28. THE DISCOVERY AND DEFINITION OF THE LESSARD BASE METAL DEPOSIT, QUEBEC

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Abstract

In 1971, prospector Antoine Lessard, using a ground VLF-EM instrument, identified an electromagnetic conductor during a search for the source of copper-nickel sulphide float found in the lac Frotet area of northern Quebec. Lessard outlined the conductive zone to its apparent limits with VLF-EM and magnetic surveys. Diamond drilling to test the conductor intersected copper-zinc sulphides in a favourable Precambrian volcanic environment. Subsequent drilling outlined a deposit containing 1.46 million tons to a depth of 1700 feet (520 m).

The presence of copper-zinc sulphides in the initial drill core was sufficiently encouraging to carry out more extensive geophysical surveys including airborne Input EM, ground horizontal-loop EM, induced polarization, gravity and mise-à-la-masse. These surveys have provided useful information about the deposit and its environment. Each method has supplied guides to the drilling program by showing some different aspect of the deposit. Discrimination between the sulphides and nearby peridotite bodies became a necessary requirement for the geophysical surveys. Clear discrimination was achieved by the magnetometer, airborne Input EM and ground horizontal-loop EM. Induced Polarization and VLF-EM surveys produced similar responses over the sulphide and peridotite bodies. The gravity survey did not produce an anomaly over the sulphides. Mise-à-la-masse was particularly informative both on surface and down holes. It is apparent however, that the initial VLF-EM survey made the major contribution to the discovery and definition of the near-surface portions of this deposit.

Résumé

En 1971, le prospecteur Antoine Lessard, en utilisant au sol un appareil pour levés EM-VLF (méthode électromagnétique aux très basses fréquences radio) a identifié un conducteur électromagnétique, alors qu'il recherchait la source de débris minéralisés contenant des sulfures de cuivre et de nickel, que l'on avait découverts dans le secteur du lac Frotet, dans le nord du Québec. Lessard a tracé les limites apparentes de la zone conductrice en effectuant des levés magnétiques et EM-VLF. Des forages au diamant que l'on a faits pour explorer le conducteur ont recoupé des sulfures de cuivre et de zinc dans un milieu volcanique précambrien favorable. Par la suite, des forages ont permis de délimiter un gîte contenant 1.46 million de tonnes, à une profondeur de 520 m (1,700 pieds).

La présence de sulfures de cuivre et de zinc dans la carotte de forage initiale a été un élément assez encourageant pour que l'on entreprenne des levés géophysiques plus poussés, en particulier des levés aéroportés EM par la méthode INPUT, des levés EM au sol par la méthode des bobines horizontales et coplanaires, des levés de polarisation induite, gravimétriques, et de mise à la masse. Ceux-ci ont apporté des informations utiles sur le gisement et son environnement. Chaque méthode a contribué à orienter le programme de forage, en révélant un caractère particulier du gisement. Pour faire les levés géophysiques, il a été nécessaire de pouvoir établir une distinction entre les sulfures et les masses de péridotite proches. On a pu clairement établir cette distinction, en effectuant des levés magnétométriques, des levés aéroportés EM par la méthode INPUT et par la méthode des bobines horizontales disposées au sol. Les levés de polarisation induite et EM-VLF ont donné des réponses similaires au-dessus des corps composés de sulfures et de péridotite. Le levé gravimétrique n'a pas indiqué d'anomalie au-dessus des sulfures. La méthode de mise à la masse a apporté des renseignements particulièrement importants, à la fois au sol et dans les trous de forage. Cependant, on se rend compte que c'est grâce au levé initial EM-VLF que l'on a découvert et pu définir les portions de ce gisement proches de la surface.

INTRODUCTION

The Lessard copper-zinc-silver deposit is located in the Frotet-Troilus greenstone belt some 360 miles (580 km) north of Montreal and 58 miles (93 km) north of the town of Chibougamau, Quebec, at approximately 50°30' north and 74°40' west (Fig. 28.1 and 28.2). The overall trend of this small Archean greenstone belt is northeasterly. The trend of the southern half of the belt, in which the Lessard Deposit occurs is east-southeast. The belt is some 50 miles (80 km) long and 25 miles (40 km) wide. It lies west of the Grenville front and north of the Abitibi greenstone belt. The Frotet-Troilus belt consists of volcanic and sedimentary rocks intruded by granite, gabbro and ultramafic bodies. The sulphide deposit is situated at the top of a narrow sequence of felsic volcanic rocks at a contact with overlying mafic volcanic flows.

Drilling to date on the deposit has indicated a reserve of 1.46 million tons of 1.73% copper, 2.96% zinc, 1.1 oz. of silver per ton, and 0.019 oz. of gold per ton, to a depth of 1700 feet (520 m). A dilution factor of 15 per cent was allowed. The deposit does not appear viable under current economic conditions. The zone is open at depth with the deepest hole, at a vertical depth of 1600 feet (490 m), having a grade of 3.8% copper, 3.1% zinc, 3.3 oz. of silver per ton and 0.05 oz. of gold per ton over a true thickness of 20 feet (6 m). Further exploration including the use of drillhole geophysics is contemplated.

INITIAL DISCOVERY OF THE LESSARD DEPOSIT

The discovery of the deposit in 1971 was the result of persistent work by prospector Antoine Lessard who was attracted to the area by copper-nickel float which had been found in 1958 (Murphy, 1962) some 4.5 miles (7.2 km) southwest of the deposit. Prospecting northeast along the trend but in the opposite direction to the latest glacial ice movement, Lessard discovered chalcopyrite in quartz within a gabbro at lac Strip, south of lac Frotet, and staked a number of claims.

A search for buried conductive sulphides was carried out using a Crone Radem VLM electromagnetic (EM) instrument (Crone, 1977). This instrument employs signals from VLF transmitters to detect subsurface conductivity contrasts. Dip angles of the magnetic field component were read. Traverses were made along claim lines (0.25 mile (0.4 km) intervals east-west and north-south). A strong conductor was found southwest of the lake and a detail grid was traversed to the limits of the conductive zone (Fig. 28.3).

Lessard found that the conductor changed strike so that it was necessary to read lines at orthogonal and diagonal directions to the initial east-west lines. It was also necessary to use different VLF transmitters depending on the local strike of the conductor. The station at Cutler, Maine (17.8 kHz) was used for conductors having an east-west and northwest-southeast strike, while the station at Balboa, Panama (24.0 kHz) was used for conductors having a north-south strike.

Lessard also carried out a magnetometer survey on this grid using a pocket magnetometer made by L.A. Levanto Oy of Finland (Hood, 1967). His survey showed the VLF-EM conductor to be magnetic. The results of a more recent magnetometer survey are shown in Figure 28.7.

The VLF-EM data was filtered using Fraser's (1969) technique to move the data by 90° in order to change the cross-overs into peaks and to reduce noise. Contours of the filtered data are shown in Figure 28.3. The strongest portion of the conductor is arcuate. A weaker north-south component appears to the west.

