Geophysical Exploration and Discovery of the Candelaria Copper-Gold Deposit in Chile

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ABSTRACT

The Candelaria copper-gold deposit is located in the Punta del Cobre district, Region III of Chile, approximately 805 km north of the capital, Santiago. Candelaria was discovered in 1987, following a six-month exploration program. In 1986, Phelps Dodge's Chilean subsidiary, Cia. Minera Ojos del Salado, was mining the Lar and Bronce manto deposits. The two deposits contained copper grades as high as 2%, with appreciable gold values. With the exception of a few shallow holes which showed copper mineralization, potential beyond the main workings was unknown. Induced polarization/resistivity surveys conducted in late 1986 outlined a target within the Lar area. The first test hole in late February 1987, had ore grade intersections totaling 49 m with an average grade of 1.97% copper, along with significant gold. Succeeding nearby holes showed similar values. Drill testing of a second IP target one kilometre to the south resulted in discovery of the Candelaria South ore body. Stripping began at La Candelaria in March 1993, and production began in late 1994. Tonnage of this world class deposit is reported at 390 million tonnes with copper grades at 1.09% and 0.26 grams gold/tonne. Annual production is approximately 120 000 tonnes of copper and 80 000 ounces of gold. A mine expansion is underway which will double present production. High sensitivity airborne magnetic and radiometric surveys, as well as ground reconnaissance electrical and electromagnetic methods utilized increasingly over the last ten years, appear to be helpful additions to successful exploration in the Chilean environment.

INTRODUCTION

Exploration in Chile which resulted in the discovery of the Candelaria copper-gold deposit was not the result of a *classical* approach where one progresses from a regional program to a specific target. The area west of the Punta del Cobre district had been recognized as a potential (albeit small) source of copper-gold early on after Phelps Dodge's entrance into Chile. Specifically, the Lar and Bronce deposits had been sporadic producers for over fifty years. Regional exploration, at least from a geophysical standpoint, began only after the discovery.

Candelaria is located about 20 km south of the town of Copiapó in the Atacama Province, Region III, Chile (Figure 1). It is situated 805 km north of Santiago and 75 km by paved road from the Pacific Ocean. The village of Tierra Amarilla lies approximately 4 km to the northeast.

The deposit is at an elevation of approximately 500 m above sea level, and mineralization occurs beneath the Quebrada Los Bronces valley and its western slope. Reserves are estimated at 390 million metric tonnes at an average grade of 1.09% copper and 0.26 grams per tonne gold using a 0.4% copper cut-off grade. Production started in early 1995 at an initial milling rate of 28 000 tonnes per day. At this time a major expansion is underway which will double present production.

HISTORY OF THE DISCOVERY

The only recorded mining activity in the Candelaria area was a small copper prospect first staked in the 1930s and subsequently abandoned. In 1969 the deposit was restaked as the Violeta prospect, but again abandoned. It was restaked again in 1981 as the Lar concession and mined on a small scale for copper oxide ore.

Phelps Dodges's involvement in the area dates to 1983 when Compañia Minera Ojos del Salado, a wholly owned subsidiary, leased the Lar property and mined about 1800 tonnes of oxide copper-gold ore from the small outcropping manto deposit. Drilling to explore for additional sulphide ores, recommended by the Ojos del Salado staff, was rejected, and the property was dropped in 1984 due to poor metallurgical recovery of gold from the oxidized ores. By 1985 there was a shortage of mill feed for the Ojos del Salado mill, and the mill and concentrator

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Figure 1: *General location map of Chile showing the Candelaria deposit.*

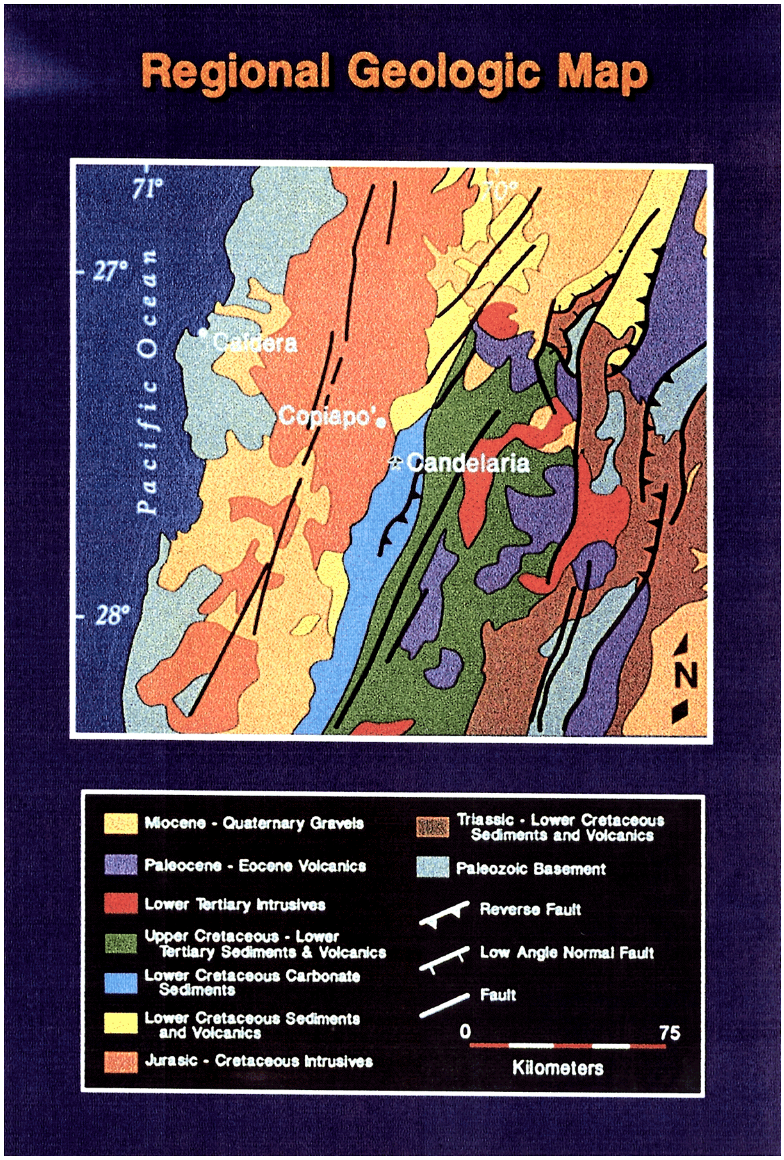

Figure 2: *Regional geology of the Punta del Cobre district and surrounding area.*

