Discovery of the Cerro de Maimón South VHMS

Kate Hine
Mitre Geophysics
khine@mitregeophysics.com.au

Martin Jones
Chief Geologist, Perilya Ltd
Martin.jones@perilya.com.au

SUMMARY

The recent discovery of the world class Cerro de Maimón South deposit is an excellent example of a blind discovery at >350m depth by a dedicated and persistent exploration team. The discovery was made as a result of downhole EM follow up on a drill hole targeting a deep IP anomaly. Factors critical to the success included careful processing and reprocessing of the IP to yield a better model. Systematic drilling of all 8 of the best IP anomalies (not just the best two or three) and, most importantly, follow-up DHEM surveys to define whether there were any 'near miss' conductors.

Finally, the drilling of the DHEM plate model required not just one but three drill holes to locate the main mineralisation. The discovery hole intersection was >50m at 2-5% copper at 515m below surface. Subsequent DHEM guided extensional targeting. The integration of high-quality soil sampling data, analysis and careful geological interpretation provided confidence that a substantial deposit could potentially be discovered. Impediments to success were the narrow-mineralised copper lenses at the nearby Rio Sin prospect that drew focus away the wider area.

Drilling has currently defined a ~ 2.5km long and continuous southeast plunging massive sulphide deposit that extends from 350m to over 1km depth with potential extension of at least 500m to the southeast.

Key words: VHMS, DHEM, 3D IP, 60Hz, Pueblo Viejo, current channelling, Cerro de Maimón

INTRODUCTION

This paper is a case history of the exploration for, and discovery of a world class, blind, VMS deposit at 350m below surface (at its shallowest). The discovery of the Cerro de Maimón South deposit was a result of a systematic, but still carefully budgeted, geochemistry and geophysics led exploration program some 700m southeast of the existing Cerro de Maimón open pit. The discovery was made in 2016 and put into development in 2018 with production commencing in 2021. The Cerro de Maimón deposits are the only VMS deposits under production in the Caribbean and is the first underground metalliferous mine in the Dominican Republic.

In January 2011 Perilya (an Australian mining company) acquired 100% of the TSX-listed GlobeStar Mining Corporation ("Cormidom") which gave Perilya immediate access to their Dominican Republic exploration concessions and assets. The region is highly prospective for volcanic-hosted massive sulphides, porphyry, and epithermal deposits. Previous exploration, including an airborne electromagnetic (HeliGeotem) survey in 2007, had failed to outline targets. After acquiring the project, Perilya introduced a trace gold sampling program. This identified elongated zones of semi-continuous copper and gold anomalism over several areas. These data were integrated into the exploration model and, in 2013, chief geologist M. Jones engaged Mitre to design an exploration geophysics program over the best few of these geochemical anomalies. The subject of this paper is the work done and subsequent major discovery in an area called 'Cerro de Maimón South'.

Location and geology

Perilya's extensive Maimón concession group is in the Dominican Republic on the Island of Hispaniola in the central Caribbean. The island is composed of a tectonic collage of upper mantle rocks and oceanic crust units uplifted and accreted in the aftermath of the collision between the Caribbean island-arc and the Bahamas platform. Rock units are typical of oceanic crust and island arc assemblages, including ultramafics (mostly serpentinised peridotites), basalts, volcanics, volcaniclastics and sediments (Lewis and Draper, 1990).

The subject area is located about 75km northwest of the capital city Santo Domingo in the Monseñor Nouel Province. The geology primarily comprises the Maimón Formation, a 9km wide and 73km long NW-SE elongated belt of primitive, bimodal mafic-felsic volcanics and volcaniclastic rocks and a thin belt of well-laminated sedimentary rocks, altogether deformed and metamorphosed to variable grade (Lewis et al., 2000). It is part of the Early Cretaceous Caribbean volcanic island arc system (Draper, 1996) and hosts several small VMS deposits including Cerro de Maimón North (CDMN), Loma Pesada, and Loma Barbuito. Of these, CDMN was the most significant and was developed into a small, open cut mine with an initial sulphide resource of just under 5Mt at ~ 2.5% Cu, 1g/t Au, 35g/t Ag.

Notably, Barrick's giant Pueblo Viejo epithermal deposits are only 8km east-northeast of the survey area (Figure 1), but they are in the Los Ranchos formation rather than the Maimón Formation. Although Draper et al. (1996), indicated that the Maimón formation could represent the fore-arc equivalent of the Los Ranchos Formation.

The Cerro de Maimón South ("CDMS") survey area extended from the southern boundary of the CDMN open pit, 3km towards the southeast (location and geology shown in Figures 1 and 2). It was centred on the thrust faulted contact between the Maimón Formation (to the northeast) and Peralvillo Sur Formation (to the southwest), all of which are part of the Ozama shear zone. The southwestern edge of the survey area also extended onto the Loma Caribe peridotite, interpreted to be a dismembered ophiolite (Draper *et al.,* 1996). The most notable prospect in this area is the Rio Sin prospect. The region is tectonically very active; and as seen in Figure 1, strikes predominantly NW-SE.