The source of the conductor does not outcrop, although gabbro, peridotite and andesite outcrop near the conductor. Therefore, the identification of the zone by geophysical surveys played the major role in the discovery after the discovery of the copper-nickel sulphide float.

At this stage the property was brought to the attention of Muscocho Explorations Limited, and then in turn to Selco Mining Corporation Limited. Subsequent work on the property has been managed by Selco on behalf of a joint venture between Selco and Muscocho.

Limited confirmation of the conductor was made using a vertical-loop electromagnetic instrument (Ward, 1967). The vertical-loop survey (not shown) located conductors at each of the first four drillholes. Then, the four holes appearing on Figure 28.3 were drilled. Holes L1, L2, and L4 intersected copper-zinc sulphides in felsic volcanics. Hole number L3 identified graphite slips in serpentinized peridotite.

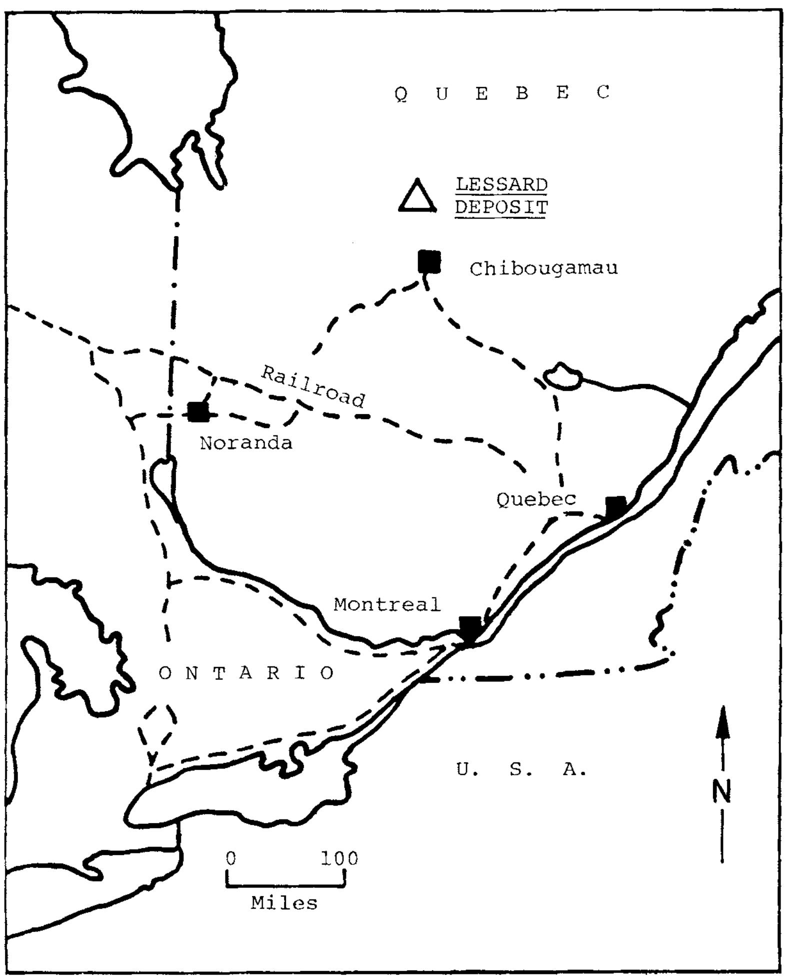

Figure 28.1. *Index map*

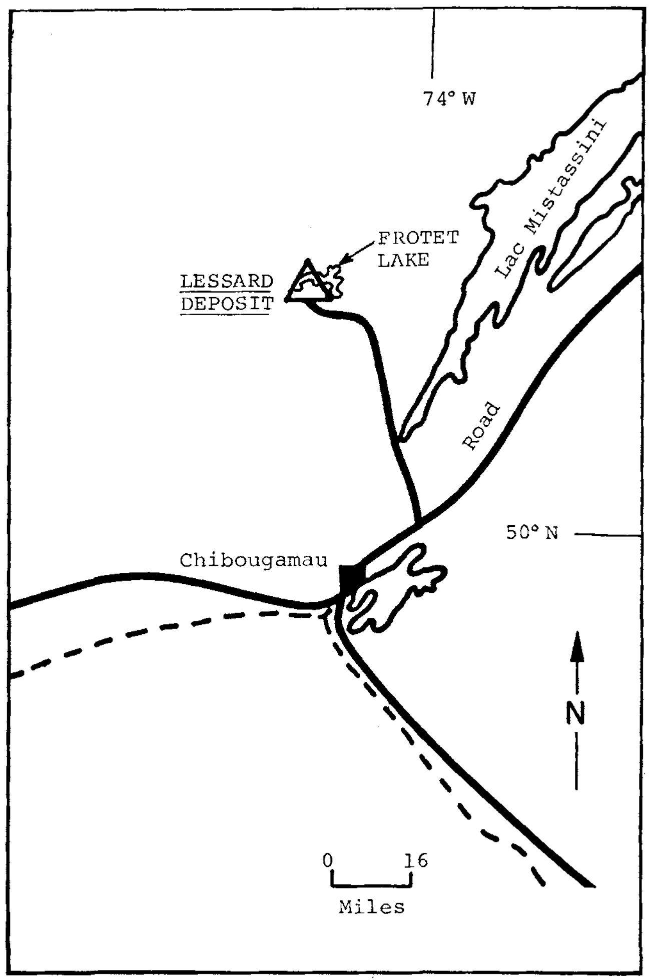

Figure 28.2. *Index map*

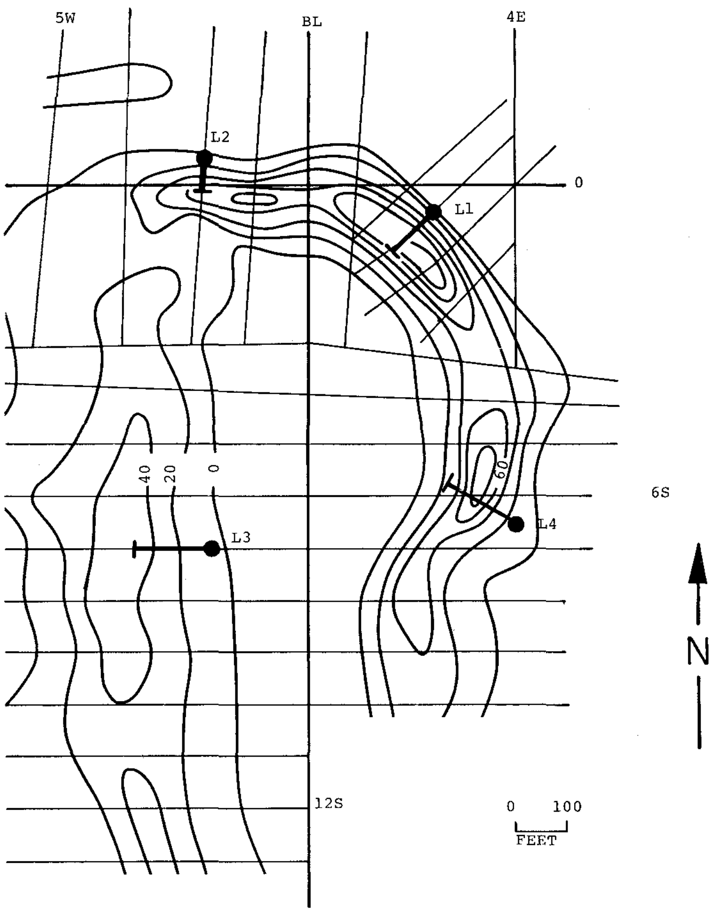

Figure 28.3. *VLF-EM survey on the discovery grid. The contour interval is 20 filtered degrees. L1, L2, and L4 are the discovery drillholes.*