were in danger of being closed. Phelps Dodge exploration geologists renewed work in the area and recommended further exploration of the Lar concession as a potential source of ore. The Lar concession was reoptioned in late 1985, and a percussion drilling program was carried out to explore for sulphide mineralization downdip from the outcropping copper oxides in the Lar manto. This program outlined a small manto-like sulphide copper-gold ore body at the Lar Mine, and another at the Bronce Mine, located approximately 1 km to the south.

In a first effort to expand known mineralization, a percussion hole was drilled roughly 200 m southwest of the Lar Mine. Two metres of chalcopyrite mineralization were encountered at a depth of 70 m, but the hole was abandoned due to a heavy inflow of water.

Exploration continued during mining at both Lar and Bronce and geophysical surveys were recommended to evaluate sulphide potential at depth. During the course of the initial surveys, a well-defined induced polarization (IP) anomaly suggested that significant mineralization could be present at depth, below the bottom of the previous percussion hole. In February 1987, the anomaly (Figure 6) was tested with a diamond drill hole which intersected more than 49 m of mineralization, averaging almost 2% copper, with significant gold values. This was the discovery hole. Detailed follow-up IP surveys further outlined a second anomalous IP response about 1 km south of the discovery hole. Drilling of this target eventually led to the discovery of what is now the South Pit at Candelaria.

Limited ground magnetics were carried out during the regional exploration phase. This followed initial drilling and made no direct contribution to the discovery, nor did it appear to correlate with economic mineralization which might have been useful in the drilling program.

During the exploration phase, 215 line-km of IP and ground magnetic surveys were completed. Three hundred twenty-five holes were drilled during the exploration and development phase (1987–1990). Approximately 37 000 m of percussion and 99 000 m of diamond drilling were completed during these phases of the project.

Regional geologic setting

Candelaria is located just east of the coastal batholith of Jurassic-Cretaceous age that intrudes a basement formed of Upper Paleozoic accretionary prism rocks and Permian intrusives (Figure 2). The Atacama fault, a major strike slip system that has been active since at least the middle Jurassic, cuts the batholith along the length of its axis.

Local geology

The oldest rocks found in the Candelaria deposit are metavolcanics of the Punta del Cobre Formation of early Cretaceous age (Figure 3). These have been divided into three units in the mine area; a lower biotitized andesite, a sequence of tuffs and volcaniclastic sediments and an upper andesite. Lower andesites are the major host rock of the Candelaria mineralization. The Punta del Cobre Formation is overlain by fine grained clastic and calcareous sediments of the Cretaceous Abundancia Formation which are in turn overlain by calcareous rocks of the Cretaceous Nantoco Formation. Overlying and to the west of the Candelaria deposit the Abundancia and Nantoco Formations have been metamorphosed to a series of garnetites and skarns with thin interbedded layers of hornfels. Igneous rocks of the mid-Cretaceous batholith crop out about 1 km west of the Candelaria deposit.

Two major structures are present in the mine area and are mapped as the Lar and Bronce faults. The Lar fault is a high angle reverse fault that cuts the northern part of the ore body in half and marks the eastern limit of the ore body to the south. It has an apparent vertical displacement of around 35 m in the north and over 150 m in the south. Paralleling the Lar fault 350 m to the west, is the Bronce fault. It appears to be a normal fault with an apparent offset of up to 200 m. Both the Lar and Bronce faults also show some evidence of left-lateral movement; the true vertical and horizontal displacements are not known.