The proximity to the CDMN mine means it is worth including some information on the nature of this deposit. According to Roos et al. (2007), CDMN is a tabular shaped VMS body composed of massive (>50%) and semi-massive 15-50%) sulphides, about ~1000m long by 300m depth extent, and located about 40-70m below the thrust faulted boundary between the Peralvillo Formation and the Maimón formation. The sulphide horizon dips moderately to the southwest, plunges at about 25° towards the southeast, and averages 10-15m thick.

The CDMN deposit was discovered within the Maimón Concession in 1978. It was initially owned by Falconbridge Dominicana (Roos *et al.*, 2007) and in 2002 was acquired by the GlobeStar Mining Corporation, who commenced open pit production in September 2008. Upon acquisition, Perilya was able to increase the mine life to 2020 and establish underground resources. CDMN started underground development and production in 2018.

Prior to mining, the body was essentially outcropping, but it had been weathered/gossanised down to about 30m below surface. The ore mineral assemblage (in order of decreasing abundance) consists of closely packed, rounded to angular grains of pyrite with interstitial chalcopyrite, chalcocite, bornite, sphalerite, galena, and tetrahedrite. Gangue minerals include quartz, sericite, and chlorite (Torró *et al*., 2018). Importantly from a geophysics perspective, surrounding the deposit in the footwall is a halo of disseminated pyrite.

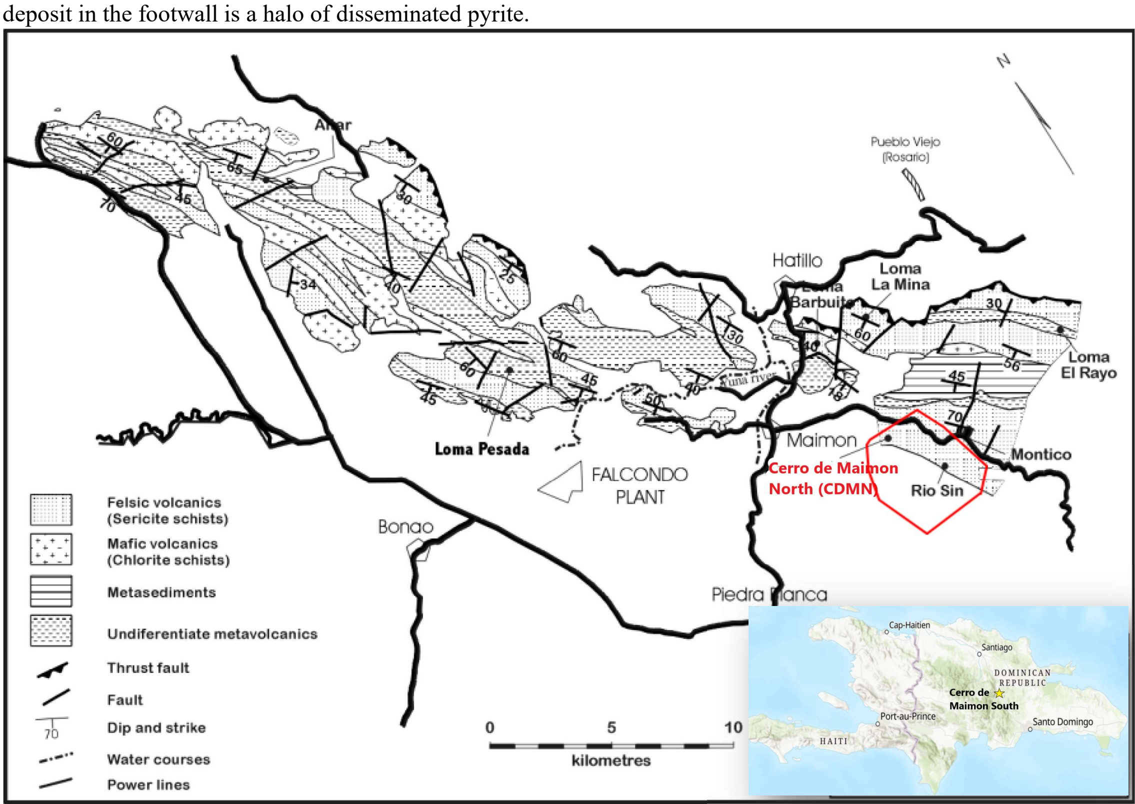

Figure 1. Regional geological map of the northern and central parts of the Maimón Formation, showing the Cretaceous volcanics of the Maimón Formation (Roos et al., 2007). The target area is outlined in red and includes the south-eastern extensions from CDMN and the Rio Sin prospect.