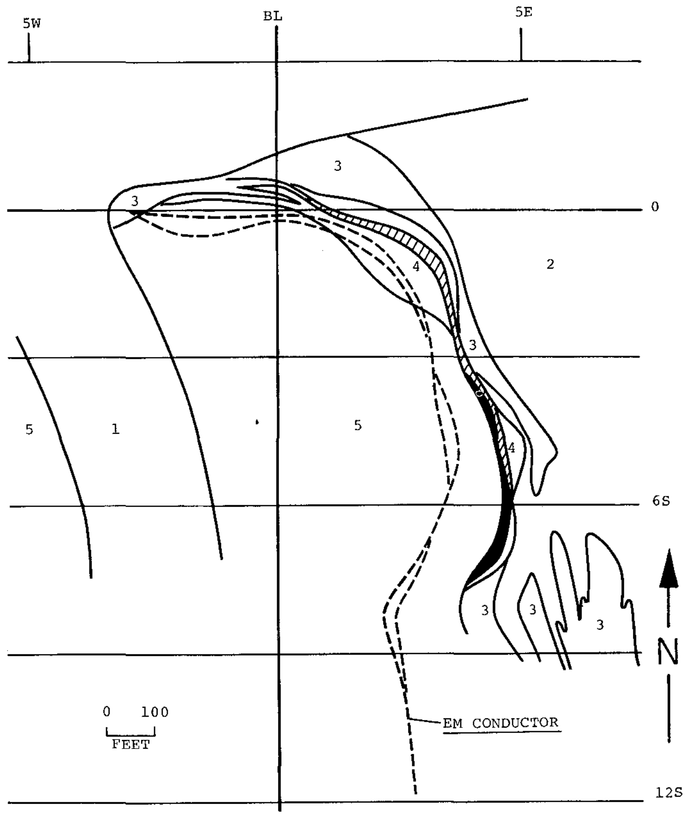

Figure 28.4. *Geology of the Lessard Deposit at 400 feet (122 m) below surface (legend on Fig. 28.5).*

DETAILED GEOPHYSICAL FOLLOW-UP

After the first four holes were drilled, a new grid was cut using the original grid as a base. Lines were generally cut with a 100 foot (30 m) line spacing. A number of these lines have been left out of figures accompanying this paper. However the instrument data or trends from the data on these lines are presented. Magnetometer, horizontal-loop electromagnetic, induced polarization (IP), gravity, and mise-à-la-masse surveys were carried out during the next two years. A Mark VI Input airborne electromagnetic survey carried out in the region also covered the deposit. These surveys provided definiton of the ore zone and guided the drill program as it progressed.

GEOLOGY OF THE LESSARD DEPOSIT

Most geological knowledge of the sulphide zone and its immediate environment comes from diamond-drill core since outcrop is sparse near the deposit. A plan of the 400 foot (122 m) elevation (Fig. 28.4) and a cross-section at 600S (Fig. 28.5) show the relationship of the sulphide zone to lithology. (The trace of the surface electromagnetic conductor defined in Fig. 28.6 is indicated in Fig. 28.4). The sulphide mineral assemblage, alteration, and volcanic stratigraphy suggest that the deposit is similar to other volcanogenic deposits in the Canadian Shield described by Sangster (1972). A description of the local and regional geology of the deposit, drawn from Selco maps and reports, is presented by Bogle (1977).

The sulphides are confined to a felsic volcanic unit at, or stratigraphically below, a contact with mafic volcanic rocks. Within the felsic unit there are rhyolite flows and intermediate to felsic tuffs. Argillaceous units are occasionally seen within the tuffs, below, and marginal to the sulphides. The rocks have been overturned so that the stratigraphically-lower felsic rocks are above the mafic rocks. Dips are generally to the east and north, although in places, they are nearly vertical. The felsic rocks are truncated by a gabbro sill which bounds the felsic rocks to the east. To the north, the volcanics, including the sulphide zone, are terminated by a serpentinized peridotite intrusion. Serpentinized peridotite also defines the western margin of the mafic volcanics.

Mineralization is in the form of stringer to massive sulphides. The mineralized zone is a few feet to over fifty feet (15 m) wide. The stringer sulphides occur stratigraphically below the massive sulphides. In the massive sulphides, pyrite predominates over pyrrhotite and sphalerite and chalcopyrite are in about equal proportions. In the stringer zone, pyrrhotite and chalcopyrite are the dominant sulphide minerals.

GEOPHYSICAL SURVEYS

Horizontal-loop EM Surveys

The electromagnetic conductor initially identified by VLF-EM (Fig. 28.3) was more completely defined by a horizontal-loop EM survey. Some of the profiles are seen in Figure 28.6. This survey employed a McPhar VHEM instrument using a coil separation of 200 feet (61 m) and a frequency of 600 Hz.

The resulting arcuate anomaly corresponds exactly with the strong VLF-EM conductor identified by Lessard. The strong EM response between 0 and 3S east of the base line indicates the shallowest part of the zone. This was subsequently confirmed by drilling. The response to the west along line zero, indicates that the zone remains shallow. The amplitude of response, however, drops as the sulphides become thinner and terminate between 3W and 4W. The diminishing response east of the base line south of line 6S occurs as the main body of the sulphides plunges toward the south.

Horizontal-loop EM profiles suggest that near-surface dips are very nearly vertical. This was confirmed by drilling (Fig. 28.5). Chalcopyrite, pyrrhotite, and pyrite, in both massive and stringer zones, were identified in the drilling as the cause of the EM conductor.

A complex response west of the base line on line 9S identified the VLF-EM conductor over the peridotite body. Graphitic slips and serpentine seen in drillhole L3 are the likely source of the weak negative quadrature. The positive in-phase appears to be a high magnetic susceptibility response generated by magnetite in the peridotite.

Magnetic Surveys

The vertical-field magnetic surveys were repeated using a McPhar M-700 fluxgate magnetometer and the results are shown in Figure 28.7. The two prominent highs west and north on the grid identify the peridotite bodies which contain magnetite. The high response at the western end of line zero also has its source in peridotite, although it is possible to confuse this with the responses just to the east, which have their origin in pyrrhotite in the sulphide zone. The responses from the pyrrhotite, which are occasionally bipolar, follow the arcuate form of the conductor.