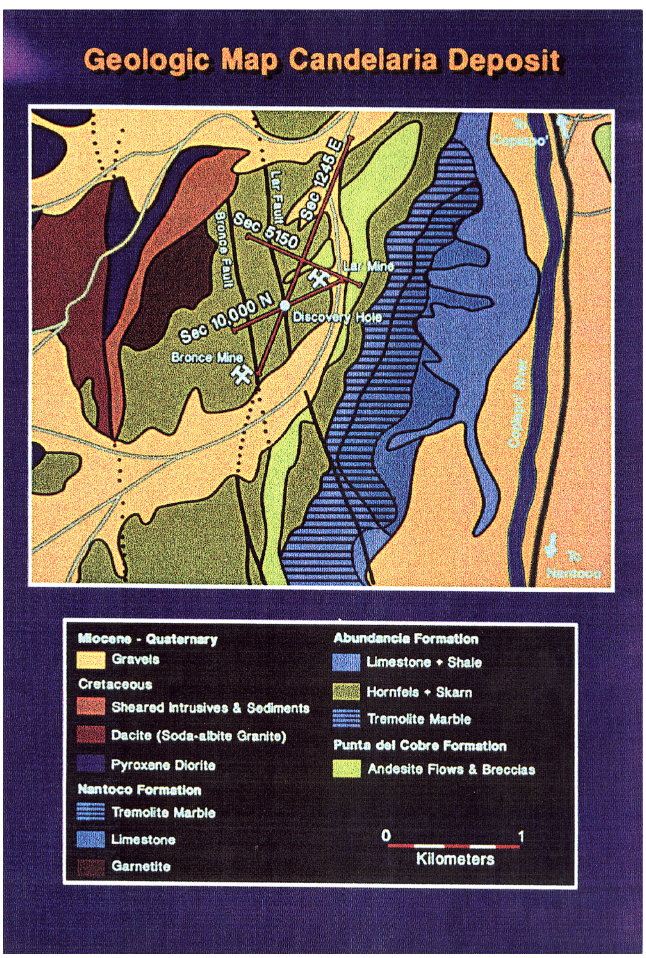

Figure 3: *Geology of the Candelaria Mine area.*

Mineralization

Candelaria ore is made up of varying proportions of chalcopyrite, magnetite, pyrite, pyrrhotite, and sphalerite, in a gangue of biotite, actinolite, calc-silicates, quartz, albite and/or potassium feldspar. The vast majority of mineralization occurs in the lower andesite, however, highest grade mineralization often occurs in the overlying tuffs and volcaniclastic sediments. Only minor economic mineralization occurs in the upper andesites, and economic mineralization in the metasediments is confined to a few small, isolated mantos such as those originally mined in the Lar and Bronce deposits. At Candelaria, copper mineralization occurs almost exclusively as chalcopyrite in veins, breccia fillings, irregular pods, stringers along foliation planes or as fine to coarse disseminations. Gold occurs principally as micron-sized grains associated with chalcopyrite or in fractures in pyrite. Moderate to strong IP responses are associated with sulphide mineralization, mainly chalcopyrite, in the ore body. Unfortunately, similar responses are also related to the ubiquitous pyrite which occurs throughout the district complicating interpretation from an economic standpoint.

Ore bodies

Candelaria ore bodies, at a 0.4% Cu cutoff, are crudely sheet-like in form with the main part of the deposit averaging 2000 m long by 600 m wide and elongated north-south. In the main part of the deposit mineralization reaches thicknesses of over 450 m and is open at depth. The main part of the deposit did not outcrop and was buried under 70 to over 300 m of metasediments and metavolcanics. The presence of magnetite in the Candelaria deposit is ubiquitous and averages over 10%, but there does not appear to be a direct relationship between intensity of magnetite mineralization and copper or gold grades.

Geochemistry

Geochemistry played no role in the discovery of the Candelaria deposit but studies of major and trace element distribution and zoning are being carried out on intrusive rocks, wall rocks and ore minerals. As yet no conclusions can be drawn from these preliminary studies. Elsewhere in the nearby Punta del Cobre district it has been shown that alkali metasomatism is associated with mineralization and with an early period of sodic metasomatism later overprinted by potassic metasomatism. A similar but more complex relationship appears to exist in the Candelaria deposit but details of these metasomatic changes and their relationship to mineralization remain to be worked out.

Geophysics

IP/resistivity surveys at Lar and Bronce (now called Candelaria) were initiated in early December 1986 and continued until late December. Their purpose was to evaluate sulphide potential of the two small manto deposits at Lar and Bronce, as well as the surrounding area. Little was known about sulphide potential away from the main workings except for the one percussion hole west of the Lar Mine which had intersected low grade copper sulphide mineralization at 70 m. The hole was abandoned after only a short intersection due to the heavy inflow of water. The presence of this relatively deep sulphide mineralization was the basis for the recommendation to carry out geophysical surveys in the area.

The survey covered a portion of the Lar concession and a second area approximately 1 km to the west. A total of eighteen lines were completed on the concession and surrounding area to the west although only the 13 lines within the Lar and Bronce Mine Areas are shown (Figure 4) (Note that all illustrations of geophysical data utilize the convention of warm colors (e.g., reds) to denote high values, and cool colors (e.g., blues) for low values.) Lines 100N to 1100N relate to lines in the Lar area, while Lines 3900N to 4200N were part of the original Bronce grid. The dipole-dipole electrode array was utilized, and because envisioned extensions of the Lar and Bronce mantos were at shallow depth, a dipole spacing of 50 m was used. It's worth noting that the target(s) sought at this time were small mantos, not porphyry size deposits like Candelaria. Lines were spaced 100 m apart except that Line 800N and Line 1100N were 300 m apart. Line 1100N was located approximately 200 m to the northeast of the Lar mine portal and run to obtain information over known mineralization.

This and the subsequent survey were carried out using a Phoenix IPV-2 system capable of measuring IP response both as percent frequency effect (PFE) and phase angle. PFEs were measured between 3.0 and 0.33 Hz while phase angles were obtained at 0.33 and 3.0 Hz.

Relatively high background phase angle values obtained during field measurements confirmed that substantial amounts of sulphide mineralization, probably as pyrite, occurred throughout the area. Analysis of IP and resistivity data suggested that unwanted electromagnetic coupling effects were minimal.

The survey started beyond the western edge of the concession and proceeded northeasterly across it. Data from the first lines indicated that anomalous values were increasing across the Ojancos valley to the southeast of the Bronce Mine. However, this was an overburden covered area outside the major focus of geologic interest and follow-up work was deferred until later in the program. As the survey proceeded to the

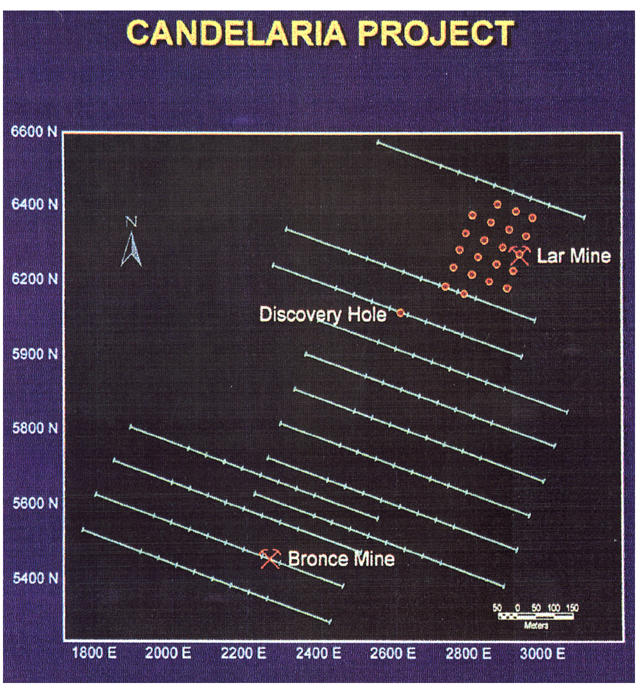

Figure 4: *Initial grid within the Lar and Bronce areas showing exploration drilling prior to the induced polarization surveys (IP), and the discovery hole based on the IP.*