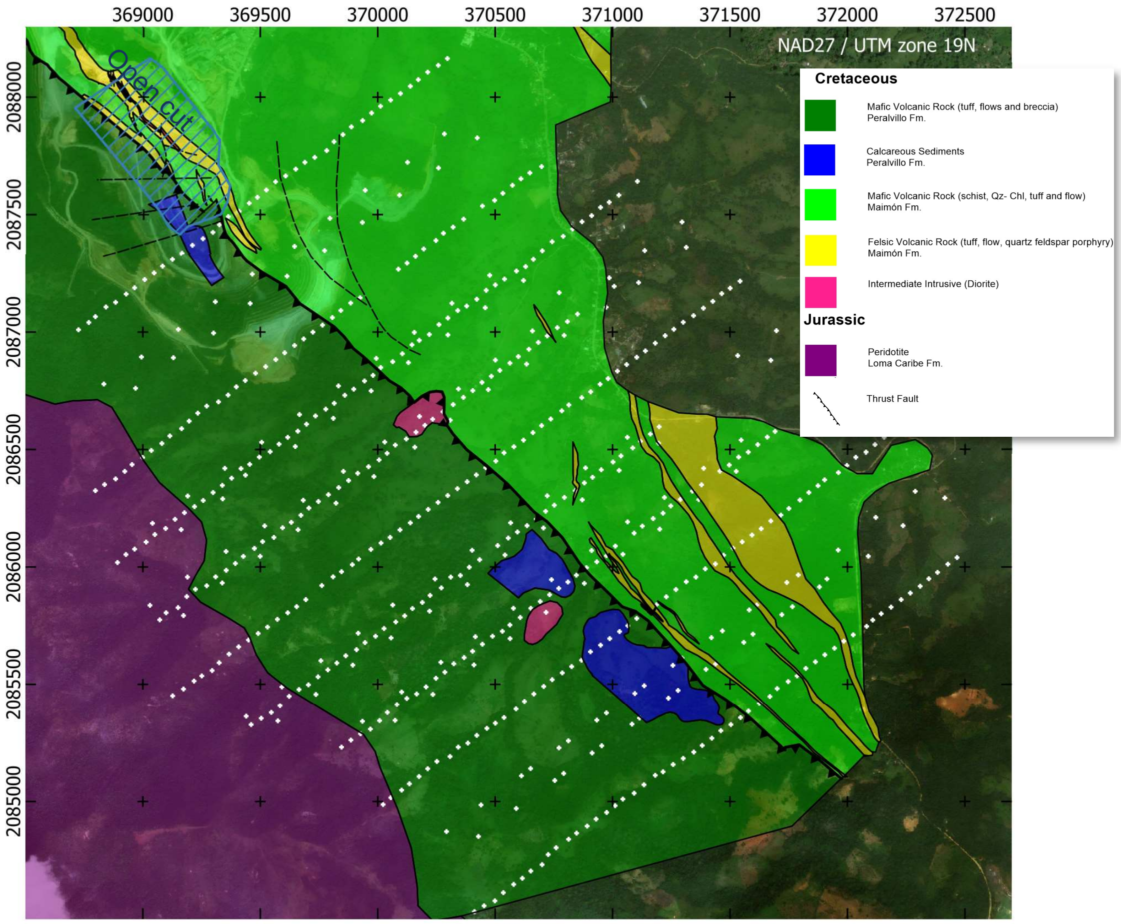

Figure 2. Geology map and station locations for the 2013 Rio Sin Phase 1 IP survey

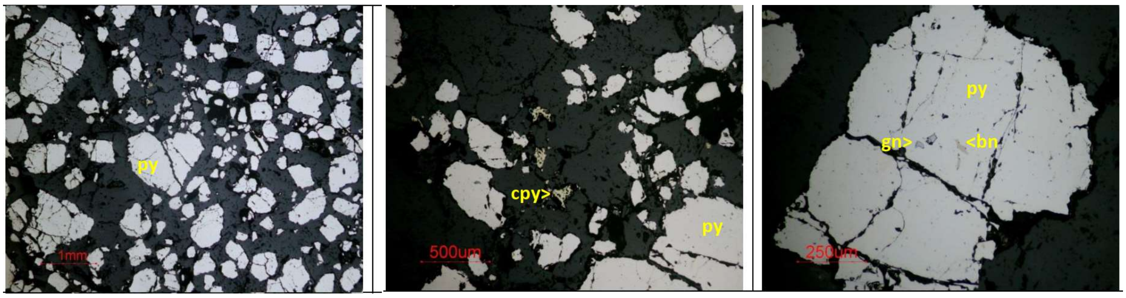

Figure 3. Examples of CDMS mineralisation on petrographic microscope using reflected light. The sample consists of individual pyrite crystals in a gangue (60% chlorite, sericite and quartz). Chalcopyrite and minor sphalerite are found in the gangue. Galena and bornite are minor phases lining vugs within the pyrite crystals (modified after Torró *et al.*, 2018).

Previous geophysics

The legacy data archives included Globestar's 2007 regional Fugro HeliGeotem survey and various small scale ground EM and IP surveys. These data were reprocessed and reviewed as part of preparation for the exploration program to ensure the most appropriate geophysical methods would be employed. The review showed that the known deposits are generally highly chargeable, moderately conductive, and essentially non-magnetic. Thus, IP was selected over surface EM because it seemed likely to have a greater depth of investigation for a wider range of possible targets, especially given the multiple powerlines and electric fences across the survey area which would likely impact EM methods more than IP.

Interestingly, CDMN itself was covered with both a magnetics and EM survey in 1973 (CDMN was discovered in 1978), but both reportedly failed to detect the deposit (Roos *et al.*, 2007). The former presumably because the mineralisation is basically non-magnetic, but it seems that EM data quality must have been an issue because, as the later HeliGeotem results showed, CDMN gives a strong EM response.