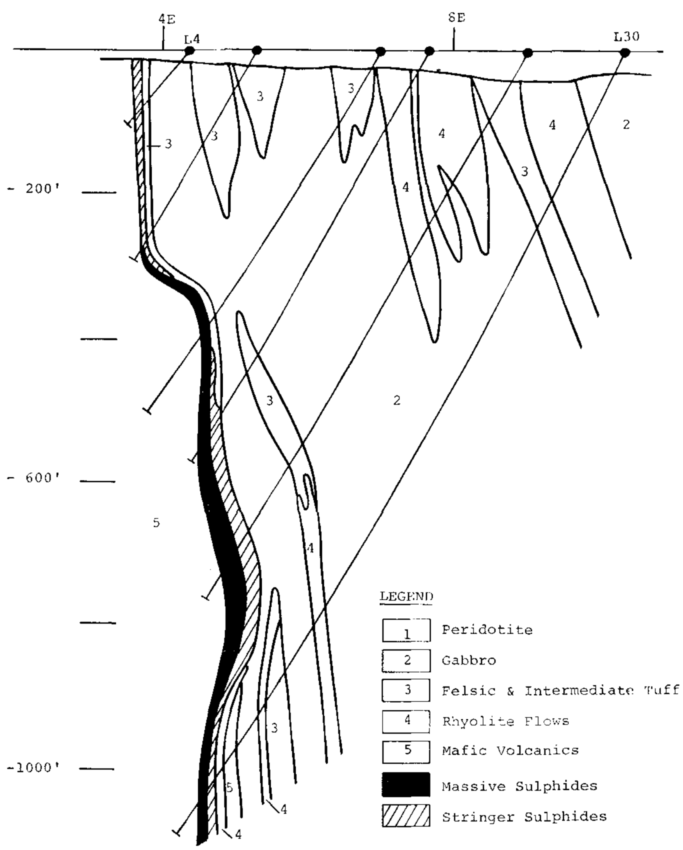

Figure 28.5. *Geology Section 6S.*

A comparison of VLF-EM and magnetic responses over the two peridotite bodies demonstrates that the westerly body is weakly conductive while the northerly body which has a similar magnetic intensity, is not conductive. The cause of these differences has not been revealed by drilling.

The magnetic surveys have not clearly discriminated between the gabbro and the volcanic rocks. The decrease of magnetic response to the southeast, however, does correlate with an increase in felsic rocks. The gabbro to the east is not distinctively magnetic and has a similar response to the mafic volcanics west of the ore zone.

Airborne EM Survey

A Mark VI Input EM survey was flown by Questor Surveys Ltd. of Toronto. Details of the system are given by Lazenby (1973). The direction of the profile, presented in Figure 28.8 is reversed from normal in order to match the presentation of the ground responses in this figure. The locations of the Input EM flight line over the deposit and the resultant anomalies are shown in Figure 28.6.

The six-channel conductor C identifies the main sulphide zone. The leading anomaly, B, also has its source in this sulphide zone. Anomaly B results from the asymmetry of the Input system which generates a secondary leading anomaly over a conductor which is vertical or dips toward the approaching aircraft (Palacky and West, 1973). The weaker, poorer, conductor D identifies the serpentinized peridotite. Anomaly A on Figure 28.8, which looks much like anomaly D, also has its source in a peridotite body about a mile north of the Lessard Deposit. Uneconomic sulphide stringers were identified as the source of anomaly A.

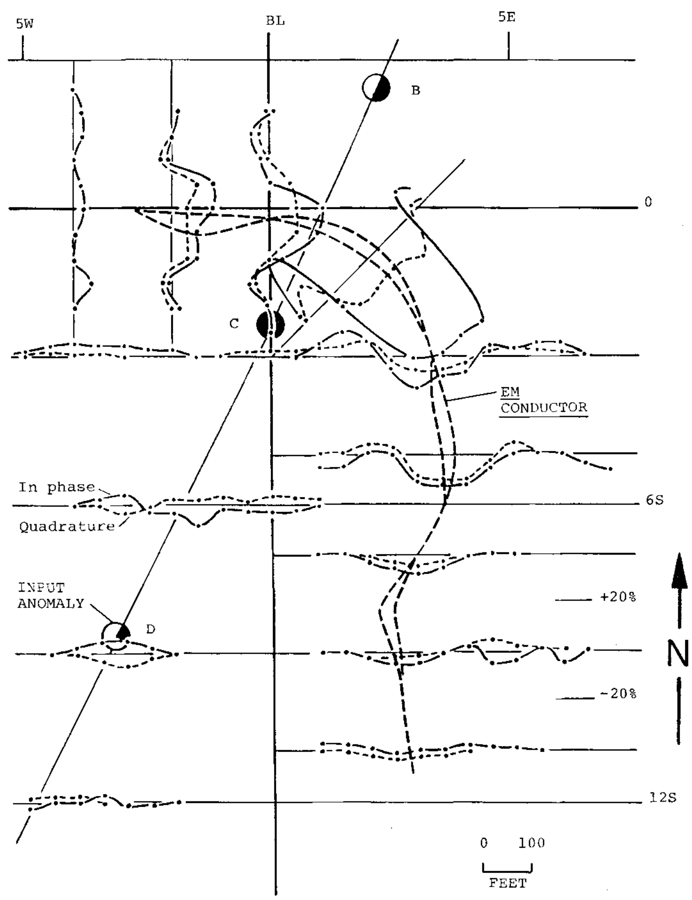

Figure 28.6. *Horizontal-loop EM survey (using 200 foot (61 m) coil separation) and airborne Input anomalies.*