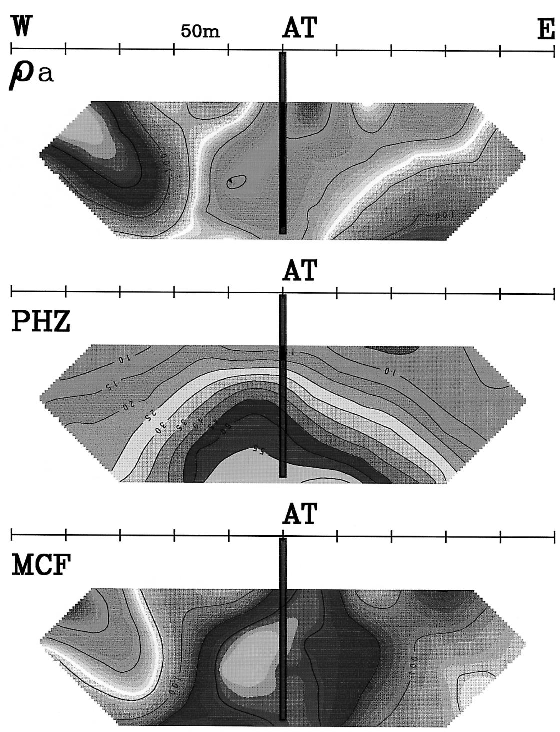

Figure 5: *Resistivity, phase, and MCF pseudo-sections of dipole-dipole Line 300N using 50 m dipoles from n=1-6, and the air track drill hole (AT).*

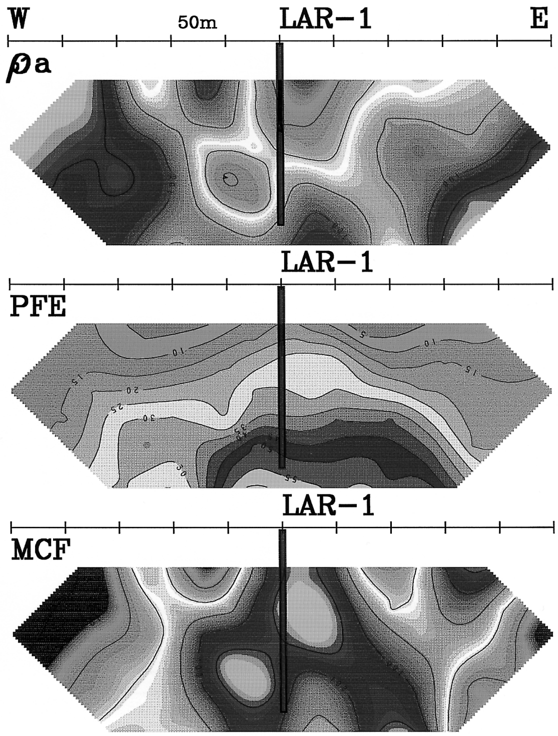

Figure 6: *Resistivity, phase, and MCF pseudo-sections of dipole-dipole Line 700N using 50 m dipoles from n=1-6, and the discovery drill hole LD-1.*

northeast, a nicely patterned anomaly began to develop. Line 300N (Figure 5) showed a pronounced resistivity low from west of the center of the line. A well-defined, near surface, polarization (phase) high was also located 75 m west of the spread center. Persistence of high phase angle values at n=6 indicated that mineralization might continue to greater depth.

Based on these early results, a track mounted air drill was sited at the centerpoint of Line 300N while the IP survey was continuing on subsequent lines. At a depth of 57 m, sulphide mineralization was encountered. The hole was terminated at 60 m due to water infiltration. Three 1 m assays at the bottom of the hole averaged 0.7% copper as chalcopyrite, with one interval running 1.4%.

Figure 6 shows the pseudo-section plot for Line 700N using 50 m dipoles. Resistivity, phase and metallic conduction factor (MCF) are similar to those observed on Line 300N, i.e., a resistivity low near the center of the line with coincident phase and MCF highs. No indication of depth limited mineralization is indicated. Drill results and recent modeling of the 100 m pseudo-section for Line 700N verify the initial interpretation of significant mineralization continuing to depth (Figure 7). Although not apparent in the abbreviated illustration, mineralization is indicated to the northwest.

The first diamond drill hole, LD-1, was collared on the 0.0 baseline (center of the line) between Lines 700N and 800N, approximately 40 m north of Line 700N. The interval from 59 m to 154 m averaged 1.17% copper with appreciable gold values. One 22 m interval averaged 2.50% copper. The hole was bottomed at 178 m. Drill holes LD-2 and LD-3 encountered similar mineralization.

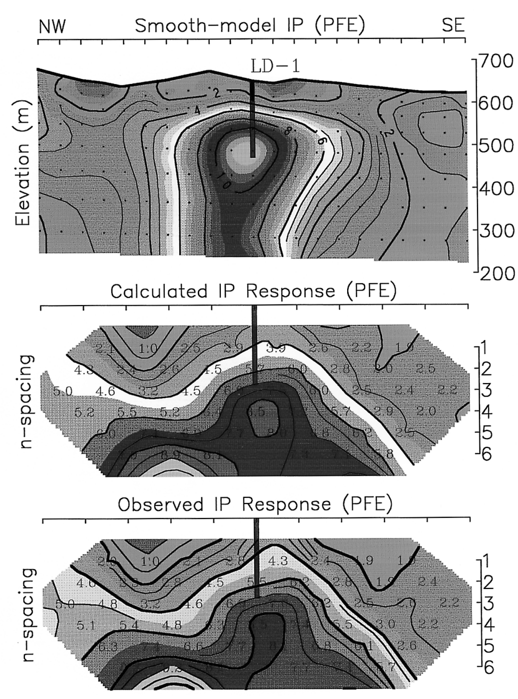

Figure 7: *Pseudo-sections of dipole-dipole Line 700N using 100 m dipoles showing from top to bottom: smooth model IP (PFE), calculated IP response (PFE), observed IP response (PFE), and discovery drill hole LD-1.*

