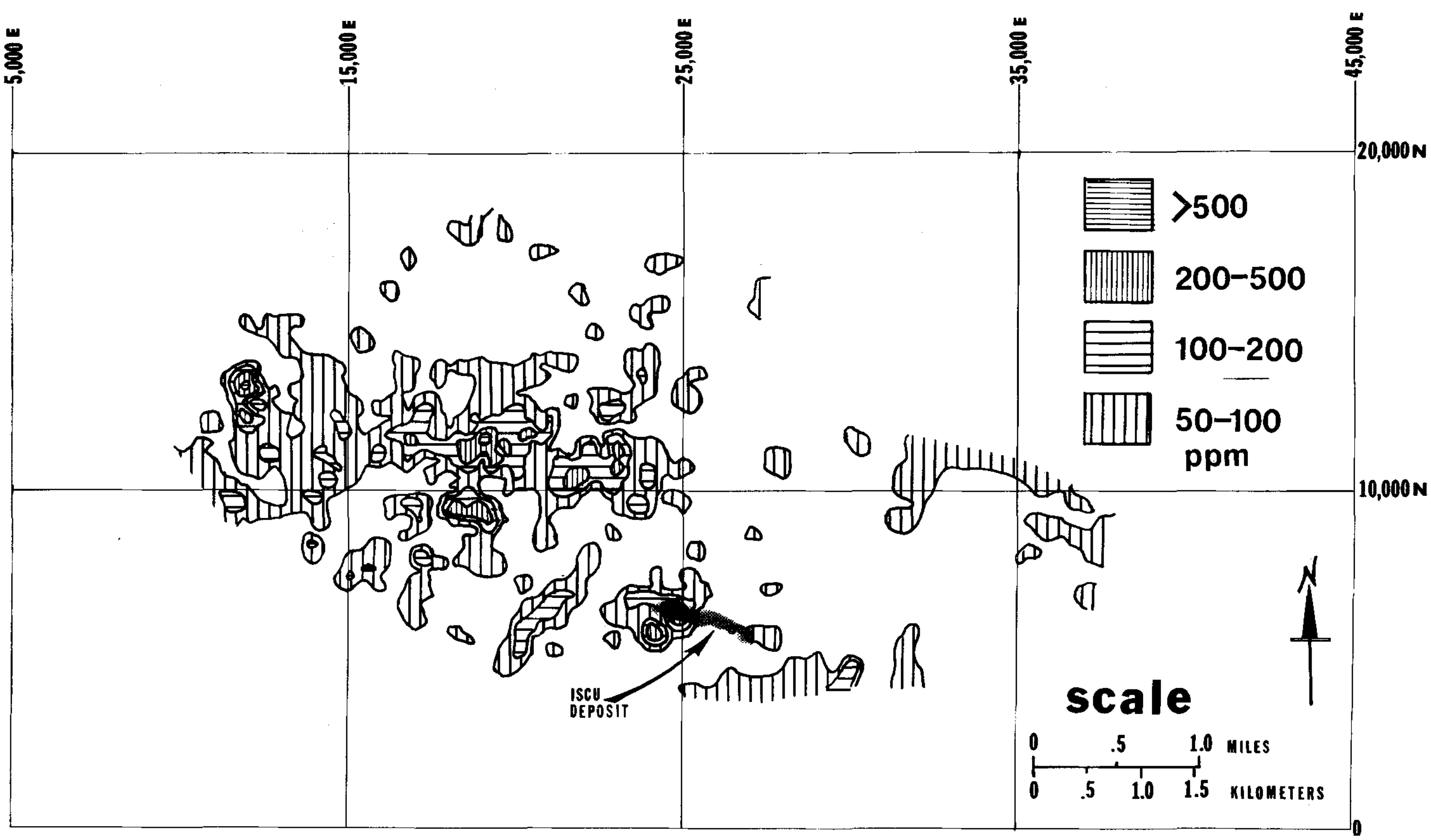


*Figure 32.13.* Regional geochemical survey.

The major geochemical anomaly, just north of Frances Lake, was tested in a number of places along strike and the underlying bedrock was found to be mostly volcanic rock containing subeconomic copper (0.2% to 0.25% range) with a variable amount of magnetite. The Frances Lake magnetic zone is coincident with a large part of the geochemical zone and based on the observed correlation between copper and magnetite, it was felt that considerable low-grade copper might occur along the length of the magnetic anomaly. A limited amount of drilling has tended to bear this hypothesis out.

The geochemical anomaly southwest of Frances Lake, coincides in part with the more massive vein-type mineralization as was first located by Milbourne and later confirmed from drilling by Utah Mines Ltd.

The anomaly southeast of Frances Lake is centred over a portion of the ISCU deposit. Subsequent drilling of this anomaly indicated the area of the anomaly above the 200 ppm level corresponded fairly well with the part of the orebody overlain by less than 9 m of overburden.

Testing of other geochemical anomalies on the property most often encountered some low-grade copper mineralization in the bedrock. This observation encouraged the reliance upon the geochemical anomalies as being a prime source of drill targets, since, even though much of the glacial till had been transported, a significant amount of the soil at a given site was apparently locally derived. Extensive drilling of the anomaly over the deposit did show, however, that more than 15 m of the overburden could inhibit the surface expression of even subcropping ore-grade mineralization.

## CONCLUSIONS

Of all the survey techniques carried out in the discovery of the Island Copper (ISCU) deposit, a soil geochemical survey was the most successful due to its advantages of speed, cost and detection of the specific element of interest. The problem of thick overburden subduing the geochemical expression was apparent on the property but did not present a serious problem.

Magnetic surveys were the most useful of the geophysical tools used at ISCU; an aeromagnetic anomaly initially focused attention on the area around ISCU, and later both during and after the exploration phase, ground magnetic surveys provided invaluable information concerning the structure and mineralization around the deposit.

Induced polarization surveys did not compare with geochemical and magnetic surveys in their effectiveness in directly locating mineralized bedrock at ISCU. However, after a regional perspective using IP was obtained, it allowed more detailed work to be put into an intelligible context, which in turn directed attention to some unique structures and alteration effects in the area of the deposit.

A VLF-EM survey demonstrated its usefulness as an aid to tracing structures, even in the presence of thick overburden and numerous poor near-surface conductors.

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