39.

GEOPHYSICAL AND GEOCHEMICAL METHODS FOR MAPPING GOLD-BEARING STRUCTURES IN NICARAGUA

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Abstract

Gold deposits in northeastern Nicaragua which are associated with Tertiary volcanic centres occur as fracture-controlled epithermal vein systems or disseminated sulphide zones within areas of deep tropical weathering volcanic breccias.

Time-domain induced polarization and magnetic surveys were used to outline a gold-bearing disseminated pyrite-sphalerite deposit hosted in a volcanic breccia. This deposit, known as Coco Mina, is located near the Honduras-Nicaragua border. Anomalous gold, copper, zinc, lead and silver geochemical values over the volcanic breccia defined the main portion of the zinc-bearing volcanic breccia, however a broader gold anomaly at threshold levels (0.03 ppm) outlined a much larger area which subsequently was defined by IP as an extensive disseminated pyrite-kaolinite-sericite alteration zone. The dispersion of zinc was greater than lead or copper, and the geochemical patterns for Cu, Pb, Zn appeared to be highly affected by drainage patterns and water courses along faults whereas the gold patterns were controlled by the lithology and the alteration zone, and correlated best with the IP – resistivity and magnetic anomalies.

VLF electromagnetic surveys were also carried out by Rosario Resources Corp. to map the fractures and alteration zones associated with two quartz vein deposits at Guapinol and LaLuna. Tropical weathering appears to enhance the conductivity of the controlling fractures, making them ideal VLF-EM targets. By filtering the in-phase response, the veins are delineated by the resultant contoured data. Soil geochemical surveys over the vein deposits revealed anomalous gold values (0.3 – 0.5 ppm), in disconnected patterns along the trend of the veins, however, the VLF-EM results were of considerable value in interpreting the geochemical patterns and when taken together define much better the various veins in the system.

Résumé

Les gisements aurifères du nord-est du Nicaragua, qui sont liés à des centres volcaniques du Tertiaire, se présentent en réseaux de filons épithermaux à fracture contrôlée ou en zones disséminées de sulfure à l'intérieur de régions de profondes brèches volcaniques à altération métérologique d'influence tropicale.

Des levés magnétiques et des levés par polarisation provoquée en régime transitoire ont servi à délimiter un gisement disséminé de pyrite-sphalérite, contenant de l'or, dans une brèche volcanique. Ce gisement, connu sous le nom de Coco Mina, est situé près de la frontière du Honduras et du Nicaragua. L'or, le cuivre, le zinc, le plomb et l'argent présentent des anomalies géochimiques au-dessus de la brèche volcanique et définissent la partie principale de la brèche volcanique à teneur en zinc, tandis qu'une anomalie aurifère plus importante à des niveaux limites (0.03 ppm) a défini une zone beaucoup plus grande qui, par la suite, a été reconnue, par la méthode PP, comme étant une vaste zone d'altération disséminée de pyrite-kaolinite-séricite. La dispersion du zinc était supérieure à celle du plomb ou du cuivre et les structures géochimiques du Cu, du Pb et du Zn ont semblé fortement altérées par les structures d'écoulement et les cours d'eau le long des failles alors que les structures aurifères étaient contrôlées par la lithologie et la zone d'altération, et correspondaient davantage aux anomalies de résistivité des levés par la méthode PP et aux anomalies magnétiques.

Des levés électromagnétiques à très basse fréquence ont été aussi effectués par la Rosario Resources Corp. dans le but de cartographier les zones de fractures et d'altération reliées à deux gisements filoniens de quartz à Guapinol et LaLuna. Des altérations météorologiques d'influence tropicale semblent accroître la conductivité des fractures de contrôle, faisant d'elles des objectifs de levés électromagnétiques à très basse fréquence. En filtrant la réponse en phase, on peut délimiter les filons à partir des données profilées qui en résultent. Des levés géochimiques du sol au-dessus des gisements filoniens ont révélé des teneurs en or anormales (0.3 à 0.5 ppm) dans les structures disjointes le long de la direction des filons, tandis que les résultats de LE-TBF (levés électromagnétiques à très basse fréquence) étaient d'une importance considérable pour l'analyse des structures géochimiques, quand ils étaient pris ensemble, ces résultats définissaient beaucoup mieux les filons du réseau.

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INTRODUCTION

Gold exploration and mining was carried out in Nicaragua before the turn of the century and numerous small quartz lode prospects were mined in northeastern Nicaragua between 1900 and 1928. The history of some operations, including the skarn gold-copper type deposits typified by the La Luz mine at Siuna and the Rosita copper mine, have been described by Plecash and Hopper (1963) and Beven (1973). Present day operations in Nicaragua consist of Sententrion's (Noranda subsidiary) mine near Leon on the west coast, the Neptune Mining Company (Asarco and Rosario) operations at Bonanza 30 km north of Siuna in northeastern Nicaragua, and the Rosario Mining of Nicaragua mines at Riscos de Oro, Blag and La Luna, 25 km northeast of Rosita. All of these ongoing operations are in epithermal quartz vein structures with widths of 2-10 m which occurs in Tertiary basaltic lavas proximal to circular-shaped caldera structures.

Three case histories are presented in this paper illustrating the application of combined geophysical and geochemical methods in outlining gold-bearing epithermal veins (La Luna and Guapinol) as well as a low-grade disseminated sulphide gold-zinc deposit called Coco Mina which is hosted in a caldera-related volcanic breccia.

In the past 10 years geochemical surveys for gold have become more of a reality with the refinement of atomic absorption analytical methods which allow for detection limits below 30 ppb Au. VLF-EM methods have become accepted for mapping structural geological features such as faults, shears, fold axes, conductive contacts etc. Multielement geochemistry is an aid to defining geological-mineralogical settings. These approaches, along with conventional time-domain IP, resistivity and magnetic surveys, are demonstrated in this paper as being effective methods for mapping gold-bearing structures in areas of deep tropical weathering.

COCO MINA DEPOSIT

History and Geology

The Coco Mina gold-zinc deposit is located near the Honduras-Nicaragua border as shown on Figure 39.1. The deposit is situated within a small caldera-like structure in the shape of a cone-shaped mountain approximately 2 km in diameter, which interrupts a folded belt of Mesozoic sediments.

The Coco Mina deposit is contained in a zone of altered (kaolinized-sericitized-pyritized) intermediate volcanic breccia (andesite-dacite) and consists of black sphalerite filling the voids (matrix) of the breccia. The volcanic fragments are usually 10-25 cm in size. Minor chalcopyrite occurs within the sphalerite. Pyrite, which averages 7-10 per cent of the rock, occurs as crystalline masses 2-5 cm in size within the matrix as well as finely disseminated crystals and grains throughout the alteration zone. Isolated arsenopyrite crystals have been observed but are rare. Gold occurs in association with the pyrite and sphalerite and it is speculated from preliminary metallurgical tests that fine free gold also occurs in the upper portions of the deposit. Quartz veining has not veen observed although numerous dykelets of unaltered light grey green andesite cut the altered breccia and sulphides. The altered breccia also occurs around the central lake (lago in Spanish on Fig. 39.2 to 39.8) immediately west of the deposit. The lake itself is situated in a basin with a circular ridge composed of unaltered basalt-andesite surrounding the basin (see height of land apparent from the location of the headwaters of small creeks flowing into the lake in Fig. 39.4 to 39.8).

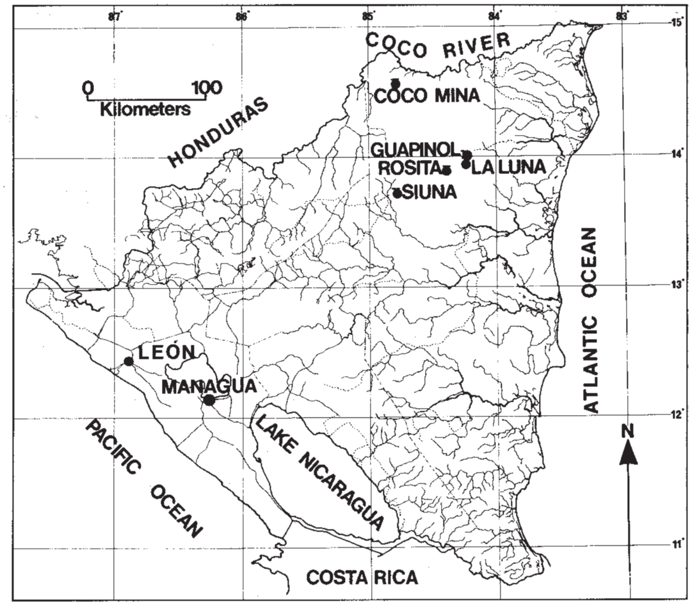

Figure 39.1. *Location map showing the position of the Coco Mina, Guapinol and La Luna gold deposits in Nicaragua, central America.*

The area surrounding the deposit has been under study by Rosario and Fresnillo since 1974. The placers surrounding the deposit were first worked by a Mr. Mueller in 1900-1944 and then by the Texana Mining Co. (1942-1945), who worked the gold-bearing laterite soil from the east flank of the deposit. Stream geochemical surveys surrounding the deposit and surface sampling were carried out in 1974 followed by the cutting of a survey grid for soil sampling, magnetometer surveys and initial drilling in 1975. An IP-resistivity survey and more drilling was done in 1976. Four more holes were completed in 1977 along with drifting and raising to take a metallurgical sample and verify drillhole assay results.

Geochemical Surveys

Placer operations yielding rice-grain sized gold granules having been carried out for a number of years downstream from the Coco Mina hill, testifying to a source of gold in the hill. Stream sediments show anomalous values in zinc downstream from the deposit; however, the gold appears to show a greater (mechanical and chemical) dispersion than zinc as is evident by comparing Figures 39.2 and 39.3.

A soil-sampling geochemical program was carried out by Rosario Resources Corp. to define the mineralized areas in Coco Mina Hill. Samples were taken at 30 m intervals on lines spaced at 60 m intervals. Samples of the hard clay-like laterite were obtained by auger from a depth of 0.5 m. Complete pulverization of the soil sample followed by screening to -80 mesh was done in the field. Analysis for Au, Ag, Pb, Zn, Cu was carried out by atomic absorption analysis. Gold was extracted into solution by placing the sample in hot aqua regia for 90 minutes and a detection limit of 30 ppb was achieved.

The results of the soil geochemical program are presented in Figures 39.4 to 39.8. The silver anomaly (Fig. 39.4) is confined to the deposit whereas the zinc (Fig. 39.5) is highly dispersed down drainage and around the base of the hill containing the deposit. The laterite soils immediately overlying the deposit are depleted in zinc and an annular-shaped anomaly results (see Fig. 39.9 also).