2013 Rio Sin Phase 1 and Phase 2 IP surveys

In 2013, an IP survey was acquired over the target area by SJ Geophysics, a Canadian contracting company owned by Syd Visser. This survey was one of four separate areas covered. The survey used SJ Geophysics' proprietary 'Volterra' 3DIP distributed acquisition system. This system was chosen because, being highly portable, compact, and flexible, it suited the challenging location, terrain, and climate. The crew also had a 'can do' attitude critical for difficult projects in remote areas.

The Rio Sin Phase 1 survey consisted of 11 survey lines of various lengths cut at 300m intervals. The survey used the GDD Tx II 3.6kW with local transmitter at intervals of 50m along the transmitter lines. The transmitter configuration requires some explanation, because it does not fall into any of the 'standard' categories. The current was transmitted between the local electrode and a variety of remotes located across the survey grid. Multiple remotes were recorded for each local position providing information not just along the survey line but between different lines. The location of various remotes and receiver electrodes are shown in Figure 4. However, in the interest of space, we have not included a complete table of which remotes were used for each location.

In a departure from 'standard' off set pole dipole survey, the receivers used a combination of in-line and across-line dipoles. For each potential set, recording units ('Dabtubes') were placed every 200m along the primary receiver line. Each receiver was then wired to electrodes offset 50m to the (local) north and south, creating two parallel 100m dipoles. Additional dipoles were also formed by bridging the gap between the two receiver lines, forming a diamond pattern of in-line and cross line dipoles (Figure 5). The aim of these was to add redundancy, and a little bit of 3D information, because the survey was plagued by wire breakage. Both the transmitting and receiving electrodes consisted of stainless-steel rods hammered into the ground.

The daily torrential downpours, mudslides, cows and lightning were a great challenge to acquisition. Soon after data acquisition commenced, it was discovered that the entire array needed to be picked up every afternoon to avoid severe damage overnight from cows and lightning.

Nearing completion, it was decided to infill the central area to better resolve some narrow near surface gossans. The Rio Sin Phase II grid consisted of 19 survey lines cut 100 m apart with stations flagged and marked every 50 m (Figure 4). Additional receiver stations were established at 100 m intervals, offset 50 m to both sides of the cut receiver lines. To speed up production and reduce costs, most of the second survey used the saw tooth array with 50m electrode spacing.

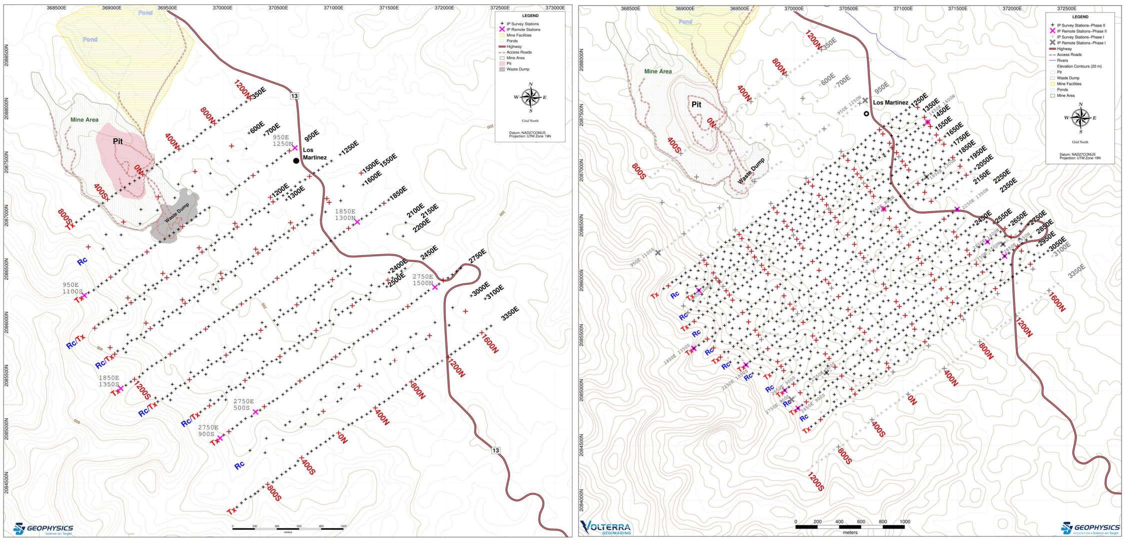

Figure 4. Survey layout for the Rio Sin Phase 1 and Rio Sin Phase 2 surveys.