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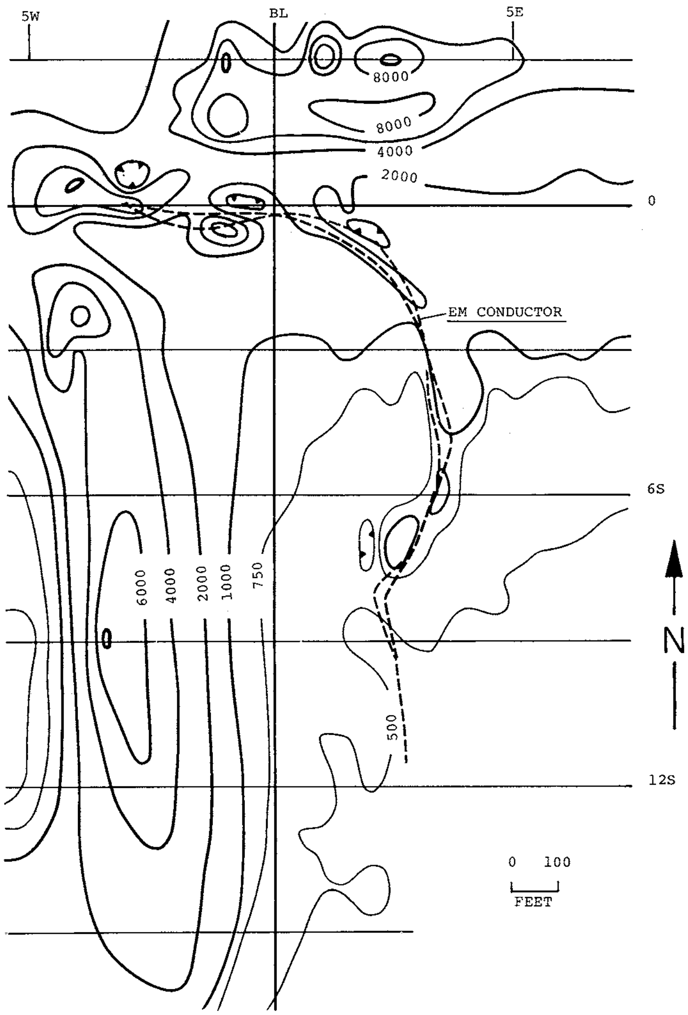

Figure 28.7. *Contours of the vertical magnetic field (in gammas). Thicker contours have a 2000 gamma interval except for the 1000 gamma level. Thinner contours have a 250 gamma interval.*

Induced Polarization and Resistivity Surveys

An induced polarization survey using a McPhar frequency-domain instrument (Madden, 1967; Hendrick and Fountain, 1971) covered the zone south from line 3S. Contours of per cent frequency effect, shown in Figure 28.9, are for a dipole-dipole array having an "a" spacing of 200 feet (61 m) at n = 1. The frequencies used for the survey were 5.0 and 0.3 Hertz. The location of the EM conductor is plotted for reference. Although it is clear that frequency effect responses occur over the sulphide zone, definition of the zone is masked by the overlapping responses of the peridotite to the west. Similarly, the resistivity component of the survey, shown in Figure 28.10, displays a markedly low resistive response over the peridotite. The resistive low between lines 3S and 6S east of the base line identifies the sulphide zone.

Pseudo-sections of the IP and resistivity response on line 6S (Fig. 28.11) show that while individual anomalies occur over the sulphide zone, large responses from the serpentinized peridotite mask the sulphide response at large electrode separations. The apparent IP effect from the peridotite is slightly higher than from the sulphides, while apparent resistivities of the peridotite are considerably lower than that of the sulphides.

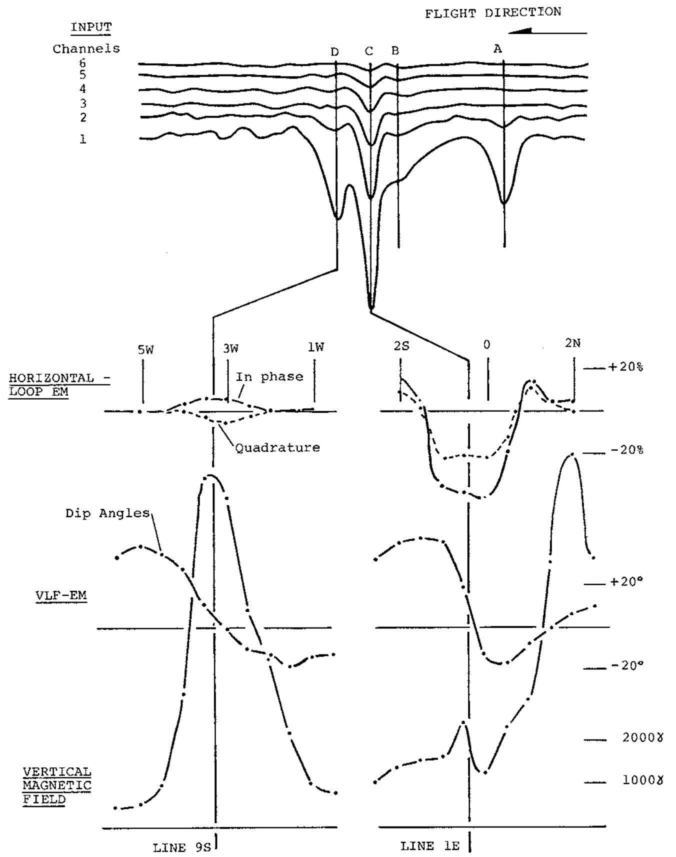

Figure 28.8. *Profiles comparing geophysical methods over sulphides (right) and peridotite (left).*

Very high resistivities to the east correlate with gabbro. Similar high resistivities to the west indicate that bedrock to the west may be gabbro as well.

Gravity Survey

A gravity survey over the deposit yielded no detectable anomaly from the sulphides. A profile of the Bouguer gravity on line 6S shown in Figure 28.11 is typical of responses in the area. The lack of a gravity response from the sulphides is due to the fact that the main mass of sulphides occurs 400 feet (120 m) below the surface. The geological section on line 6S (Fig. 28.5) shows the thickest sulphides are between 600 and 800 feet (180 to 240 m) from surface. Nearer surface, the sulphides are thinner and in stringer form. These do not provide a significant gravity target.

Mise-à-la-masse Survey

A mise-à-la-masse survey (Parasnis, 1967) employed a current electrode placed in the sulphide zone in a drillhole at a depth of about 550 feet (170 m) from surface. Current was maintained at 1.0 amp. at a frequency of 5.0 Hz. Infinite current and potential electrodes were placed 3500 feet (1066 m) north and south of the survey area respectively. Voltages were measured on surface every 50 feet (15 m) along lines at an interval of 100 feet (30 m) and every 50 feet (15 m) down available holes.

A number of features related to the distribution of sulphides in the zone are indicated by the distribution of voltages on the surface shown in Figure 28.12, and down holes shown in Figures 28.13 and 28.14.

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The arcuate shape of the contours follows the shape of the electromagnetic conductor. The highest values (over 1700 millivolts) are found at the strongest EM conductor, east of the base line between lines 0 and 3S. These identify the shallowest part of the sulphide zone. Elsewhere a ridge of high values occurs along the length of the EM conductor. Voltages decrease along the ridge in both directions from the peak, indicating increasing depth to the top of the sulphide zone. The steep gradient off the ridge of the anomaly west along line zero, appears to indicate that the sulphide zone is narrow and limited in depth extent. The voltages flanking the sulphides are reduced however, by resistive lows from peridotite bodies to the north and southwest. The gradual voltage drop south of the southerly end of the EM conductor (south of line 12S), suggests that the sulphide zone plunges to the south. The low gradients off the ridge of the anomaly from lines 3S to 15S indicate the zone extends to greater depth south of 3S than north of it. Contours are more open east of the ridge than west of it suggesting an easterly dip. The low resistivities of the peridotite to the west, combined with the high resistivities of the gabbro to the east however, probably distort the contours so that the dip interpretation is suspect.