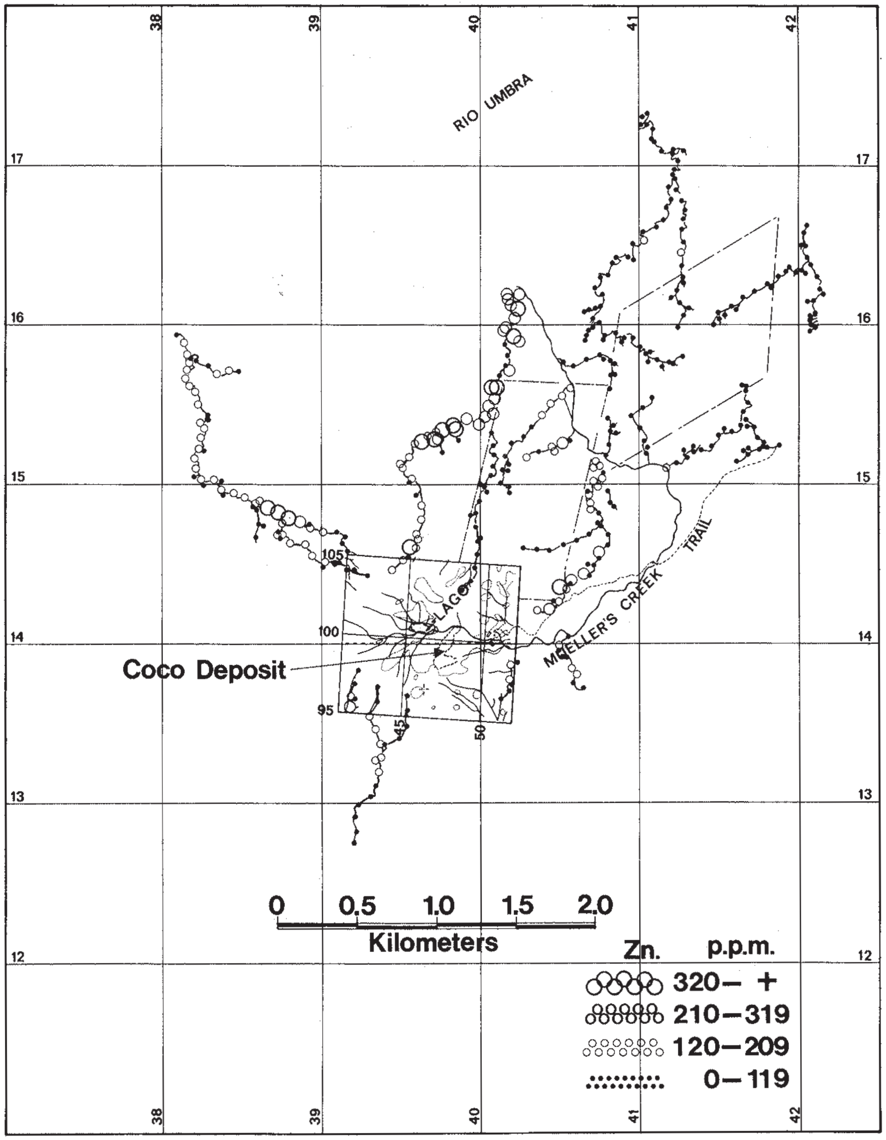

Figure 39.2. Zinc in stream sediments representing geochemical dispersion from the Coco Mina Deposit.

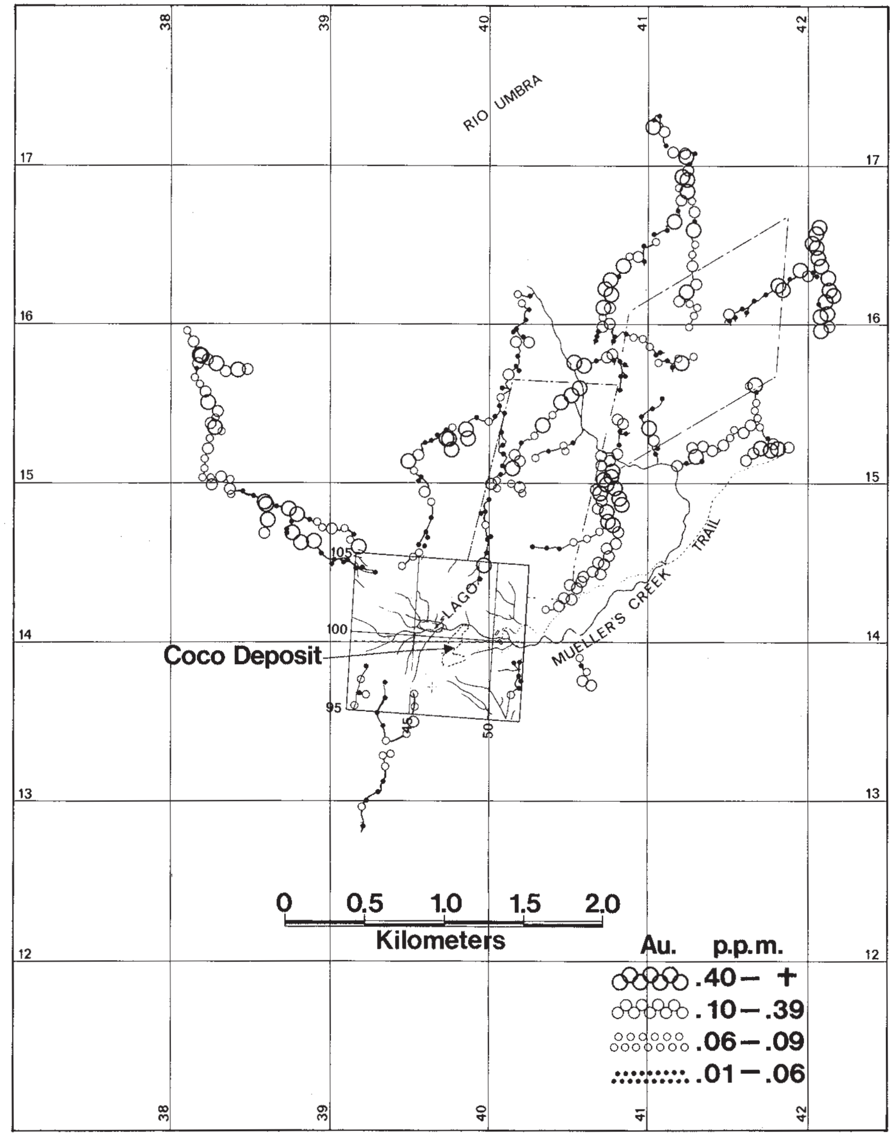

Figure 39.3. Gold in stream sediments illustrating broad mechanical dispersion from the Coco Mina deposit.

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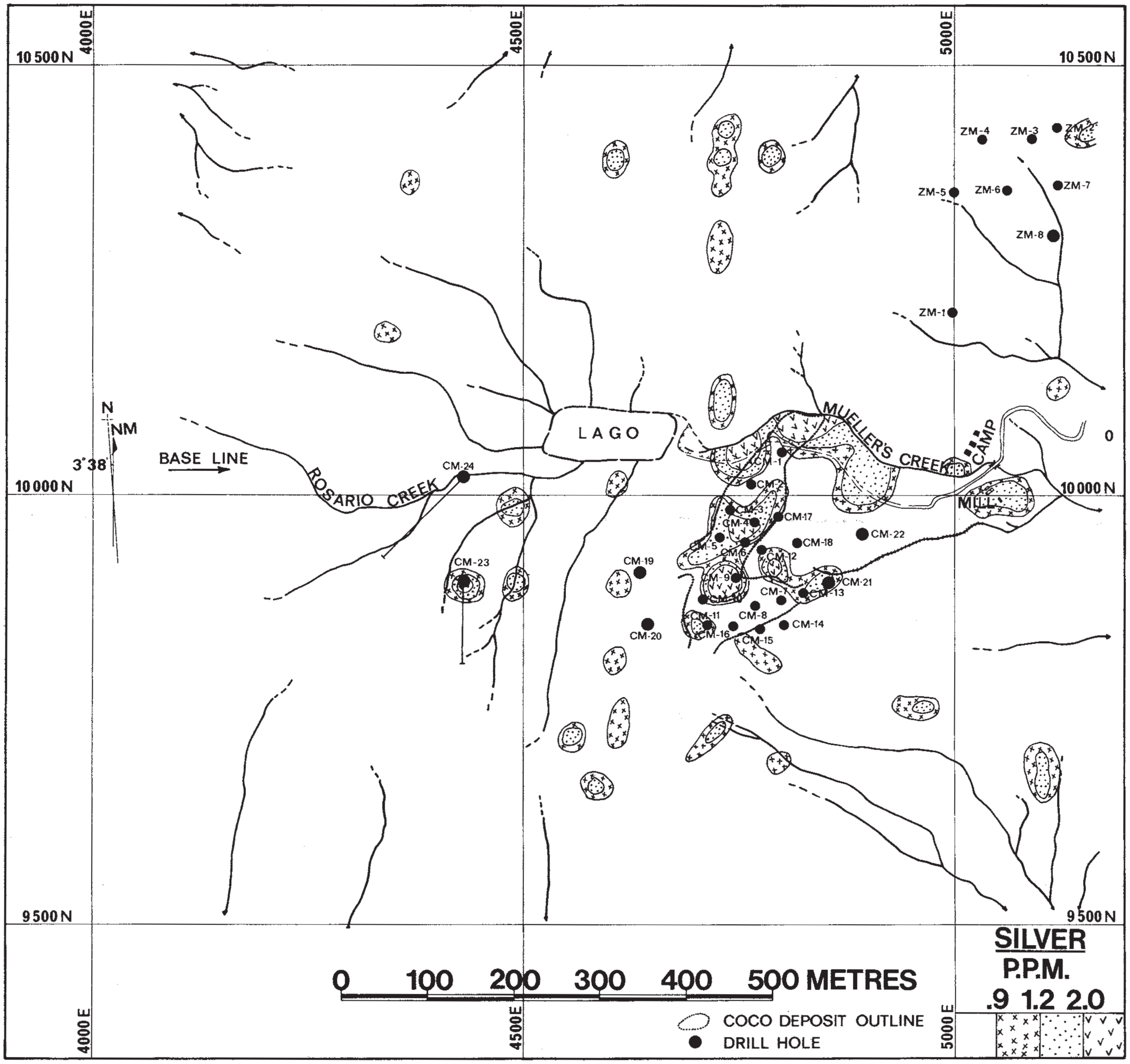