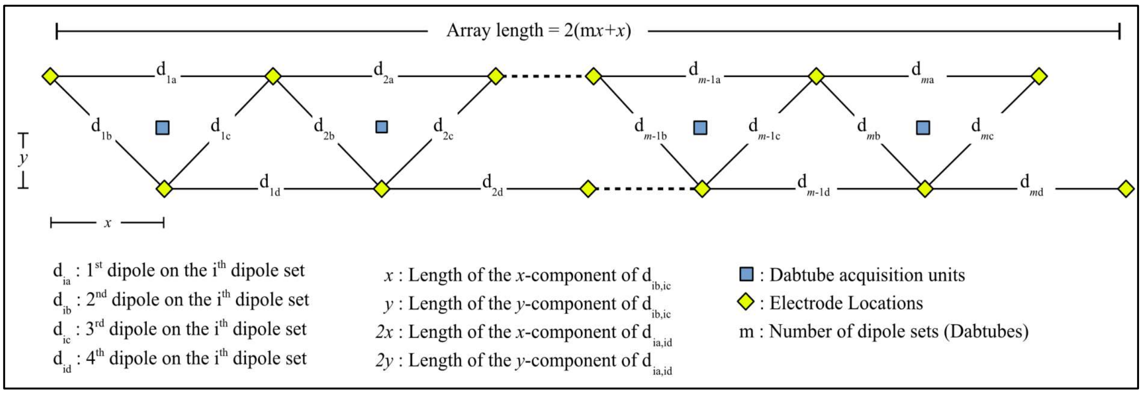

Figure 5. Diamond receiver electrode array used at the Rio Sin Phase 1 grid. Transmitter locations not shown.

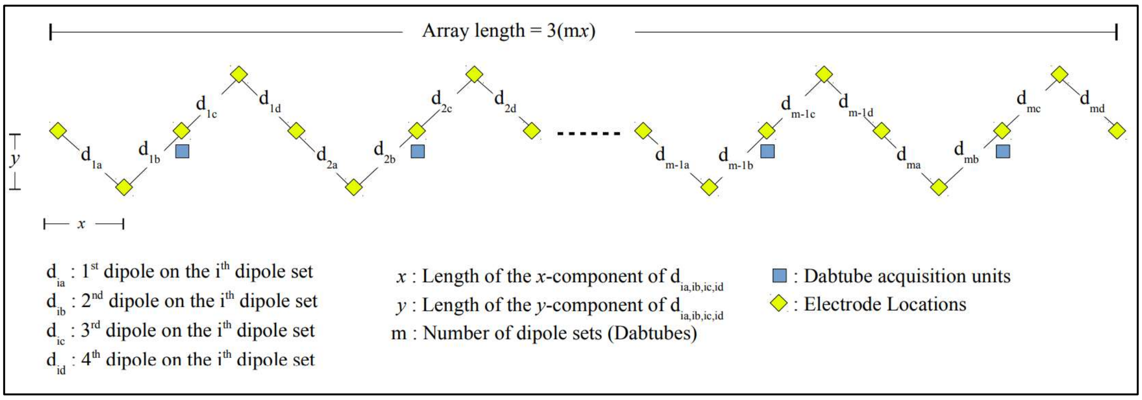

Figure 6. Sawtooth receiver electrode array used at the Rio Sin Phase 2 grid. Transmitter locations not shown.

IP Data processing

The data quality was, not surprisingly, only fair to moderate. Fortunately, given the low-power transmitter, ground contact resistance was generally good. As a result of this and the mostly weakly conductive sub-surface, the measured potential (Vp) was valid. Data from near the powerlines and township showed significant background noise. The main challenge regarding the data quality was the wire damage from cows. Data attrition was consequently relatively high, but the redundancy from the extra dipoles somewhat alleviated this problem.

IP Modelling

Unfortunately, in the intervening years, much of the detail of exactly how the models were run has been lost. Following is our best recollection of the steps taken. The original IP data (after filtering to remove obvious bad data, a process that removed about 30% of the readings) were inverse modelled by SJ Geophysics using the UBC IP/res code. The resultant models showed very large inconsistencies between the Phase 1 and Phase 2 models, and very high overall error levels (30-40%). In their processing report, SJ Geophysics attributed the discrepancies to anisotropy generating conflicting data between neighbouring dipoles (Thibauld, 2014). These issues were never satisfactorily resolved.

The initial inversion models were clearly unreliable, so a special processing and modelling project was set up to test different approaches and thereby improve model confidence. The data were reprocessed to keep only the very best of the Rio Sin Phase 1 and Phase 2 data and remodelled. Models were run using only phase 1 or phase 2 data, and with merged data, and varying the various starting parameters, such as reference models, chi-factor, error levels, etc. By comparing the resultant suite of models, we were able to gain better insight into which features were robust and which less so.

IP model targets and drill results

The final chargeability and resistivity models showed various moderate anomalies but nothing 'stood out'. Seven of the most robust anomalies were selected for drilling. In 2014 these were systematically tested with 8 drill holes ranging from 350m to 717m depth (Figure 7). The five deepest targets, Deep A, B, C, D and E were all >17msec chargeability anomalies with associated low resistivities. Of these, Deep E was the deepest and required a 717m hole to be effectively tested.

In each case, excepting Deep C, significant widths of disseminated pyrite were intersected sufficient to explain the IP response. The results at Deep C were attributed to a bad model, since, unlike the other targets, the anomaly was only present in one of the chargeability models. These discouraging results would, in most scenarios, have ended the exploration program. Instead, the company appreciated that these anomalies might be 'clouds' of disseminated sulphides enveloping massive sulphide lenses and agreed to follow Mitre's recommendation of DHEM.