The depression south of line 15S is part of a long, linear low response lying nearly east-west across the strike of the sulphides. A fault, producing low resistivities in bedrock, or a bedrock depression is indicated. Drilling has not extended far enough to confirm this.

Voltage measurements down holes in section 6S (Fig. 28.13) identify a peak response of over 1700 millivolts which generally corresponds with the location of the sulphides traced in from Figure 28.5. Apparent discrepancies occur in hole L30 where peak voltages are observed not only in the main sulphide zone (location C), near the bottom of the hole, but also higher up at locations A and B. The contours on Figure 28.13 connect the high values at A and B to the high values in the hole above, while high values at C do not connect. This is not so much a representation of what is really happening but is a condition forced by the limitations of available data. The high values at A and B do not correlate with ore intersections, but do identify 10 to 20 per cent pyrrhotite with minor chalcopyrite in siliceous volcanics. It would seem that an electrical connection (possibly by way of sulphides) exists between sulphides at A and B and the main sulphide zone C.

The mise-à-la-masse survey in holes on section 1W at the north end of the deposit, and shown in Figure 28.14, indicates a different voltage distribution than that of section 6S. Only one hole, L7, has intersected sulphides. The other

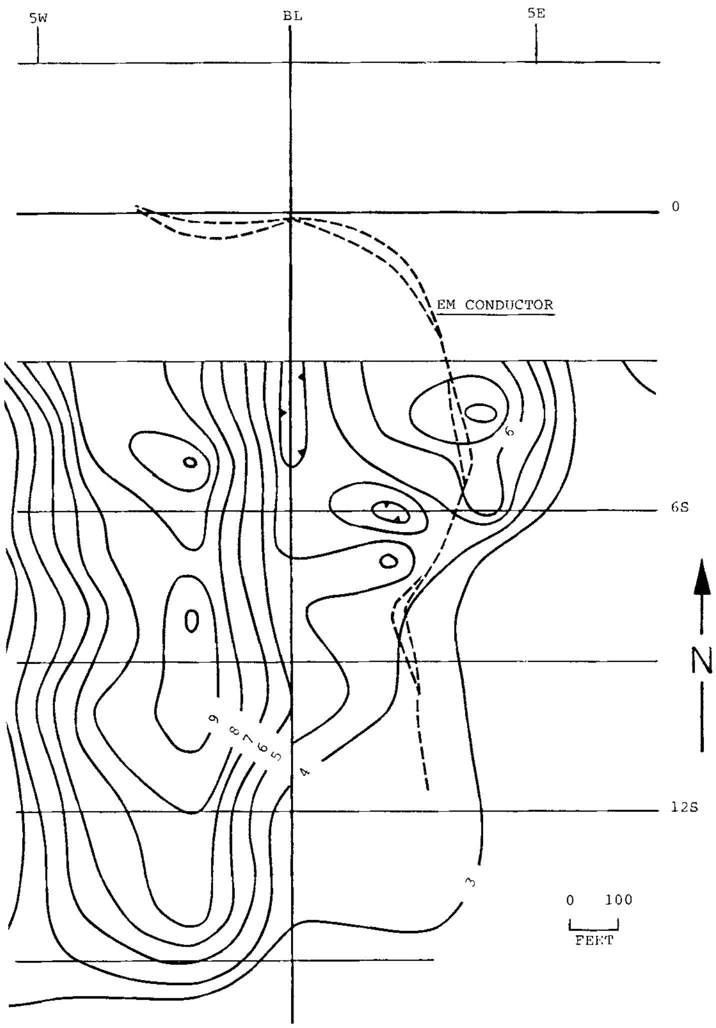

Figure 28.9. *Induced Polarization response in per cent frequency effect using a dipole-dipole array with a = 200 feet (61 m) and n = 1.*

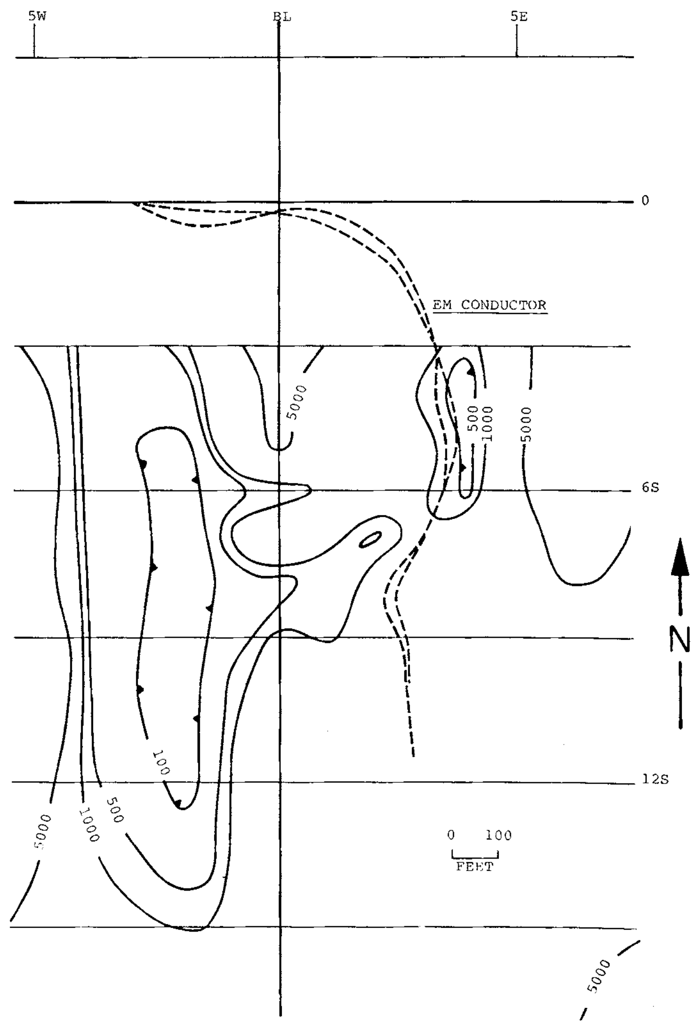

Figure 28.10. *Resistivity response in ohm-metres using the same electrode array as in Figure 28.9.*

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hole in the section, L13, may not have been drilled far enough to intersect sulphides. However, the apparent dip seen in the trend of the voltages and the low voltages at the bottom of L13 give little encouragement for the possibility of intersecting any. Rocks on the same horizon as those containing the sulphides in hole L7 are intersected near the bottom of hole L13 but contain no significant sulphides.

The small size of the sulphide zone on section 1W, compared with that of section 6S, is apparent from the distribution of the voltages. Sharp gradients appear close to the smaller part of the body on 1W, while more gentle gradients occur around the larger part of the body on line 6S. As noted earlier, however, rocks adjacent to the sulphides influence the voltage pattern. On section 1W, voltages drop rapidly to the north, in part because of the low resistivities in the peridotite. On section 6S, higher resistivities in gabbro, east of the sulphides contribute to the lower voltage gradient to the east.