Figure 39.4. *Silver soil-geochemical results over Coco Mina.*

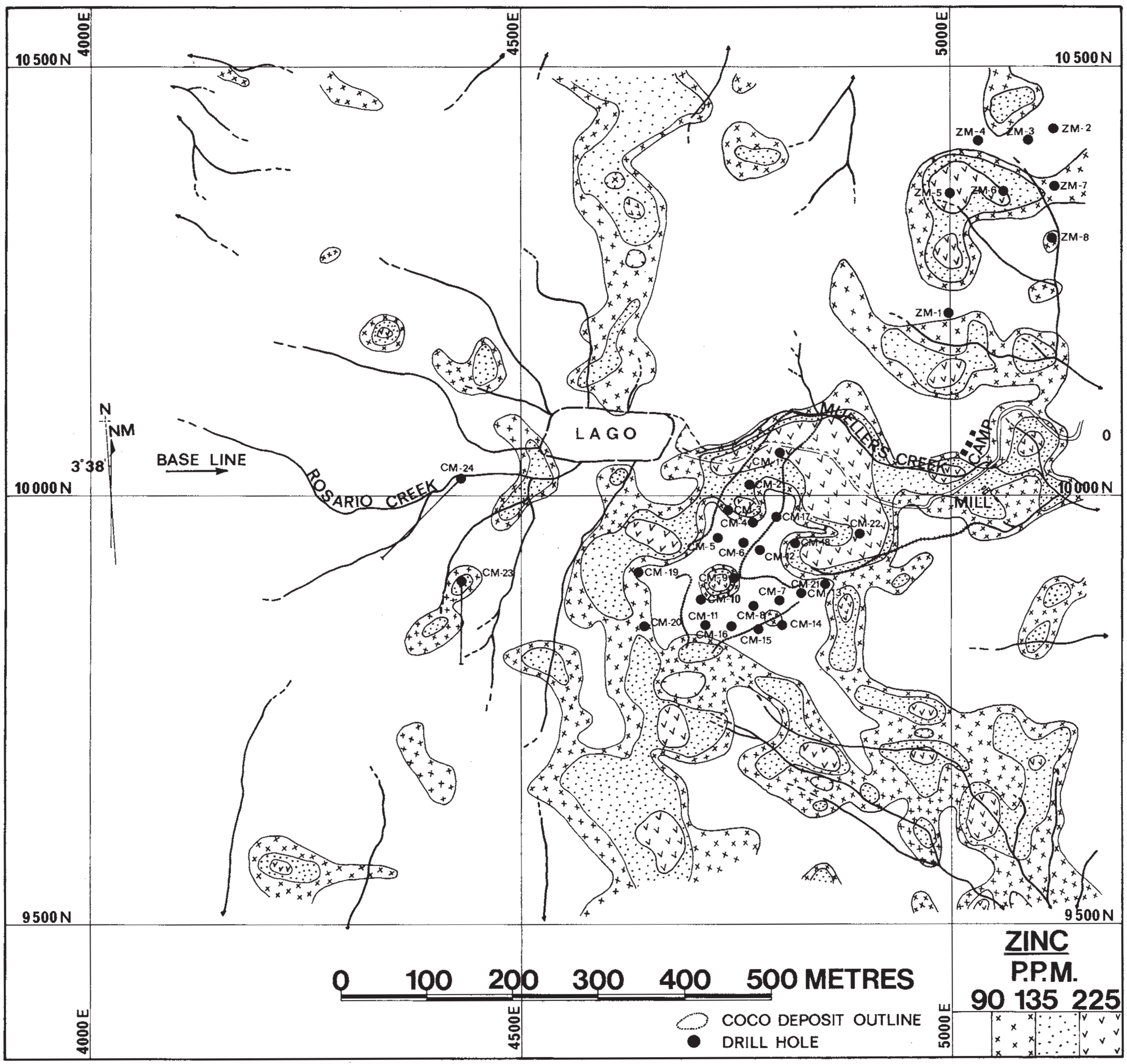

Figure 39.5. *Zinc soil-geochemical results over Coco Mina.*

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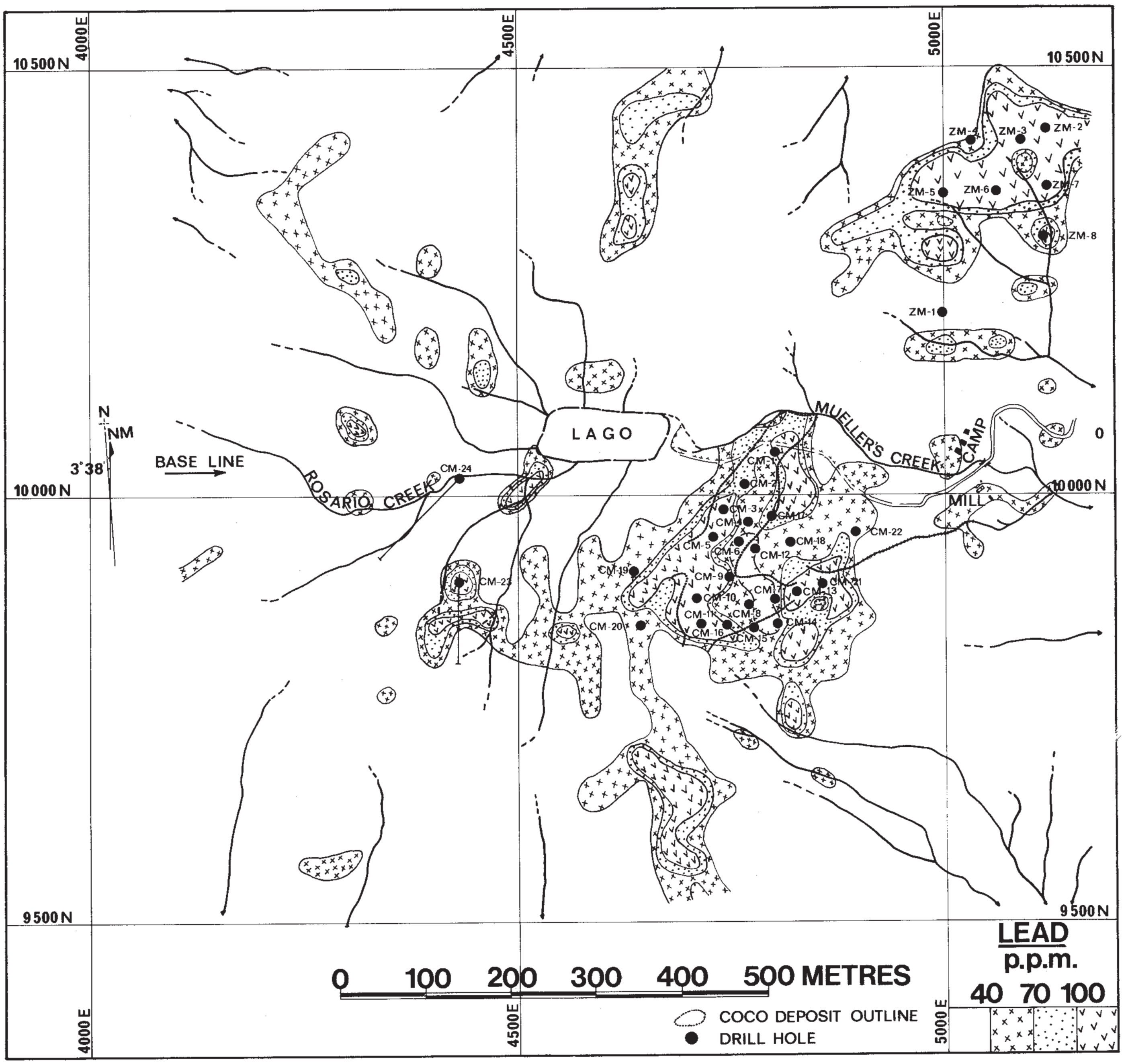

Figure 39.6. *Lead soil-geochemical results over Coco Mina.*

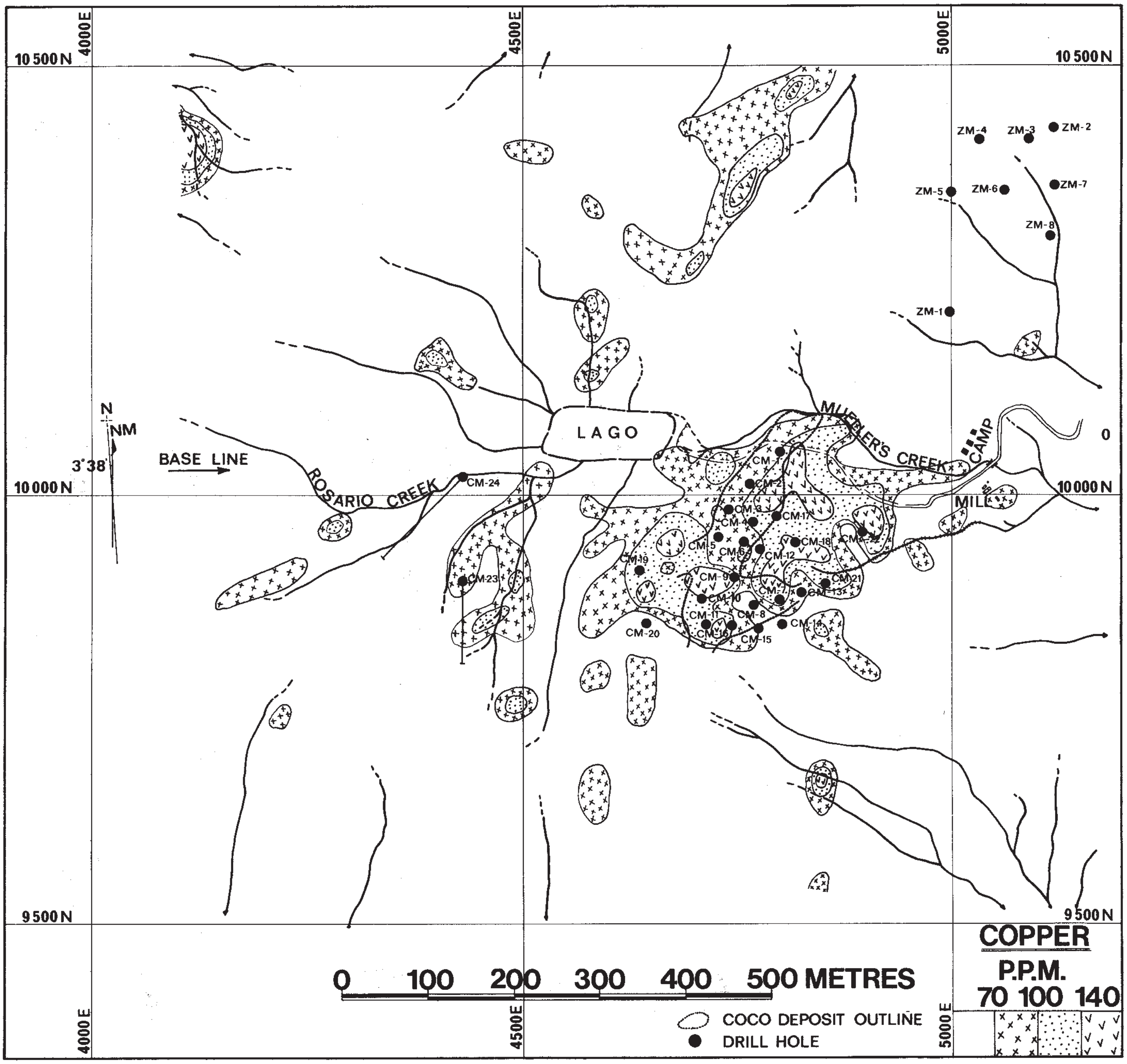

Figure 39.7. *Copper soil-geochemical results over Coco Mina.*

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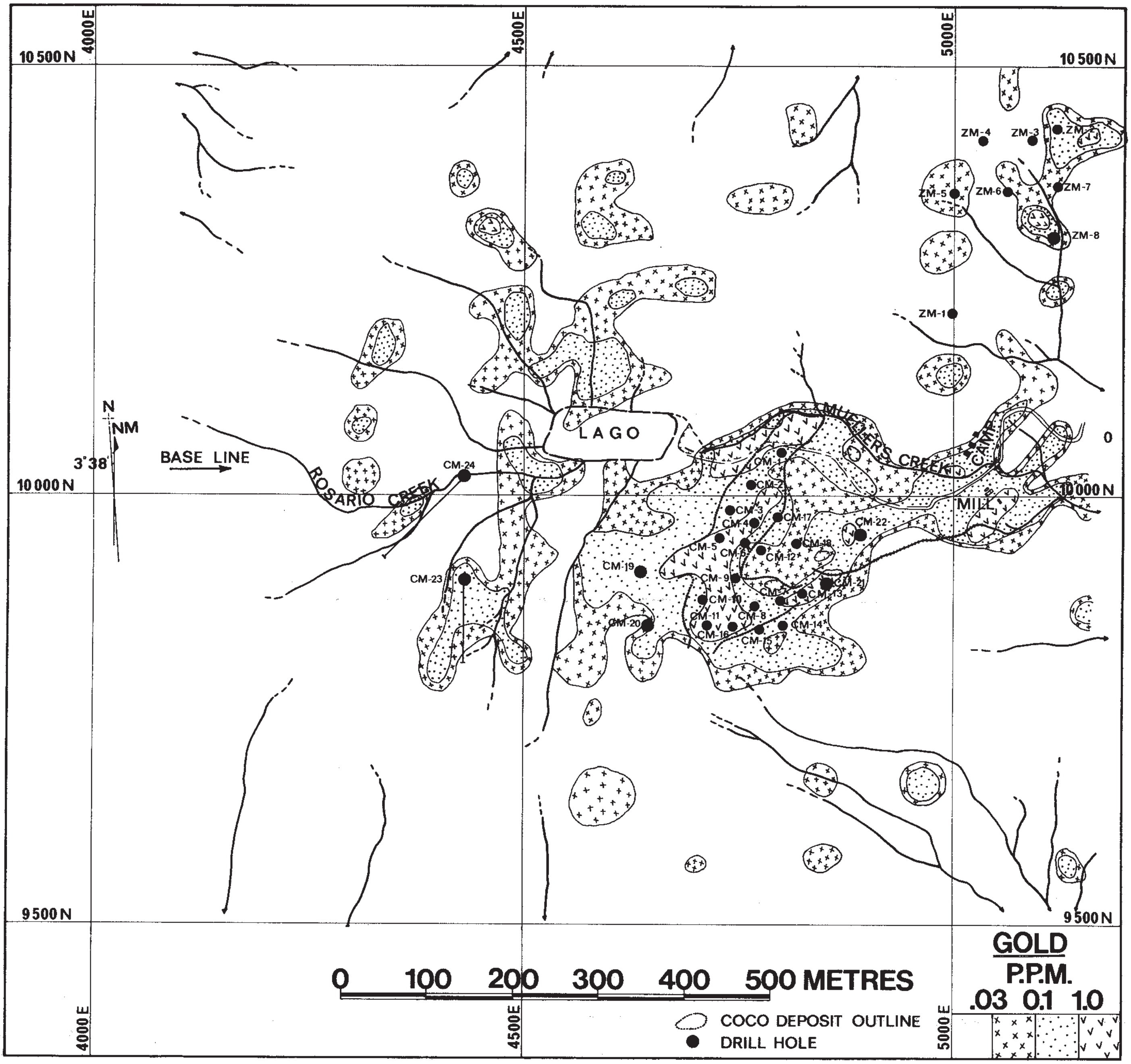

Figure 39.8. Gold soil-geochemical results over Coco Mina.