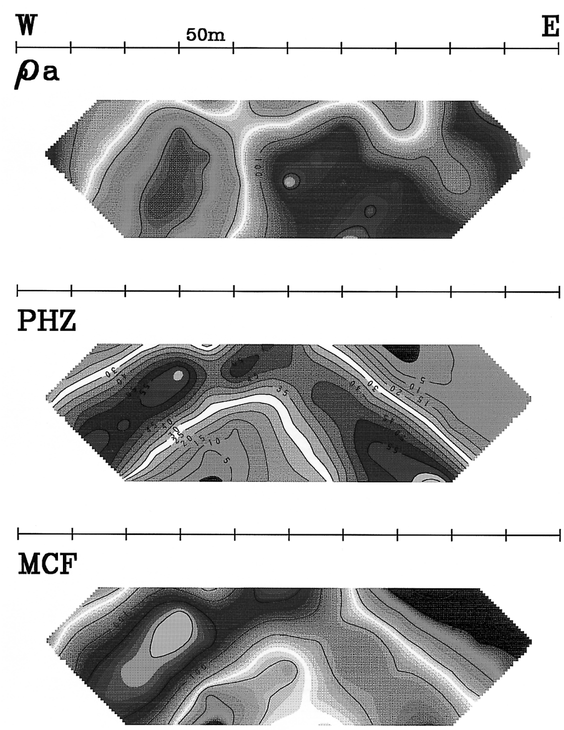

Figure 8: *Resistivity, phase, and MCF pseudo-sections of dipole-dipole Line 1100N using 50 m dipoles from n=1-6.*

Line 1100N was run over the eastern part of the Lar mineralization, as known at the time of the survey (Figure 8). Near surface resistivity lows occur close to the center of the line and approximately 100 m to the east. A strong resistivity low also extends to depth 100 m west of the center, with several values less than 30 ohm-m. The phase shows a typical pant-leg anomaly near the center. Maximum phase angles reach 60 milliradians (approximately 10 PFE). The triangle of low values at depth seems to suggest a body of limited depth extent. Mineralization in stacked mantos, separated by varying thicknesses of barren material, is now known to persist to considerable depth in many parts of the deposit. The inability to penetrate to these lower mineralized mantos with 50 m dipoles is illustrated by these data.

Line 100N (not shown) was one of the first run in the Bronce-Lar area and indicated that mineralization increased to the southeast. Resistivities decreased dramatically to the southeast while polarization values appeared to increase slightly at depth.

A plan of Fraser filtered resistivity values obtained during the first phase of the induced polarization surveys shows a pronounced north-south *low* between the Lar and Bronce Mines which is generally coincident with copper mineralization. Figure 9 shows the phase response with a high which runs between Lar and Bronce. The strong response in the southeastern portion of the grid is the northern part of the anomaly seen on Line 100N, east of Bronce. The MCF plan almost exactly duplicates the phase map.

By August, 1987 deep drilling had established the presence of significant mineralization at depths considerably greater than 100 m, and the possibility of a large bulk tonnage deposit appeared likely. For this reason the dipole spacing was increased from 50 to 100 m. All subsequent IP surveys utilized this larger dipole spacing, and coverage was extended to cover a much larger area. This continuing IP program required services of a full time Chilean field crew. From among the pick-up crew used until this time, a potential crew chief was identified. In order to simplify field operations, a switch to Heinrichs GEOEXploration Company frequency-domain equipment was also made. Data obtained with the frequency equipment was considered to be of comparable quality to that gathered using the Phoenix gear and was somewhat simpler to operate.

Line 3900N, run with 100 m dipoles, shows a strong polarization anomaly near the center of the spread (Figure 10). Drill hole LD-31 tested this IP target in late 1987. It hit bedrock and sulphide mineralization at a depth of 35 m with the first 1-m assay running 5.62% copper, as chalcopyrite. The hole was drilled to a depth of 337 m. The interval from 35 m to 276 m averaged 1.37% copper plus gold. One of the better mineralized intersections was from 235 to 257 m and averaged 2.76% copper.

The Fraser filtered resistivity plan map for the area encompassing the Candelaria deposit using 100 m dipoles shows low values in the vicinity of the Lar and Bronce Mines (Figure 11). It is part of a larger north-south *low* trend which continues well beyond copper-rich mineralization. South and west of Bronce there is another area of low resistivities which are mainly the result of pyrite mineralization.

Figure 12 shows the Fraser filtered percent frequency effect (PFE) using 100 m dipoles. It illustrates the extent of sulphide mineralization throughout the area surrounding Candelaria. The two lows west of the

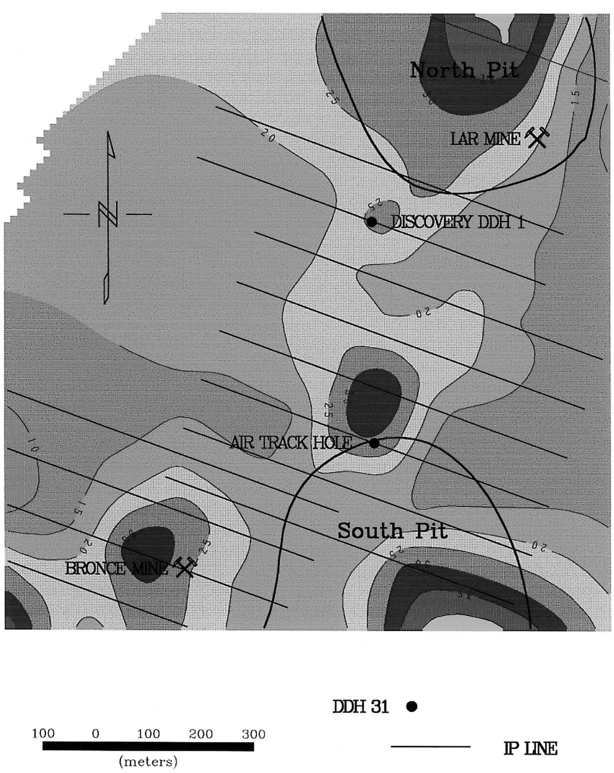

Figure 9: *Plan map of 50 m Fraser filtered (n=1-4) dipole-dipole phase response in the Lar Bronce areas.*