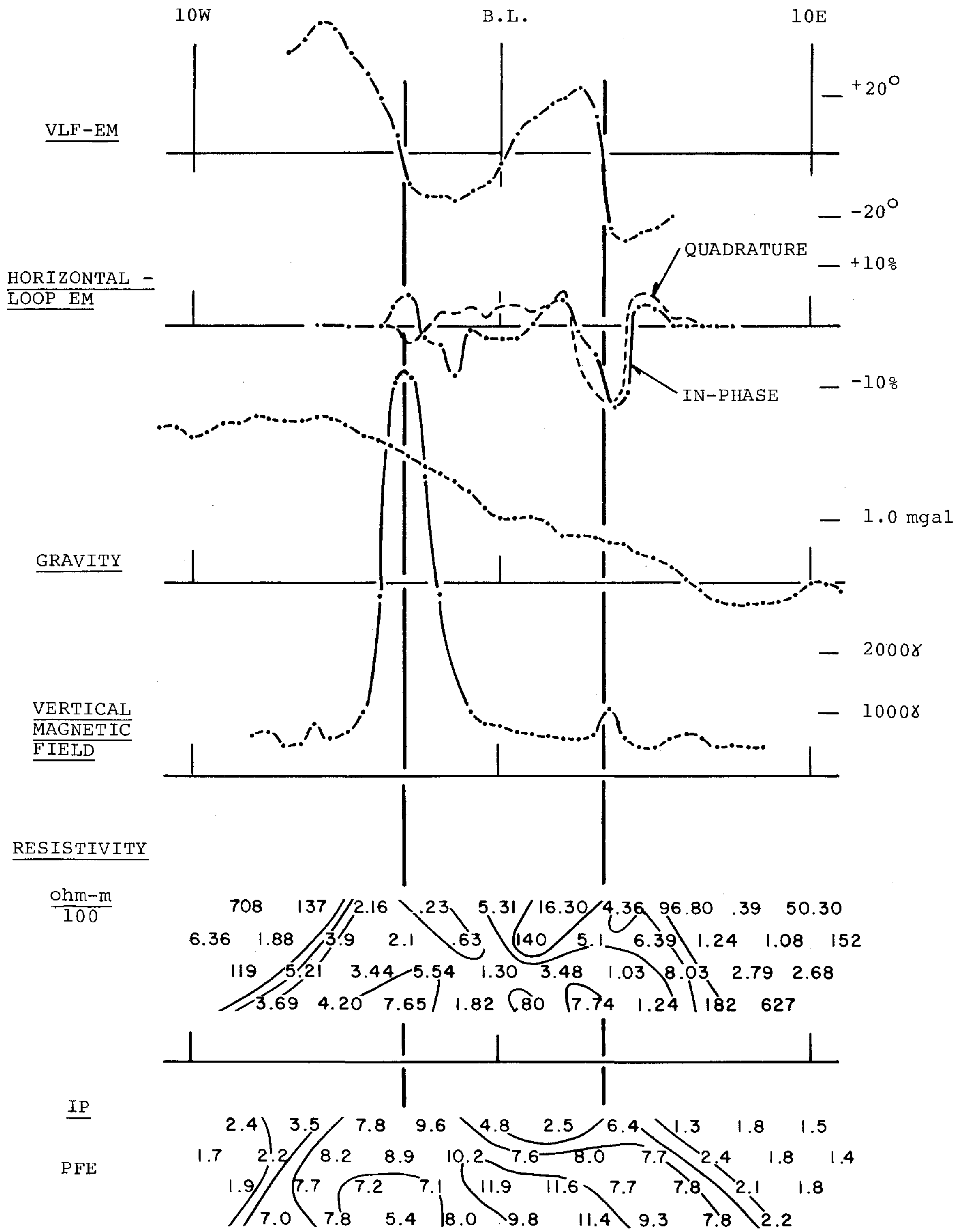

Figure 28.11. *Profiles and pseudo-sections on line 6S comparing geophysical methods over sulphides (right) and peridotite (left). IP and resistivity uses the same electrode array as in Figure 28.7.*

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COMPARISON OF GEOPHYSICAL METHODS

The profiles in Figures 28.8 and 28.11 over the sulphide and serpentinized peridotite conductors provide a useful comparison of geophysical methods. The sulphide conductor, anomaly C on Figure 28.8, and the anomaly east of the base line on Figure 28.11 have good Input EM horizontal-loop EM, VLF-EM, IP and resistivity responses. The peridotite conductor, anomaly D on Figure 28.8, and the anomaly west of the base line on Figure 28.11 have a poor Input EM and irregular horizontal-loop EM, fairly good but broad VLF-EM, good IP and good (i.e. low) resistivity responses. Taken together, there is a clear separation of response from the two different sources by these methods. The Input EM and the horizontal-loop EM responses discriminate most effectively between the sulphide conductor and the serpentinized peridotite.

The magnetic responses in Figures 28.8 and 28.11 over the sulphides and the peridotite are quite different. The bipolar 800 gamma anomaly from the sulphides shown in Figure 28.8 looks insignificant beside the 8000 gamma anomalies over the peridotite bodies north on line 1E and on line 9S. An easterly dip to the peridotite is indicated by the asymmetrical shape of the magnetic anomalies on lines 6S (Fig. 28.11) and 9S (Fig. 28.8).

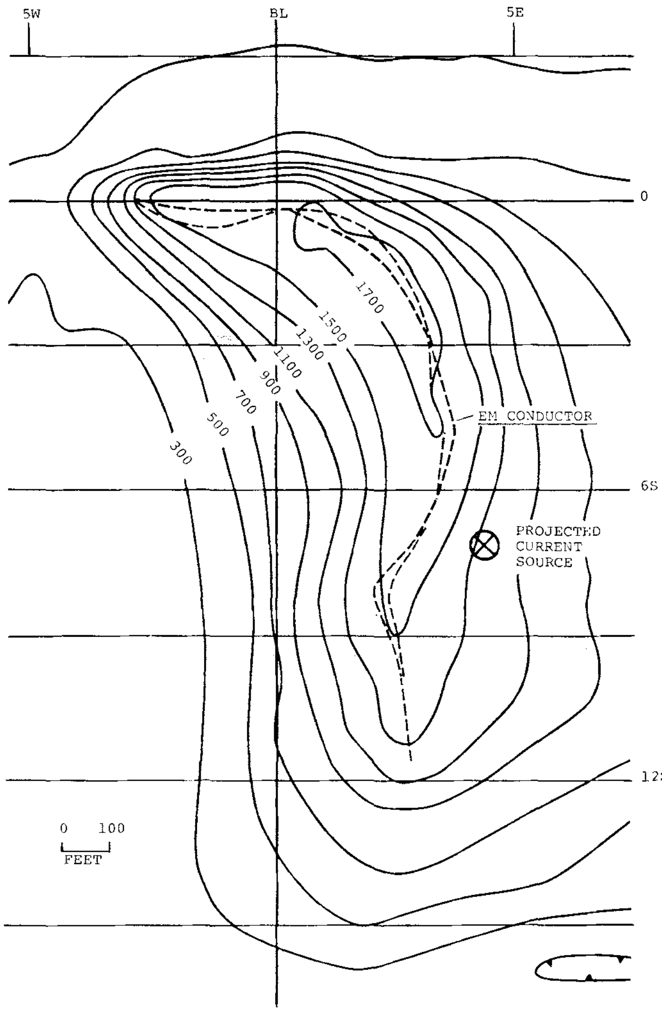

Figure 28.12. *Mise-à-la-masse survey. Contours are in millivolts for readings taken on surface. Current electrode is located in sulphides 550 feet (167 m) below surface.*