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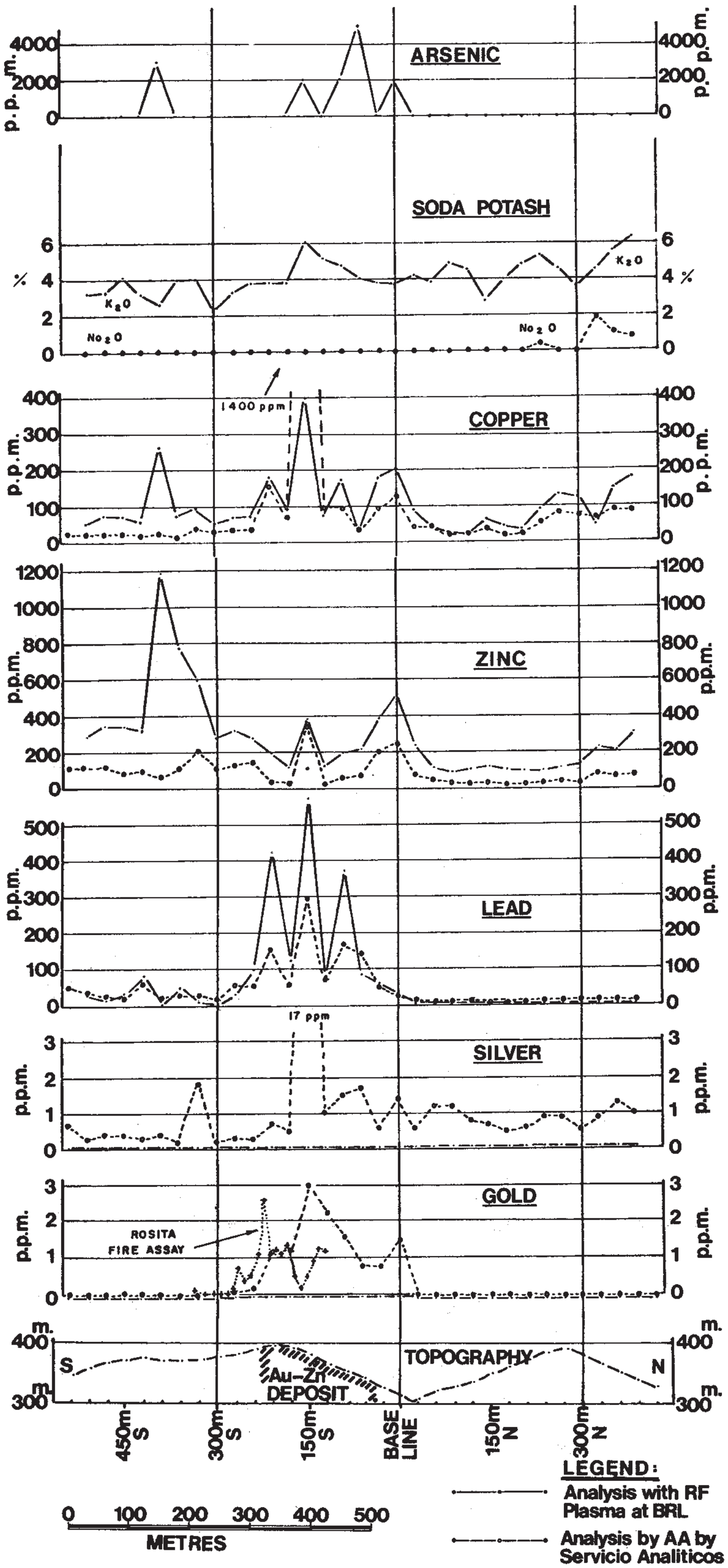

Figure 39.9. *North-south geochemical profile through the Coco Mina deposit showing atomic absorption results for soil samples taken from 0.5 m depth with surficial samples taken from the upper 2 cm analyzed in a RF plasma.*

Lead (Fig. 39.6) is more closely confined to the deposit area but also forms a large anomaly 400 m northeast of the deposit which is known as Zona Margarita (ZM on the figures). Drilling and time-domain IP work showed the Zona Margarita to be narrow and limited in extent and that the results of the soil geochemistry survey have exaggerated the apparent dimensions of the mineralization.

Copper (Fig. 39.7) is also confined to the Coco Mina zone. Anomalous gold values (Fig. 39.8) occur directly over the deposit and also form a series of smaller anomalies around the lake. This gold halo corresponds to areas of altered volcanic breccia and, as will be seen from the following geophysical results, the gold pattern corresponds to a magnetic low, resistivity low and chargeability high.

A north-south soil geochemical profile across the main portion of the Coco deposit is presented in Figure 39.4. Samples of the upper 2 cm of soil were taken and analyzed with an RF plasma unit by Barringer Research in Toronto, Canada to compare with the 0.5 m depth soil-sampling geochemical results analyzed by the atomic absorption technique. Essentially the same pattern of geochemical anomalies was obtained with a slight increase of the metal values occurring in the near-surface material.

Geophysical Surveys

A total field magnetometer survey was carried out in October, 1975 on the geochemical survey grid and the results are given in Figure 39.10. Areas of unaltered basalt (high magnetic susceptibility rocks) are defined essentially by the 41 000 gamma contour and it can be seen that a large ring-shaped pattern encloses the lake, with a branch magnetic high occurring 100 m south of the lake. This branch corresponds roughly to a chargeability low shown on Figure 39.11 and is interpreted as an area of unaltered andesite. The results of a detailed time-domain IP-resistivity survey are given in Figures 39.11 to 39.15. North-south lines were run at 60 and 120 m line spacings with east-west lines being run at 120 m line spacings.

A dipole-dipole array with an "a" spacing of 60 m was used with readings being taken at n=1 to n=5. The instrumentation consisted of a Scintrex IPR-8 receiver, IPC-7 transmitter and a 2.5 Kw motor generator system. Chargeability values on the maps represent the 650-1160 millisecond interval after the shut-off of the pulse. A 2 second on 2 second off square wave was transmitted and the chargeability values were averaged over 2 cycles (4 pulses).

The resulting pattern in plan for n=2 (90 m) (Fig. 39.13) shows the actual extent of the pyritized host volcanic breccia beyond the zinc-gold concentrations of the main Coco deposit. A basin-shaped structure, pyritized host is suggested by the IP results with dips toward the lake; however, the actual main zone on the east side of the lake is steeply-dipping to the east within the altered breccia. A chargeability low immediately west of the lake is interpreted to be a thin capping (sill?) of unaltered andesite since high chargeabilities are seen below this area on n=4 (150 m). The area to the northeast of the Coco Mina deposit known as Zona Margarita (ZM) has only moderate chargeabilities and a narrow northeast-trending pattern. High chargeabilities are somewhat contracted at n=4, again suggesting a dip toward the centre of the lake.

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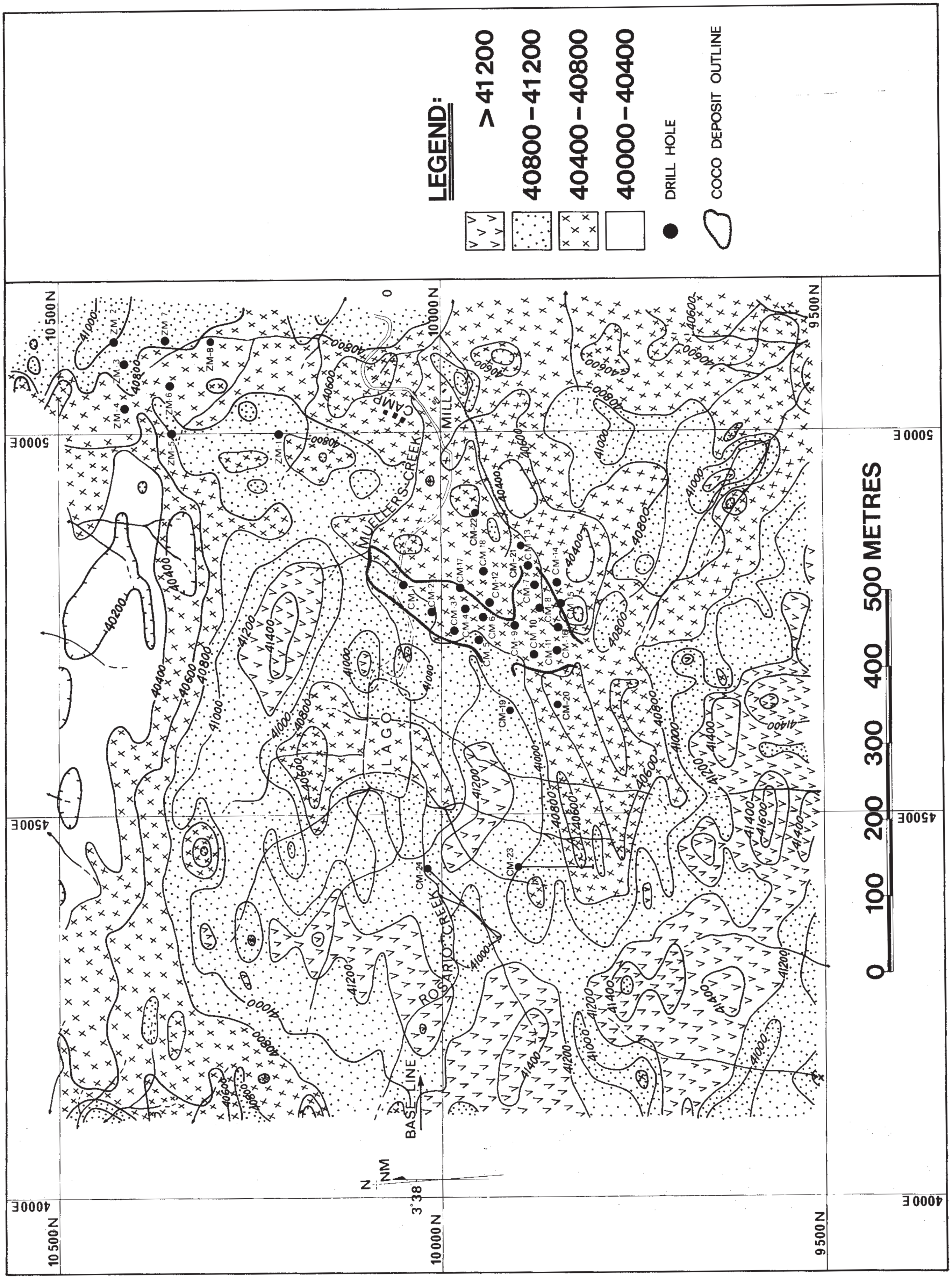

Figure 39.10. Total field magnetic survey over Coco Mina showing ring-shaped pattern produced by unaltered basalt-andesite.