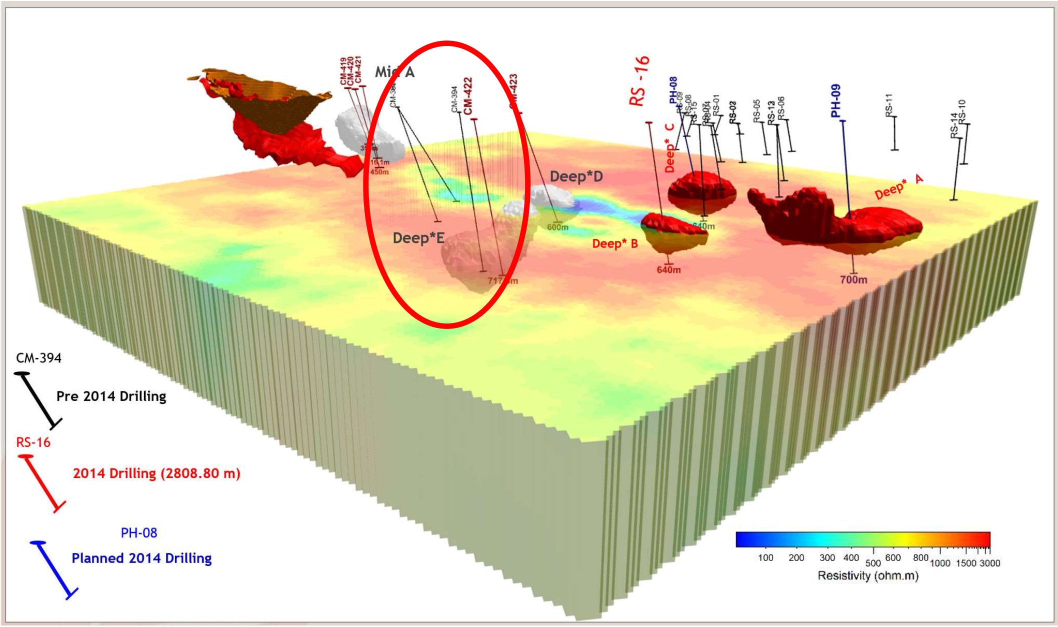

Figure 7. 3D perspective from the south showing the target chargeability anomalies (red and grey isosurfaces, all >15msec) and 3D resistivity model (clipped to show below -300mRL). Total metres drilled: 2809m.