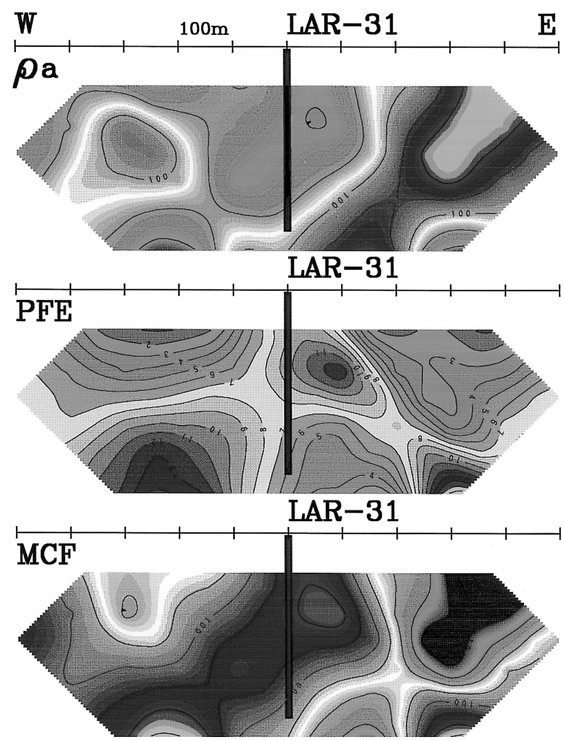

Figure 10: *Resistivity, phase, and MCF pseudo-sections of dipole-dipole Line 3900N using 100 m dipoles from n=1-6, and the South Pit discovery drill hole LD-31.*

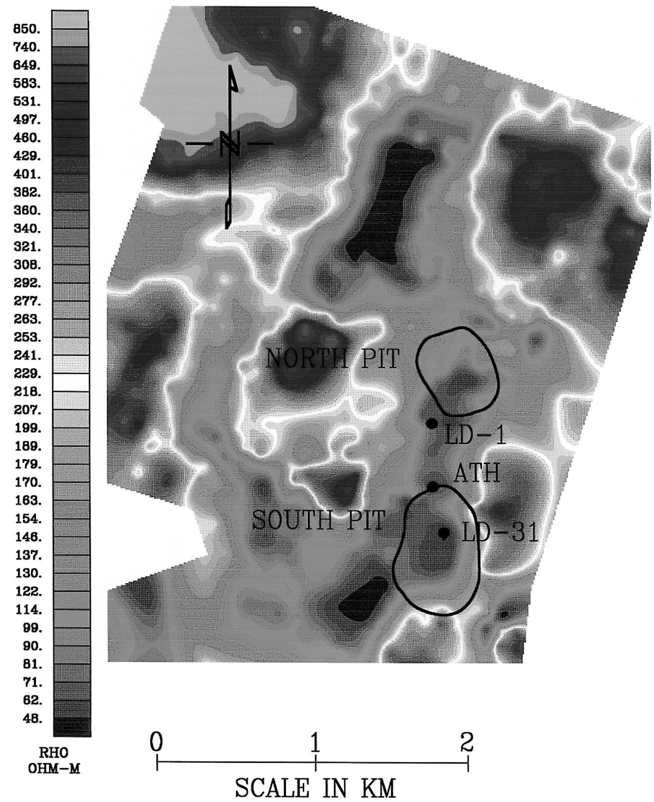

Figure 11: *Plan map of 100 m Fraser filtered (n=1-4) dipole-dipole apparent resistivity within the area surrounding the Candelaria deposit.*

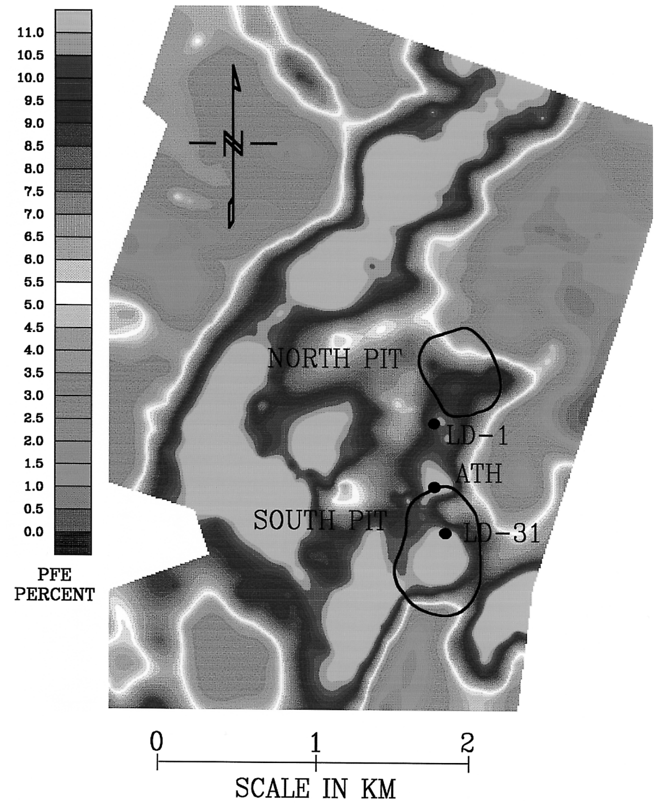

Figure 12: *Plan map of 100 m Fraser filtered (n=1-4) dipole-dipole IP response within the area surrounding the Candelaria deposit.*

north and south pits are probably due, at least in part, to the greater depth to mineralization in these topographically high areas.

When deep drilling commenced at Candelaria the necessity for determining the actual location of the drill holes at depth became quickly apparent. Based on the magnetic surveys and logged drill core, it was obvious that simple magnetic survey instruments would be incapable of accurately measuring the direction of drill hole deviation. A gyroscopic survey instrument was purchased and peripheral equipment designed and built to measure drill hole deviations. Since August 1988, over 300 drill holes have been surveyed using this instrument.