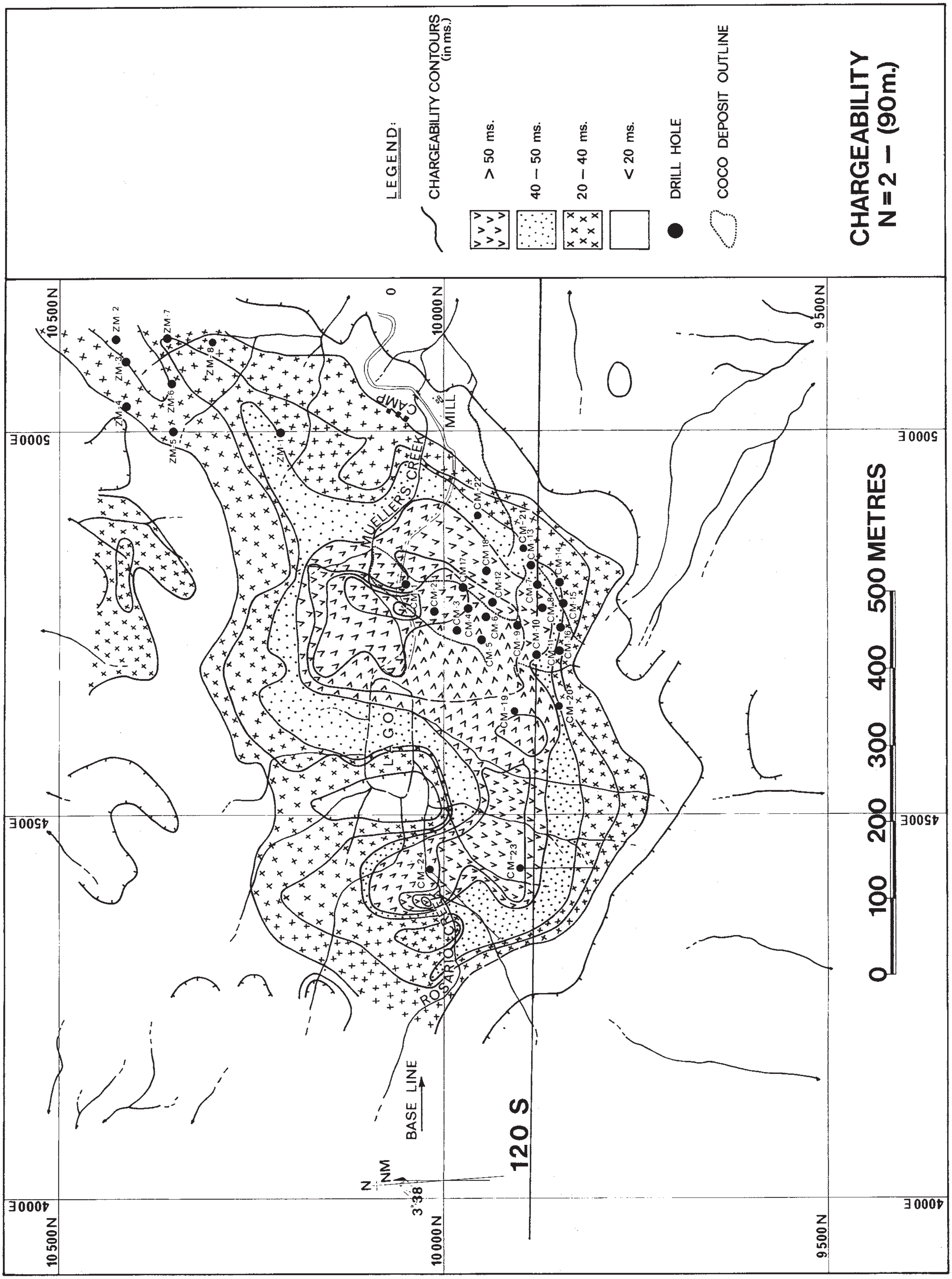

Figure 39.11. IP chargeability values for upper 90 m illustrating widespread pyritization around Coco Mina.

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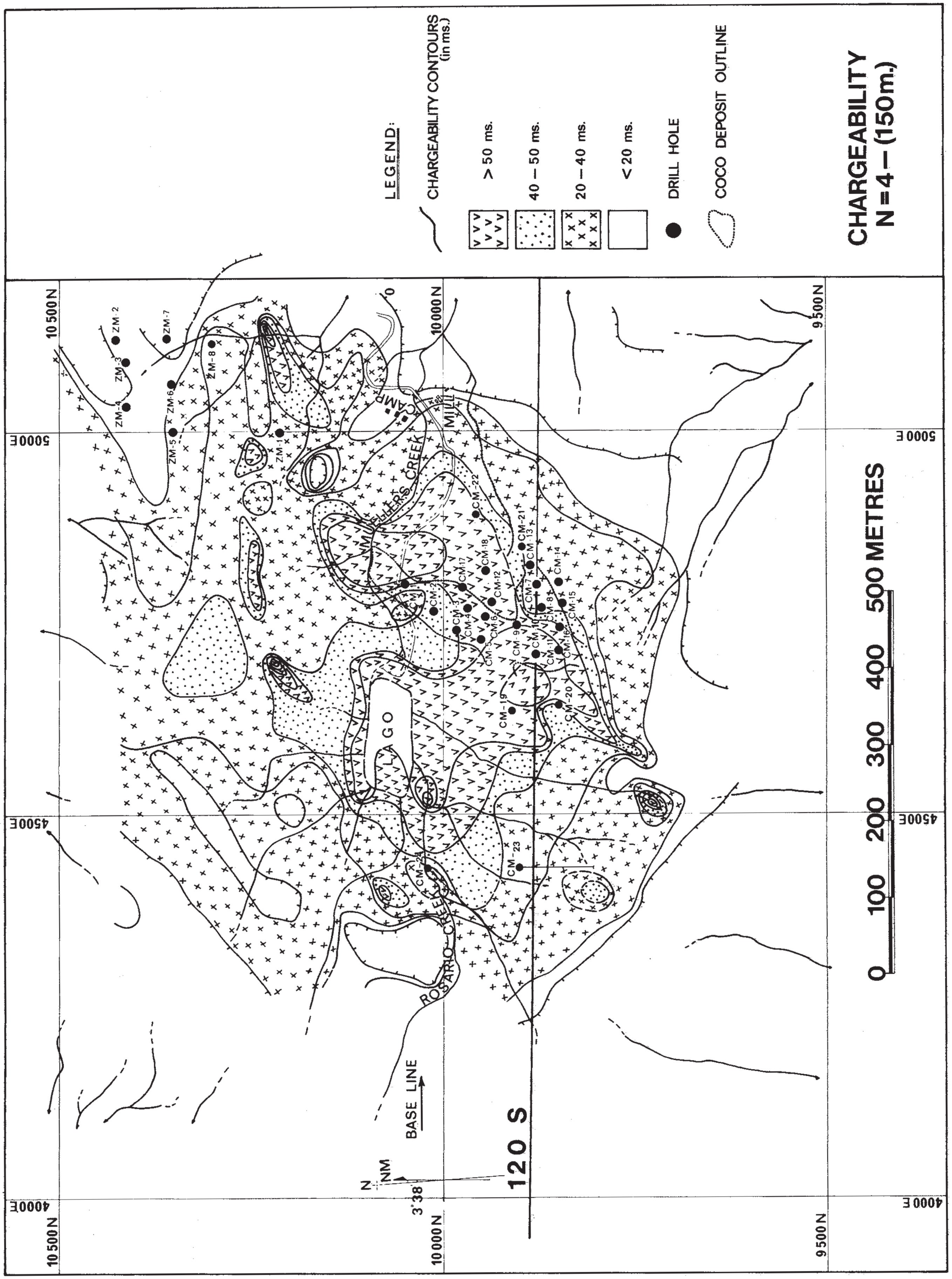

Figure 39.12. IP chargeability values for upper 150 m Coco Mina.

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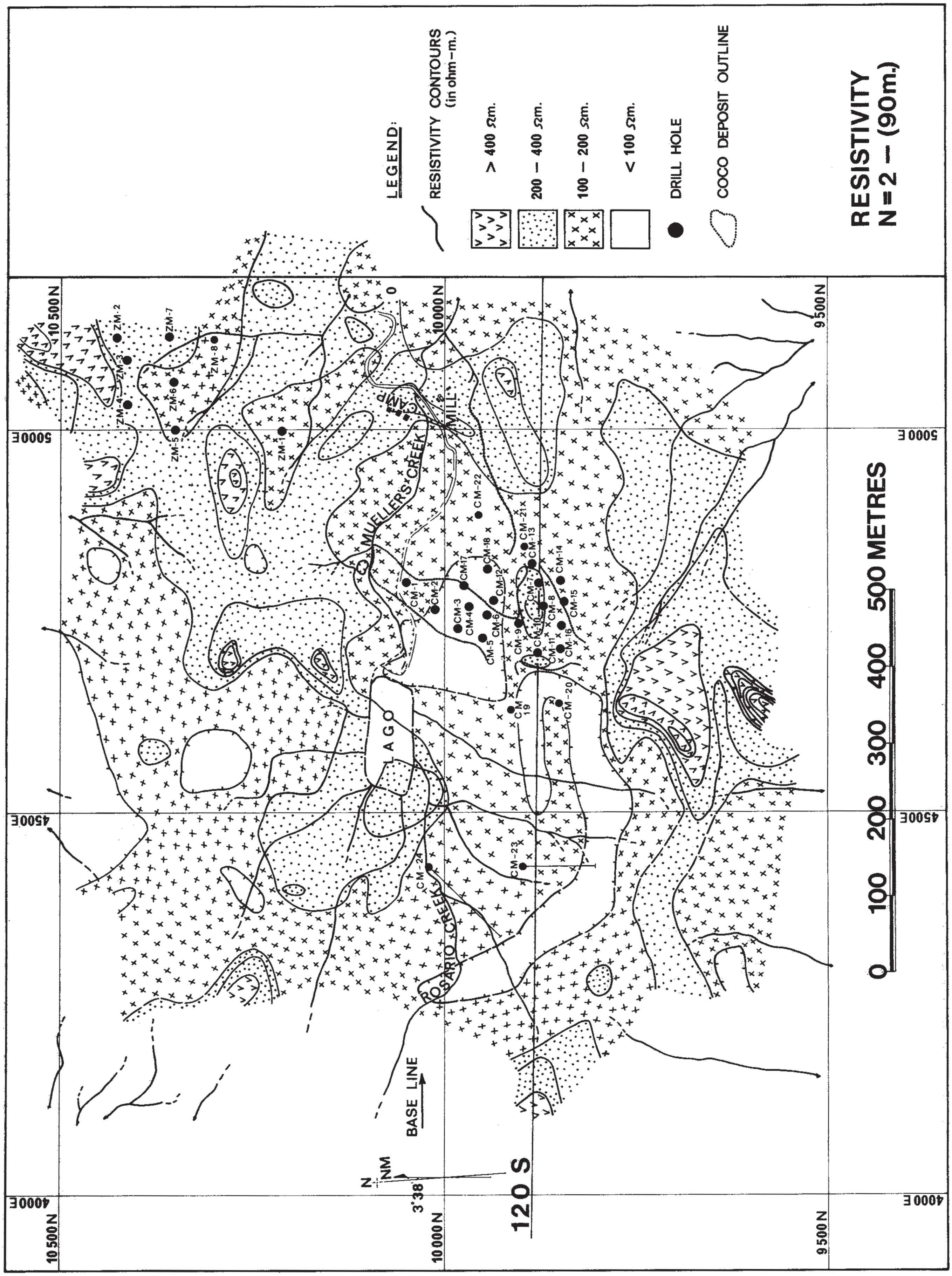

Figure 39.13. Apparent resistivity values of the upper 90 m over Coco Mina.