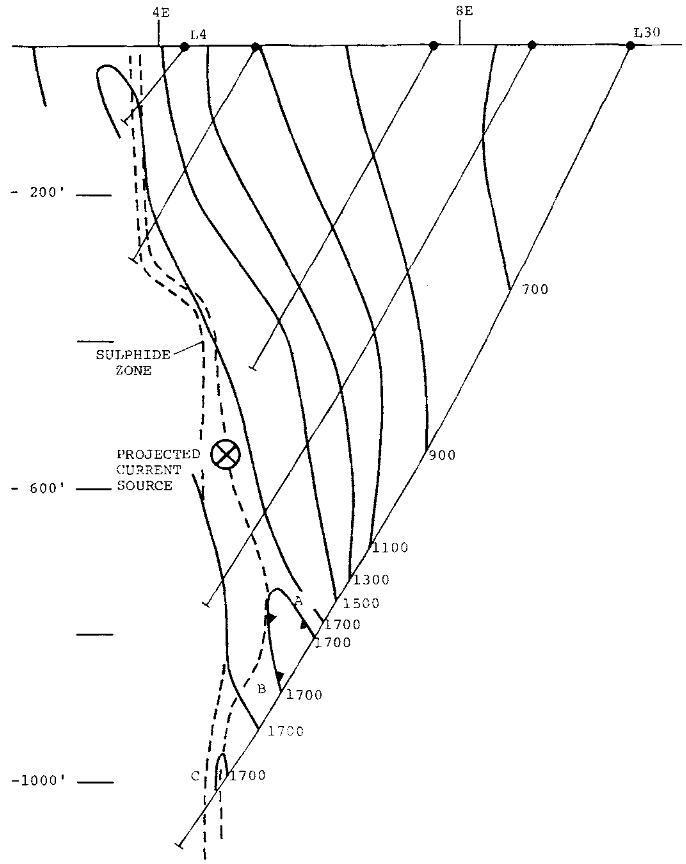

Figure 28.13. *Mise-à-la-masse survey on surface and in drillholes on section 6S. Readings are in millivolts. Current electrode is located in sulphides about 50 feet (15 m) south of the section.*

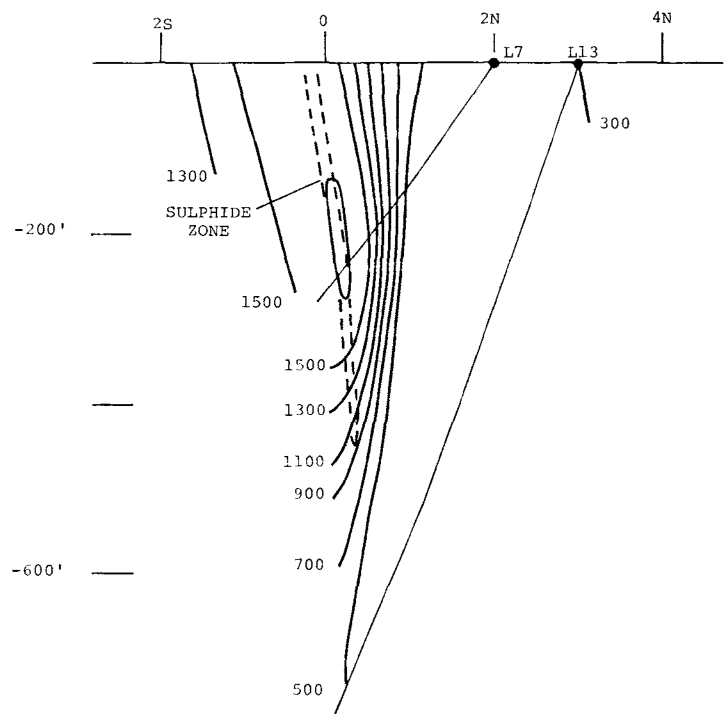

Figure 28.14. *Mise-à-la-masse survey on surface and in drillholes on section 1W. Readings are in millivolts. The current electrode near 6S does not appear in this section.*

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A comparison of Input EM and horizontal-loop EM responses may be made using the apparent conductivity-thickness (σt) products (Grant and West, 1965; Palacky and West, 1973). A vertical half-plane source has been assumed for both ground and airborne responses. The early Input EM channels (numbers 1 to 3; Fig. 28.8) show a σt of 9 mhos while the later channels (number 3 to 6) show a σt of 18 mhos. The σt response from the ground instrument on line 1E just under the flight line is 7 mhos. This compares favourably with the early channel Input EM response. Variability of conductivity – thickness is evident however, as a higher σt response of 26 mhos is observed by the horizontal-loop EM on the diagonal line just east of the flight line (Fig. 28.6).

The duality of the σt of the airborne EM anomaly suggests that the zone has two conductive components. It is not clear if these two airborne EM responses have their origin at a single location, or if two sources occur along strike from each other. The latter case is indicated by the responses on the ground. If the two sources occur together, however, it is suggested that highly conductive sulphides causing the higher σt value are part of a larger but less conductive unit causing the lower σt value. The dual Input EM response, then, may represent the massive and stringer sulphides which are observed together in drill core.

CONCLUSIONS

The Lessard Deposit is probably a nearly ideal electromagnetic target. Highly conductive sulphides found near surface in resistive rocks in a steeply-dipping attitude are easily detected by a number of electromagnetic systems. The presence of conductive and magnetic serpentinized peridotite nearby only marginally interferes with the resolution of the zone by geophysical methods. While IP, resistivity and VLF-EM surveys identified the sulphides, these methods detected similar responses over the peridotite. A clear discrimination between the sulphides and the peridotite was achieved by the Input EM and horizontal-loop electromagnetic methods. The magnetometer survey as well, discriminates between the sulphides and peridotite by identifying magnetic fields of different character over these bodies.

The persistent work of prospector Antoine Lessard using simple geophysical instrumentation which led to the discovery of the deposit, is not downgraded by the fact that more sophisticated instruments also detect the deposit. The use of sophisticated instrumentation beyond the discovery phase is justified by the definition of the sulphide deposit and the discrimination of the deposit from nearby peridotite bodies by these instruments.

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