ADDITIONAL GEOPHYSICS SUBSEQUENT TO THE DISCOVERY

Electrical and electromagnetic methods

In the ten years since the discovery of Candelaria a number of technological improvements in geophysical exploration methodology and interpretation have been developed and implemented. The Candelaria deposit was found using IP resistivity combined with geology, and little else except perseverance. In today's high technology terms the exploration was pretty much seat-of-the-pants, but it was successful. IP interpretation was done in the same manner as had been done for the last three decades, with the exception that we had the benefit of a considerable amount of modeling carried out over the intervening years. The effects of topography were basically ignored. Today we have interactive two and three dimensional inversion modeling programs to help explain observed data. Topographic effects which can be substantial, particularly with resistivity, are accounted for with the most recent programs. Figure 7 shows model results for Line 700N, 100 m dipoles, using the Zonge 2-D topographic inversion program.

Reconnaissance induced polarization surveys in the search for porphyry type deposits have seen a rebirth since the Candelaria discovery. One of the preferred methods takes advantage of the technique pioneered by the Kennecott exploration group in the early 1970s, i.e., RIP (reconnaissance IP), VIP, (vector IP), or Wagon Wheel IP, as it is most commonly called. This system in its basic form consists of a large transmitting bipole (Tx) and two roving orthogonal (generally) receiving dipoles to measure IP response and resistivity. Transmitting bipoles are on the order of 1.5 km, while receiving dipoles are generally 100–200 m. Readings are taken approximately every 30° about the transmitting dipole at a distance of one Tx dipole away from the center of the array.

Because of the difficulty and often excessive time spent in electrode preparation in the Chilean type environment (very high contact resistance), several modifications to the basic procedure have been made. These mainly consist of making additional measurements on each Tx bipole. Readings are taken where accessibility permits and often out to

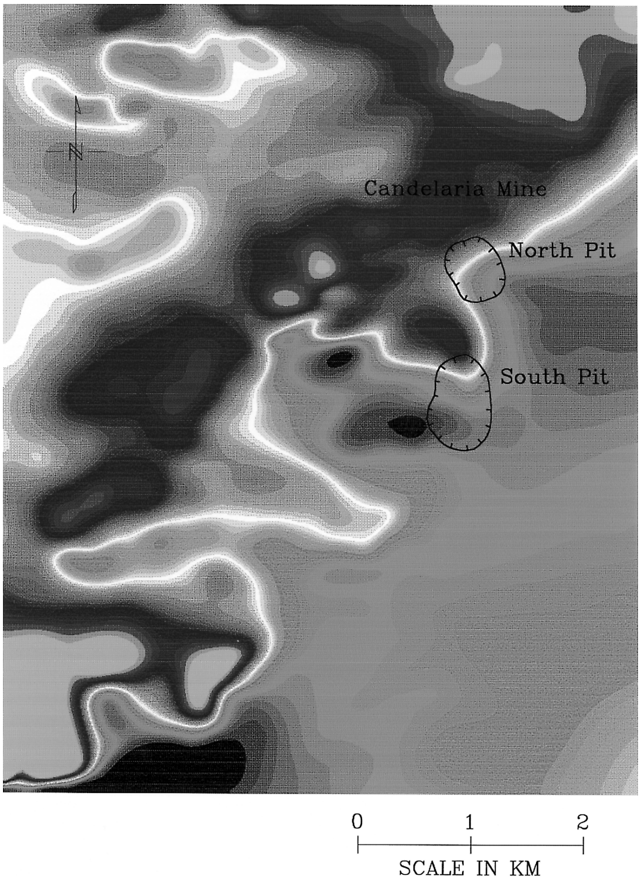

Figure 13: *Total field airborne magnetics in the vicinity of the Candelaria deposit.*

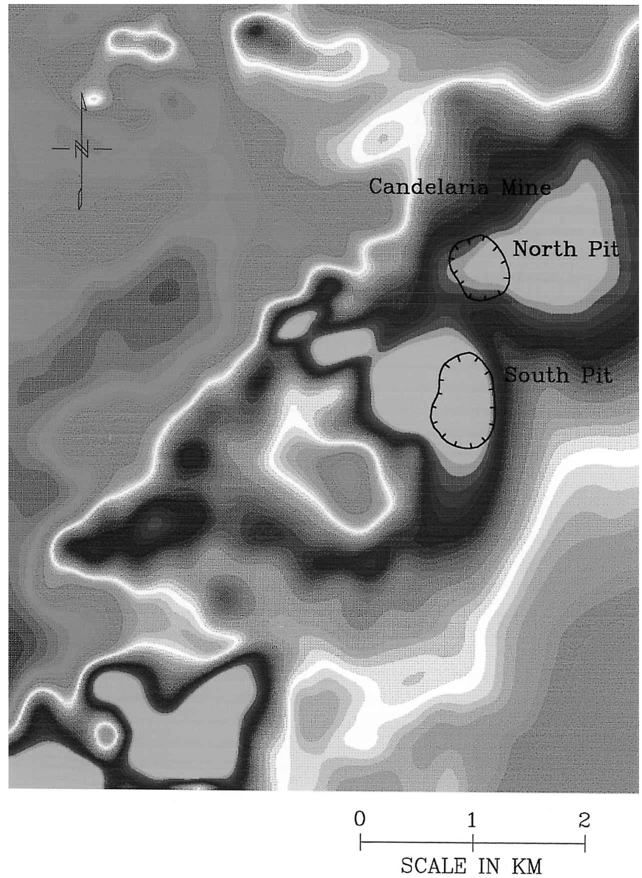

Figure 14: *Reduced to the pole airborne magnetics in the vicinity of the Candelaria deposit.*

one and one-half bipoles or more from the center of the array. The ability to obtain readings further from the center of the array has been made possible by more powerful transmitters and sophisticated receivers which take advantage of better sensitivity and filtering. Positioning is usually accomplished using global positioning system (GPS) equipment.