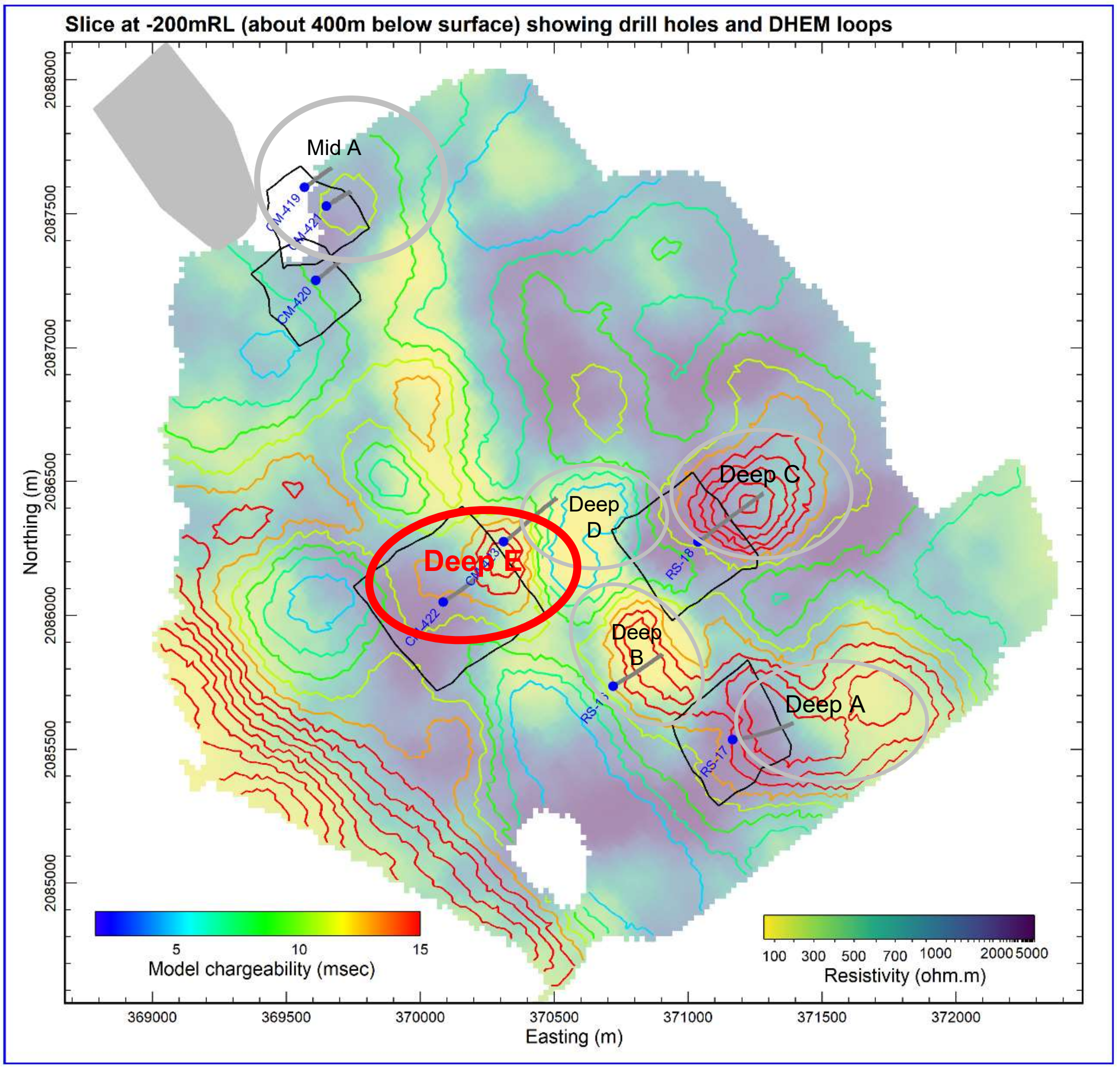

Figure 8. Depth slice though resistivity and chargeability models at -200mRL, chargeability displayed as 2msec contours and resistivity as the background image, showing the targets selected for drilling and resultant drill holes and DHEM loops.

2015 DHEM SURVEY

When Canadian company Crone Geophysics and their PEM system arrived on site the crew soon discovered all the holes were blocked with fine sediments even though the holes had been cased with PVC when each drill hole was completed. Fortunately, pumping water down the PVC casing cleared out enough mud that some holes could be partially surveyed, including CM-422 which had tested the deepest IP anomaly 'Deep E'.

The DHEM survey of CM-422 used a 500x500m collar loop and the hole was surveyed with a 5Hz base frequency and 20A in the loop. The hole's total length was 717m, but a blockage prevented the probe going deeper than 480m.

DHEM Results

Most of the holes showed a flat EM response, except for CM-422 which recorded a somewhat vague response from a possible distant conductor. This manifested as a steady increase in amplitude down the hole (Figure 9). The shape of the anomaly suggested the presence of a large conductor at a significant distance beyond the end of the survey but, because the hole was blocked at 480m, this anomaly was poorly defined. A tentative model was a distant, 400m strike length x 400m depth extent, steeply southwest dipping, 150S conductance, plate conductor with depth to top >350m. It appeared that CM-422 had intersected the conductor near the end of the hole (though, without the full profile, this was not clear), but the drill log recorded only low metal values, to a maximum of 0.2% Cu and 0.4% Zn (see Figure 9).

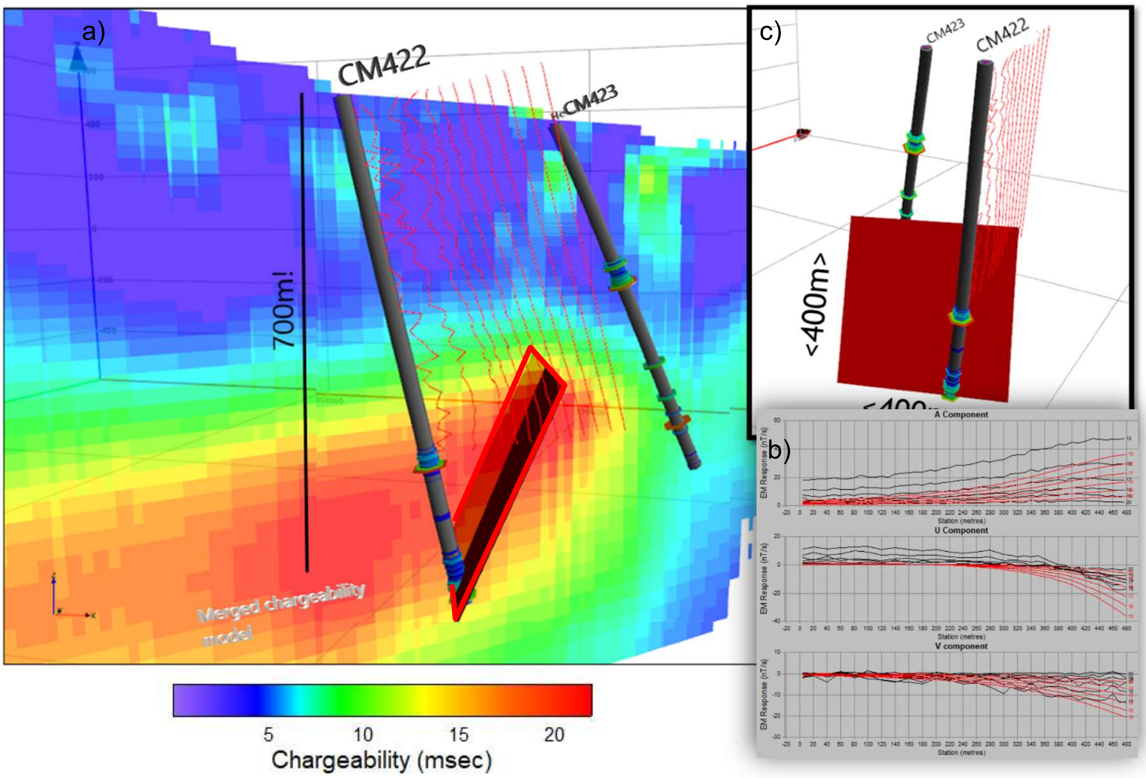

Figure 9. a) CM-422 was targeted on a chargeability high at over 400m below surface and drilled to 717m. (b) the DHEM survey shows gradually increasing response with depth, but the hole was blocked at 480m, so the profile was incomplete. c) Modelling of this incomplete anomaly indicated a large (400x400m) 150 Siemen conductor above the drill hole, dipping steeply toward the west. Note that, because the survey stopped at 480m, this conductor was nearly 200m away from the DHEM sensor.