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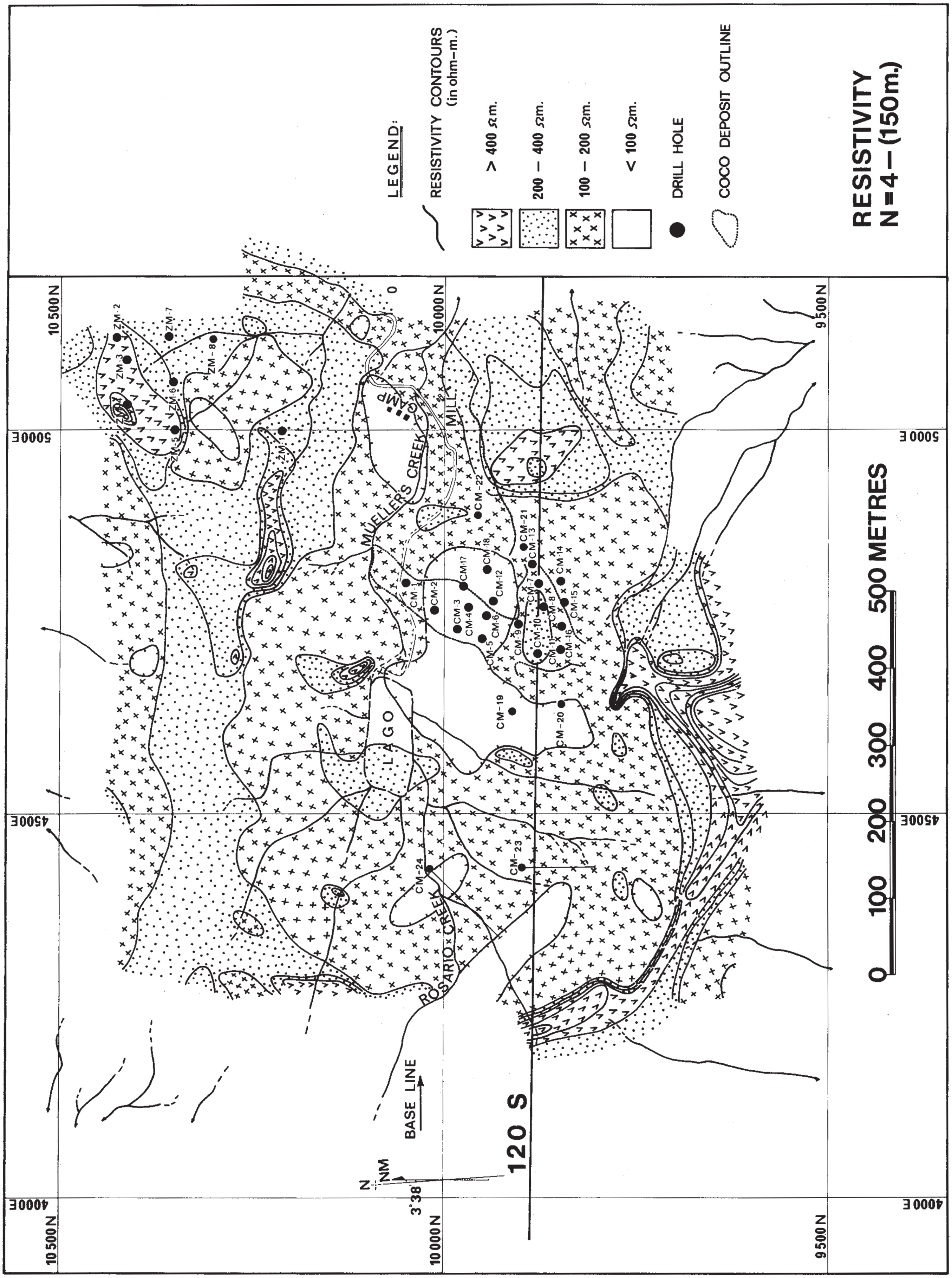

Figure 39.14. Apparent resistivity values of the upper 150 m over Coco Mina.

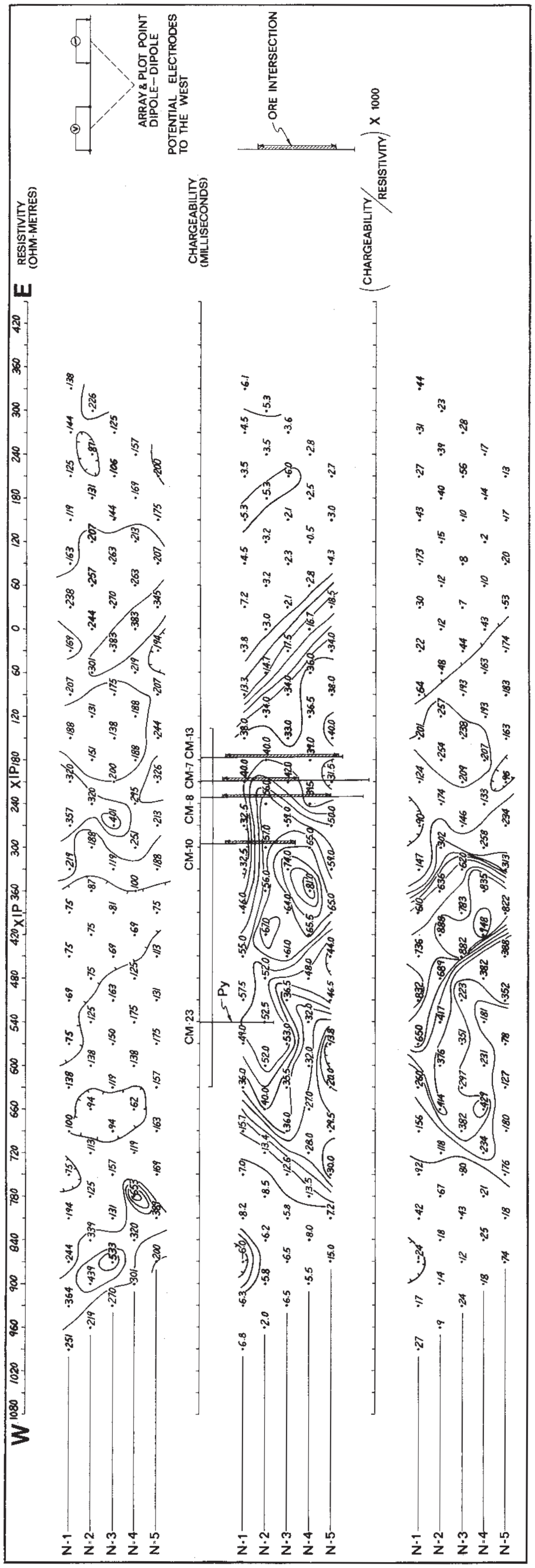

Figure 39.15. East-west section along Line 120S of Coco Mina showing apparent resistivity, chargeability and metal factor relative to some drill intersections.

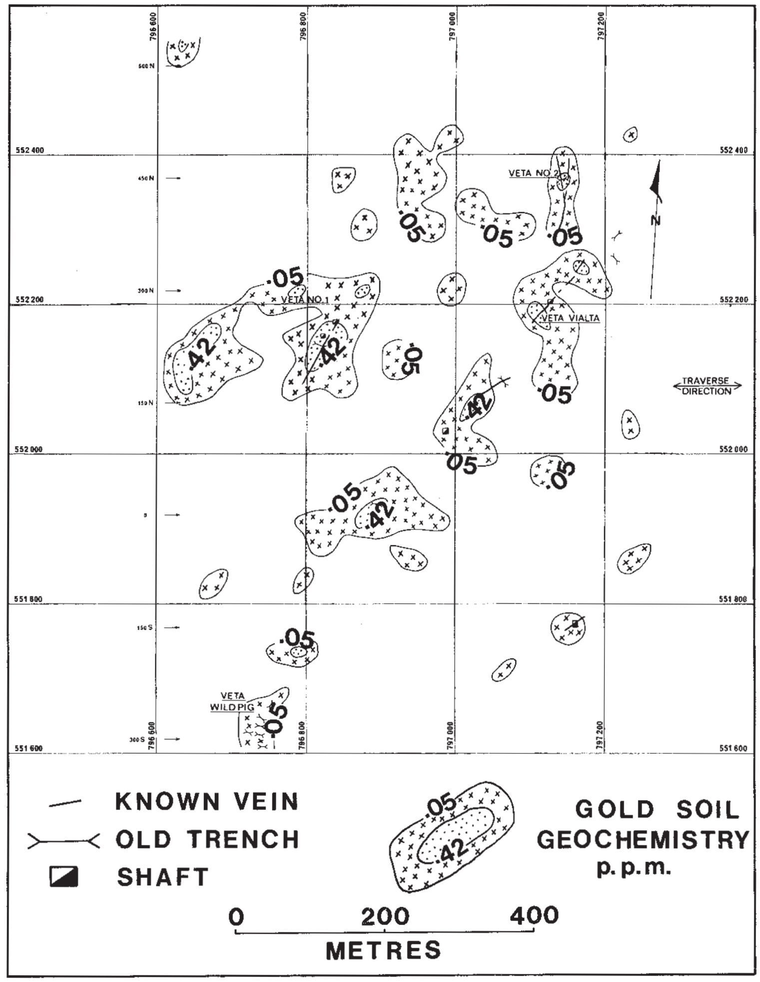

Figure 39.16. *VLF-EM profile results over Guapinol prospect.*

The section along 120 S given in Figure 39.15 shows that chargeability backgrounds of 2 to 4 milliseconds occur and anomalous values over 80 milliseconds occur within the pyritized host breccia.

The resistivity maps presented in Figures 39.13 and 39.14 show values less than 100 ohm-metres for most of the main deposit and on Figure 39.13 the near-surface expression of the altered breccia is outlined. High resistivities (greater than 200 ohm-metres) are associated with the unaltered basalts to the south and north of the lake and these same areas correspond to the magnetic highs.

Twenty-two NQ-size vertical holes have been drilled in the main zone; two holes to the west and southwest of the lake and seven holes were completed in Zona Margarita for a total of 5140 m of drilling. Drilling so far shows that the Zn-Au mineralization is concentrated on the east side of the lake and that 11.3 million short tons of 0.05 oz Au, 3.4% Zn, 0.77 oz Ag are contained in proven and probable sulphide ore reserves. These grades are based on bulk sample results factored against drillhole results with the drill results on their own giving lower grades possibly due to recovery problems.