To help in resolving multiple targets the use of tensor measurements are sometimes utilized (Bibby and Hohmann, 1994; Zonge *et al.*, 1994). This requires the addition of a second transmitting bipole, and of course double the number of readings at each station. While the increase in reading time is minimal, placement of a second bipole can be quite time consuming. When looking for porphyry size targets on a reconnaissance basis, tensor measurements may not be necessary or justified. For detail work, particularly on smaller targets it may be helpful. At that point, however, it may be more efficient to utilize a different array.

There are two considerations which must be kept in mind when using RIP. The first is the often large electromagnetic coupling effects, both positive and negative, inherent with low resistivity ground when using large arrays. This is further complicated with variable separation distances. In most cases this is handled adequately through the use of so-called three point, or more complex, decoupling routines (Zonge, 1975). The second concern is the inability to obtain detailed subsurface information at the measurement point. A major step forward in obtaining this information has been made possible by taking co-incident loop time-domain electromagnetic (TEM) soundings at each measurement station (Zonge *et al.*, 1994). With the resulting sounding, a depth versus resistivity picture of the subsurface is realized. Depending on station density, one can produce individual smooth model sounding curves and/or plan maps of the resistivity at various depths.

Both TEM and controlled-source audiomagnetotelluric (CSAMT) surveys have been tried in the Chilean environment. One of the main purposes for utilizing these techniques is to solve, or more correctly, eliminate problems of introducing sufficient current into the ground to produce an acceptable voltage at the receiver. While TEM uses a loop to generate the necessary magnetic field, CSAMT has generally used a grounded dipole. Again in an attempt to avoid the problems of galvanic contact, CSAMT has been carried out using a loop source. Active pots have largely eliminated the difficulties of extremely high input impedance encountered in these environments. Both techniques have been useful in delineating mineralization, particularly at depth. More testing is needed in this environment to fully evaluate the potential of both methods.

Magnetic and radiometric methods

Ground magnetic surveys were conducted following initial drilling and thus played no part in the discovery of the Candelaria deposit. However, these surveys did suggest that the deposit was spatially associated with large concentrations of magnetic material (mainly magnetite), and that airborne magnetic surveys would contribute positively to any regional exploration program.

Although several airborne surveys had been flown within the region, most were relatively low sensitivity, apparently with the main objective of outlining iron occurrences. These were almost all flown east-west, probably in an attempt to better define structural features which are predominately oriented north-south. It was felt that a high sensitivity survey flown in a generally north-south direction would yield results which would be much more useful in the current exploration program. One of the first high sensitivity, regional airborne magnetic survey was flown over the Candelaria deposit in 1988. It was flown using visual navigation with flight path recorded on video camera. This was recovered on photographs and finally on 1:25 000 and 1:50 000 scale topographic maps. Flight lines were oriented north-south with a spacing of 300 m and a nominal terrain clearance of 150 m. Both terrain clearance, which was of necessity *modified drape*, and positioning, were less than might be desired but were sufficient for the needs anticipated, especially when considering survey cost.

A *spec* survey by World Geoscience in 1993, was flown and positioned entirely using GPS technology. As one would expect, survey quality was considerably improved. However, basic information gained by the second survey was essentially the same as that acquired in our 1988 survey. No new targets were generated as a result of the more recent survey although target discrimination and evaluation of existing targets was improved. Known magnetite related deposits in the district were identified by both surveys, and in fact one previously unknown deposit which is now under development, was located as a result of the first survey. It was confirmed that there was a positioning error on the first survey, but this was most likely due to discrepancies in available topographic maps. In terms of target detection, they were insignificant.

The total field at Candelaria is inclined at about -24.8° from the horizontal, assuming a positive inclination in the northern hemisphere. This results in a shift of the expected high at Candelaria and from other magnetic bodies. Candelaria is located on a major gradient in the total field (Figure 13). It is not until the total field data has been reduced to the pole that the relationship between magnetics and mineralization becomes readily apparent (Figure 14). Realizing that Candelaria is just a part of a multi billion tonne magnetite occurrence, the definition of the deposit after pole reduction is quite remarkable. Pole reduced maps are virtually a necessity in correlating magnetics with geology at these low magnetic latitudes. The use of such techniques as vertical derivatives, analytic signal and apparent percent magnetite concentration have also been helpful. Physical property measurements made on rock samples from the Candelaria area suggest show that susceptibility varies over a wide range and remanent magnetization may be an important component of many of the rock units.

As part of the more recent airborne survey, radiometric data was also collected. These data have shown that radiometrics can be a very useful exploration tool in determining areas of potassic alteration when it is outcropping or within 10–20 cm of the surface. Various ratioing techniques have been useful in mapping of various rock types. In the future, radiometrics will most likely become increasingly important in exploration, particularly in semi-arid and arid environments.

CONCLUSIONS

Although the Lar and Bronce mineralization were well known for a number of years, and in fact were being actively mined from time to time, the true areal distribution and depth extent of mineralization were not. IP was successful in helping to delineate a much larger area of mineralization than was previously known. The southwestern mineralized zone, i.e., the South Pit, on the southeast side of the Ojancos Valley, was totally unknown prior to the IP survey.

IP was successful at Candelaria for two reasons: 1) the surveys were laid out in the right place, based on known prospects, geology and outcropping mineralization, and 2) because the deposits consist in large part of stacked mantos. The decision to start the exploration program in the immediate area of Lar and Bronce was fundamental to the success of the program. The entire area surrounding Candelaria carries abundant sulphide mineralization, as shown by the induced polarization surveys. However, as widespread drilling has indicated, most of the area contains little metallization. If initial surveys had started in one of the outlying, but well-mineralized areas rather than in the geologically favorable Lar and Bronce areas, it is questionable whether drilling would have persisted sufficiently far to locate the Candelaria deposit. Obviously our IP surveys were unable to *see* mineralization at depths beyond a couple of hundred metres. However, stacked mantos, which often extend from near surface, allowed indirect detection of deeply mineralized zones. This made possible the use of relatively short dipole spacings giving greater data resolution and interpretability as well as minimizing logistical problems.

The exploration program was fortunate in that we started in the right location. If we had the airborne data when we started, and *if* we had applied what we now know, we could conceivably have focused our exploration in the right place based on geophysical information, as well geological input.

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