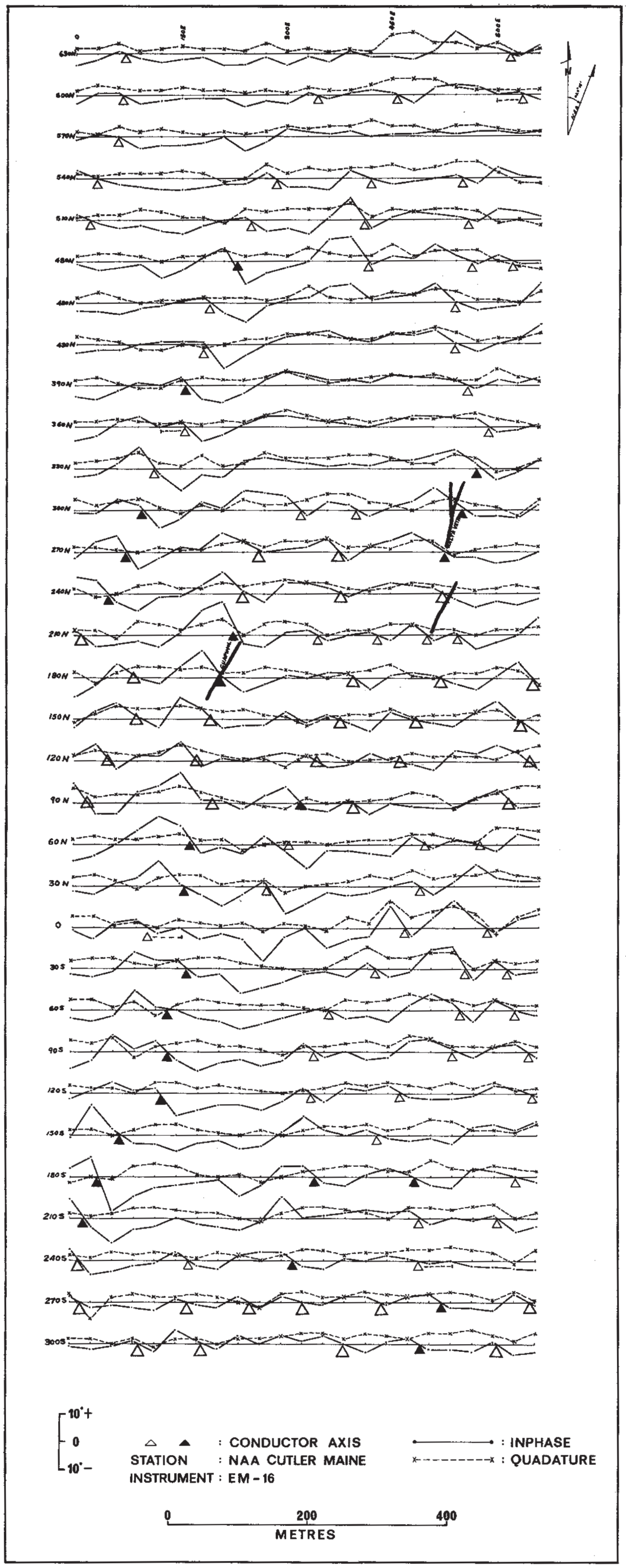

Figure 39.17. *Gold soil-geochemistry map over Guapinol prospect.*

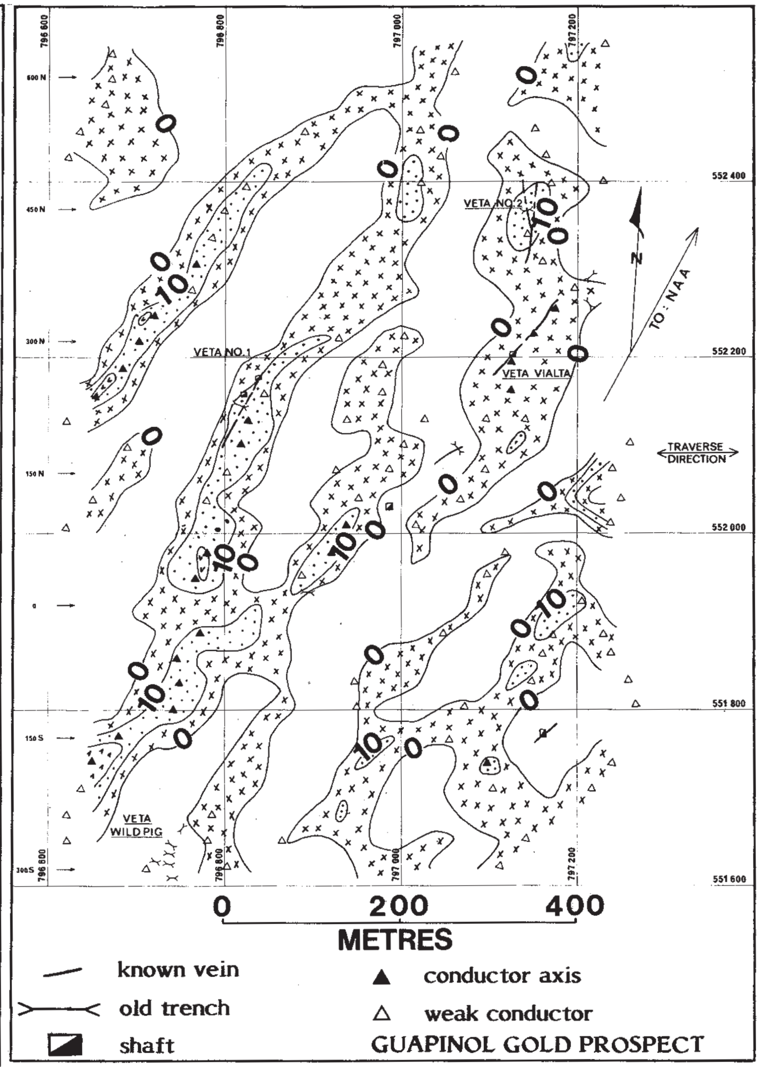

Figure 39.18. *Filtered inphase VLF-EM results for Guapinol prospect showing better definition of vein structures.*

GUAPINOL GOLD PROSPECT, NICARAGUA

A number of small epithermal vein occurrences are situated near the Riscos de Oro mine, 25 km northeast of Rosita at Guapinol (see Fig. 39.1). These veins are exposed in small, 10 m high hills in a broad flat jungle area. The tropical soils in the hills are residual whereas a thin layer of marine clays surrounds the hills. The exposures were first worked by the Tonopah Mining Co. in 1916-1917. Soil geochemistry sampling was done in 1975 with follow-up VLF-EM surveying in 1976 by Rosario Mining of Nicaragua. Survey stations were spaced at 30 m intervals with east-west lines at 30 m.

The gold soil-geochemical anomalies shown in Figure 39.17 outline the known prospects and hills, however, the marine clays break up the trends. The VLF-EM survey was carried out using a Geonics EM-16 to trace the possible vein extensions. The Cutler, Maine (NAA) transmitter, broadcasting at 17.8 kHz, was used because it was approximately on strike with the veins. The inphase-out-of-phase (quadrature) profiles are given in Figure 39.16 and a series of conductor axes are readily evident. Filtering was carried out on the inphase data using the mathematical operator described by Fraser (1969) in order to transform the zero-crossings to peaks for contouring purposes and reduce geological noise. The resultant contour patterns shown in Figure 39.18 outline the vein extensions and indicate the gold

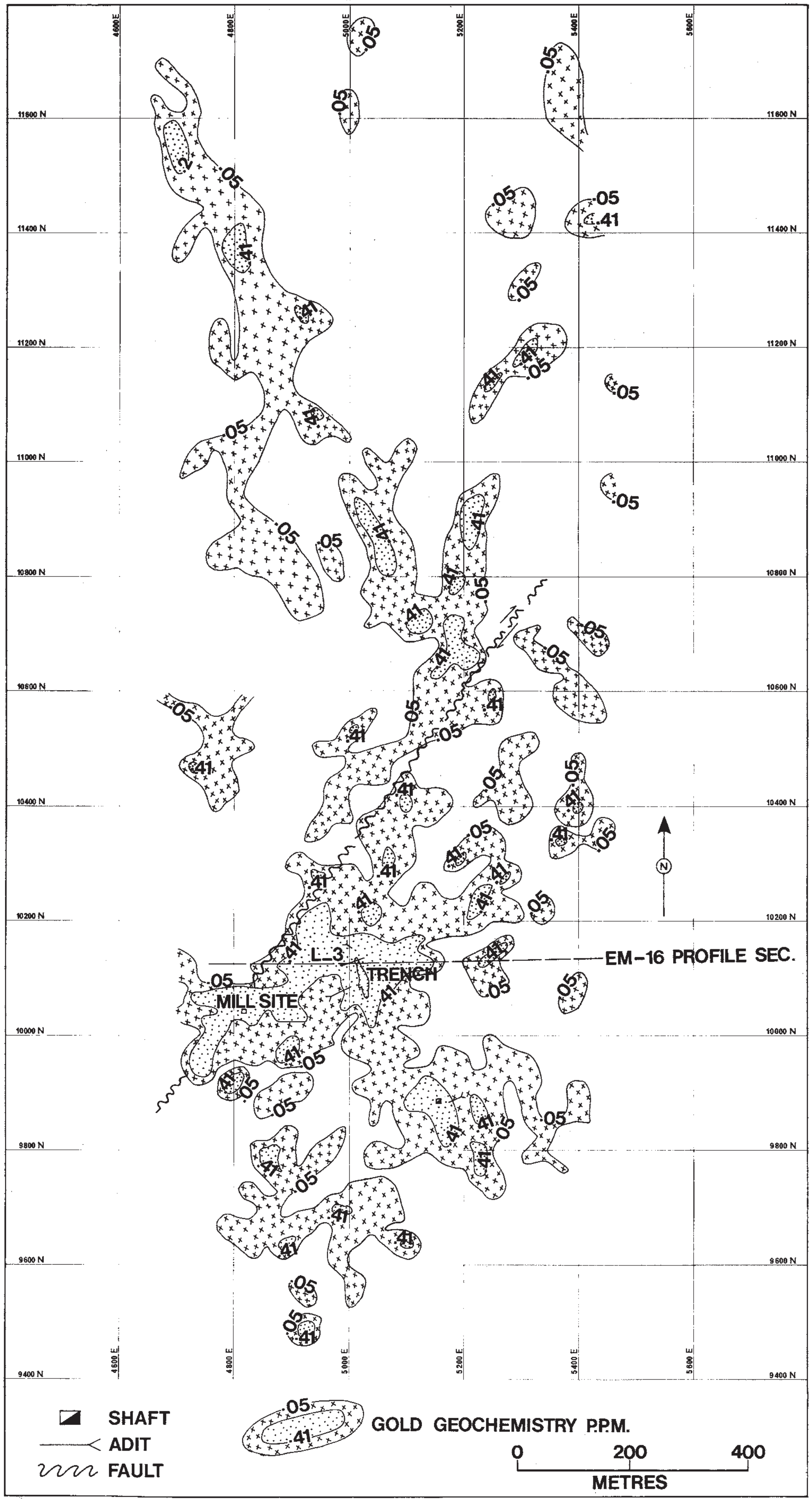

Figure 39.21. Gold soil geochemical pattern over the La Luna prospect.

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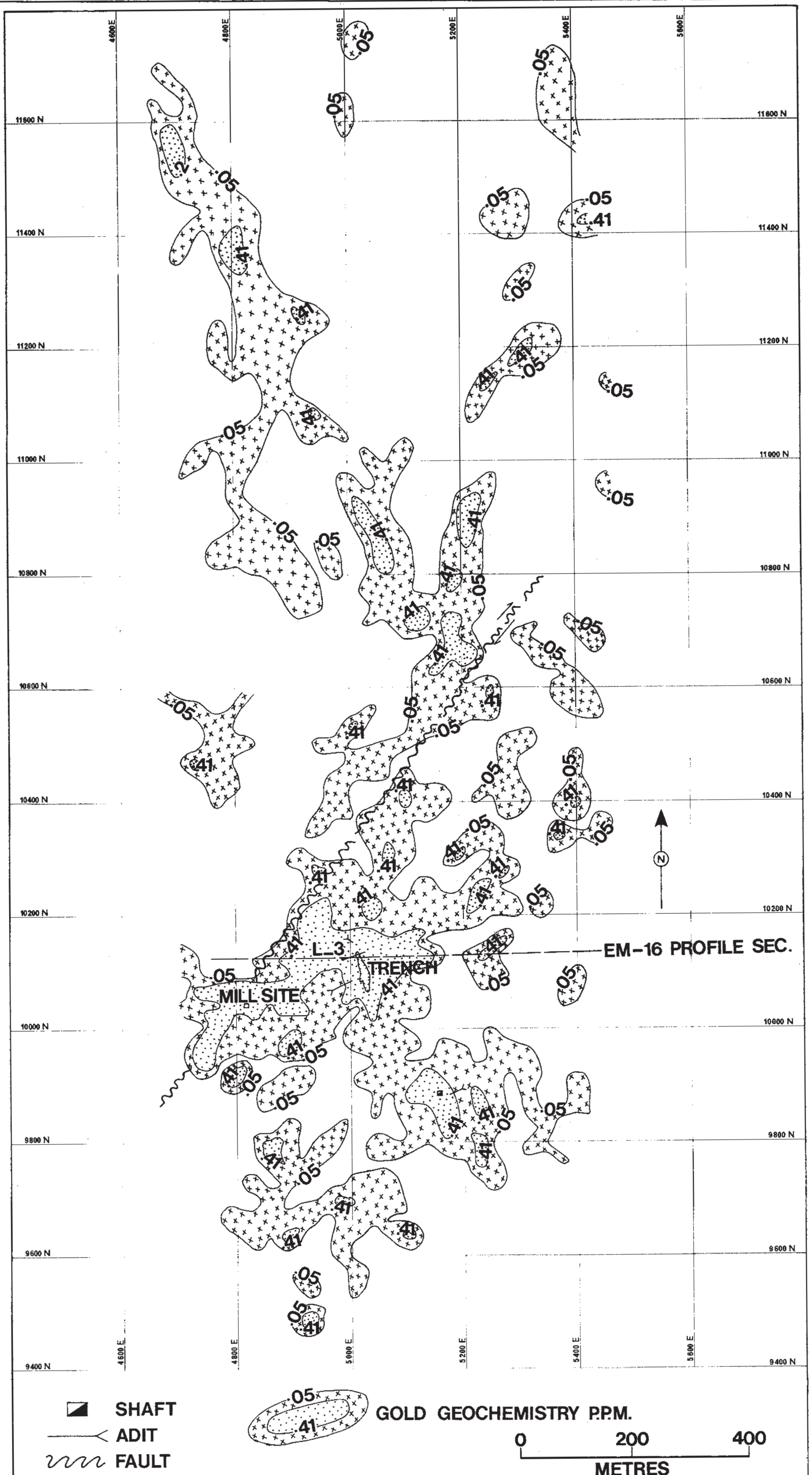

Figure 39.21. *Gold soil geochemical pattern over the La Luna prospect.*

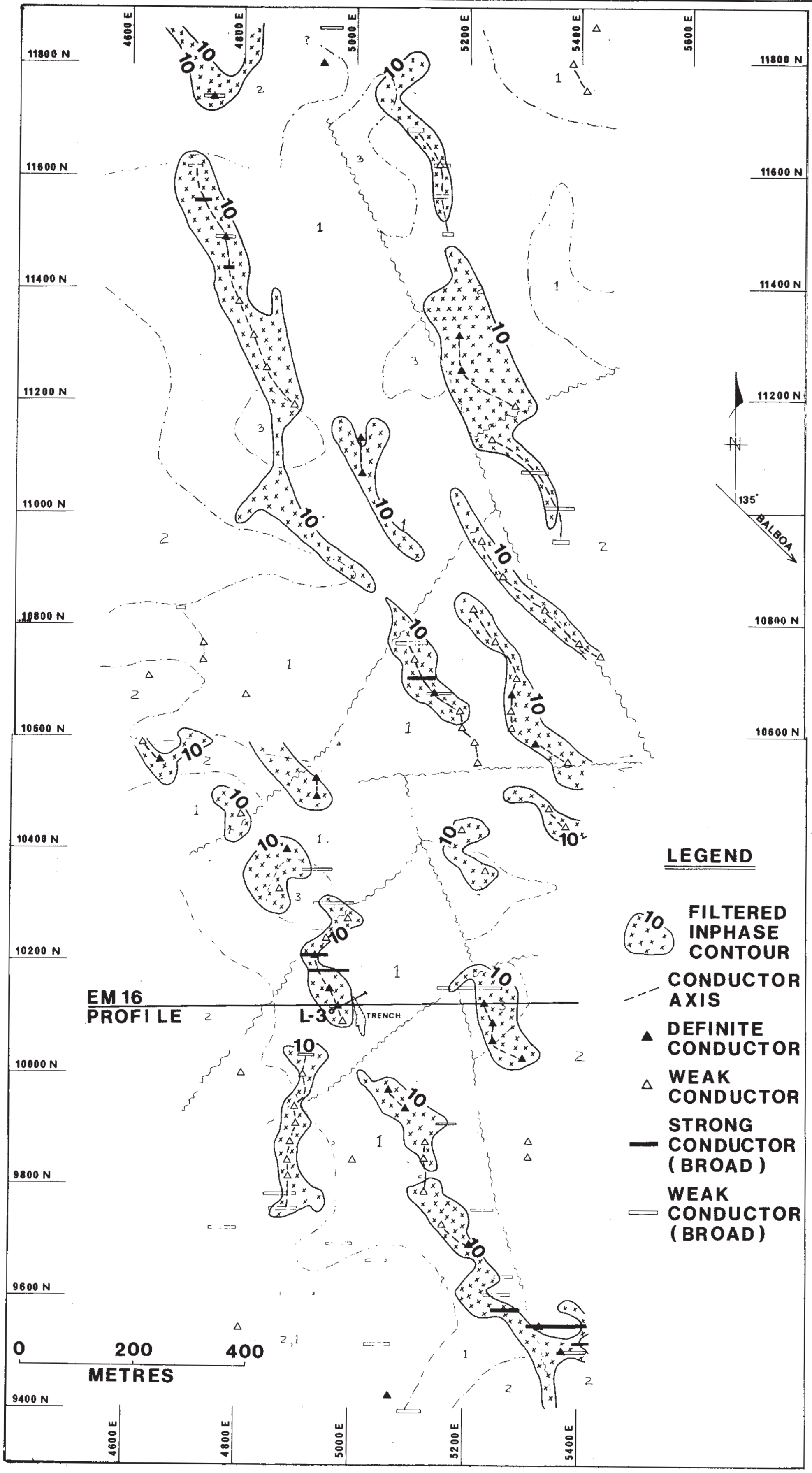

Figure 39.22. *VLF-EM results for La Luna prospect showing filtered inphase values that outline vein structures.*

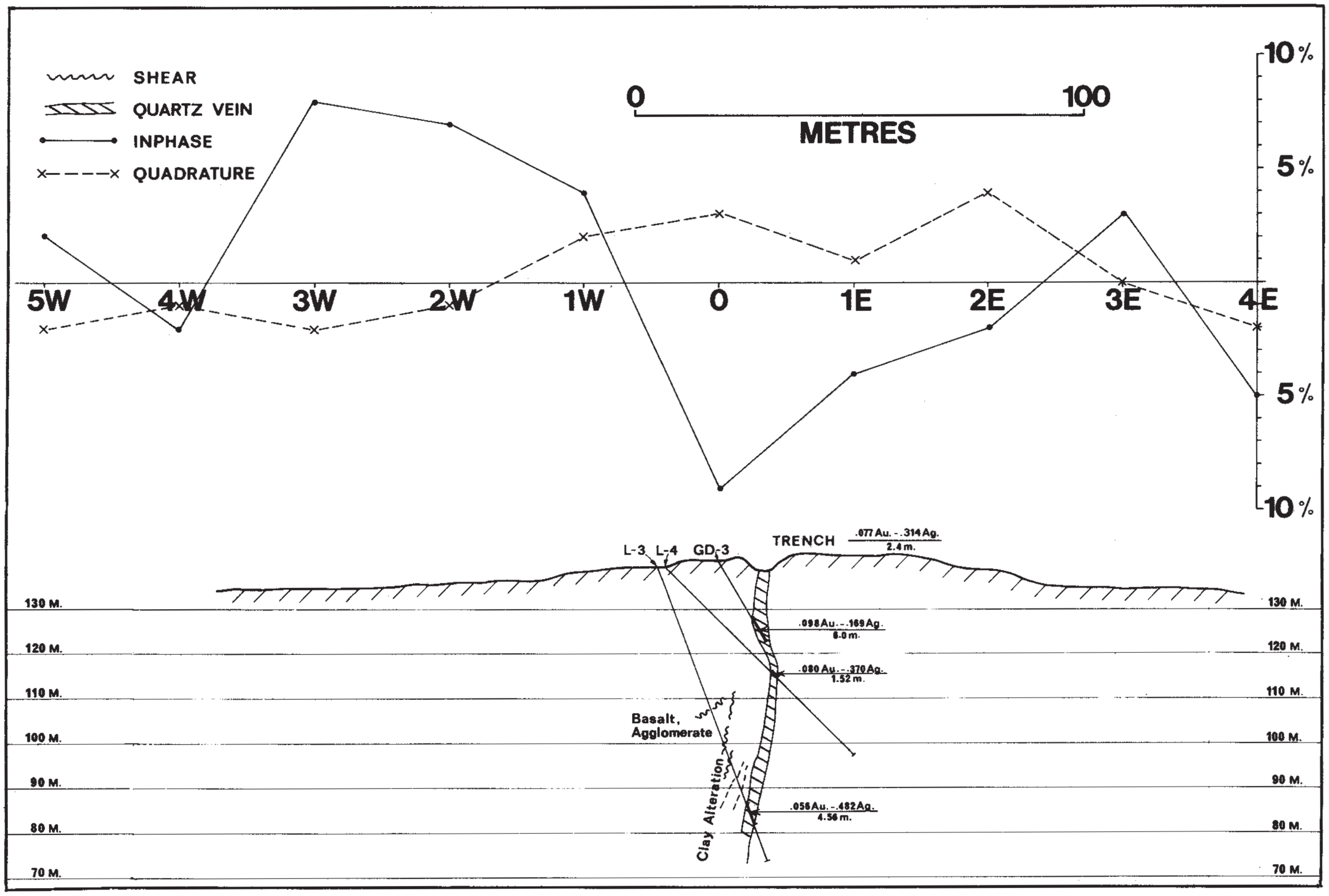

Figure 39.23. *Drill section of the La Luna mine with the VLF-EM data accompanying VLF-EM profile (it should be noted that the drill section is on different azimuth than the geophysical profile creating an apparent displacement of the conductor axis).*

LA LUNA MINE, NICARAGUA

The La Luna prospect (see Fig. 39.1) was worked prior to 1928 and was rediscovered in 1974 by Rosario native crews when a boiler and two Huntington mills were found in the jungle. Geochemical and VLF-EM surveys were carried out to trace the possible vein extensions from a single pit exposure. A Geonics EM-16 receiver was used for the VLF-EM survey and Balboa, Panama was used as the transmitter. The results in Figures 39.21 and 39.22 show an anomalous geochemical trend N20°W from the trench area which has a corresponding VLF-EM conductor. In addition other parallel conductors are indicted but are yet untested. Drilling (Fig. 39.23) shows a single vein and 33 000 tons of surface ore grading 0.15 oz Au/ton and 0.56 oz Ag were outlined. The mining of these reserves started in February 1977 to provide a part of the mill feed at a cyanide mill situated in Rosita. Further drilling and underground development is planned for La Luna.

CONCLUSIONS

The three examples presented in this paper show how conventional time-domain IP, resistivity, VLF-EM, geochemical, and magnetic surveys can be used to map lithology, alteration and structure which can provide a guide to outlining gold deposits in tropical areas. It was advantageous in all cases to use combined geophysical and geochemical methods which compliment each other in better defining drill targets.

ACKNOWLEDGMENTS

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