2016: THE DISCOVERY OF CERRO DE MAIMÔN SOUTH

Since CM-422 had putatively 'tested' the DHEM model many exploration geologists would have walked away. Nearby drill holes had previously produced poor results and corporate fatigue meant that only one more drill hole could be drilled. Fortunately, the exploration team understood the ambiguity inherent in the DHEM, and that a single *apparent* intercept at the bottom edge of the plate was not a sufficient test. Thus, as the very last hole to be drilled in the drilling program, CM-428 was designed to test the middle of the conductor (as shown in Figures 10 and 11). Attempts to drill CM-428 were frustrated by difficult drilling conditions and operator error led to the hole collapsing and it was abandoned prior to reaching the target. As a second 'stroke of luck', the contractor, at their own cost, redrilled the hole (CM-428A) and this hole successfully intercepted the target producing 5.5m @ 2.0% Cu, 3.00 g/t Au from 571m. Note that this hole deviated deeper than expected and tested the lower third of the plate model.

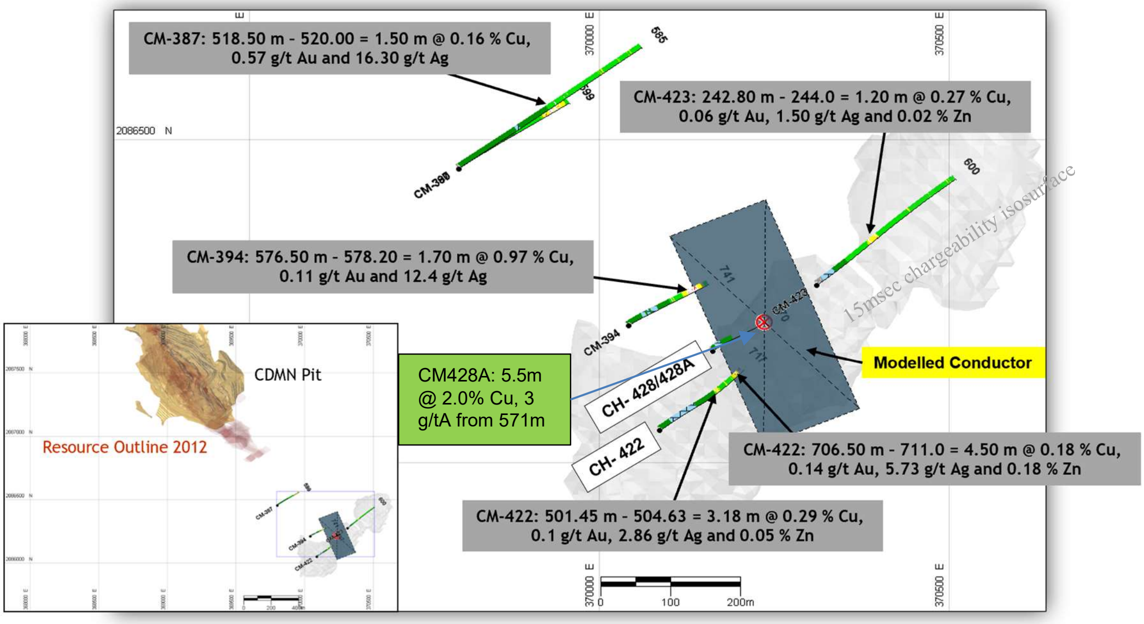

Figure 10. Contemporaneous figure from a corporate presentation showing a plan view of the modelled conductor produced from CM-422, with drill results and position of CM-428/428A that tested this target. The DHEM model was poorly constrained and CM-422 had *apparently* intersected the very lower edge of it. As a demonstration of the limitations of EM modelling, the subsequent results showed that the CM422 actually passes below the main ore zone because the DHEM model over estimated depth extent and underestimated strike length. Beware of over-confidence in models!

The next drill hole CM-429, which passed through the centre of the plate model, intersected 53.4m at 1.5% Cu, 1.7% Zn, 0.8g/t Au, and 31.6 g/t Ag at 515m downhole. This included several higher-grade intervals such as

- 5.4m at 2.5% Cu, 2.44% Zn, 1 g/t Au, 68g/t Ag from 515.45m
- 8m at 2.3% Cu, 4.2% Zn, 0.8 g/t Au, 32 g/t Ag from 532m
- 3.5m at 5.9% Cu, 4.8% Zn, 3.8g/t Au, 78 g/t Ag from 545.8m
- 7.1m at 2% Cu, 2% Zn, 0.8 g/t Au, 62.8 g/t Ag from 567.7m

Figure 12 shows that DHEM has proven an excellent tool in defining and extending the resource. It is currently over 2.5km long and approaches a depth of 1km at its current southern limits. The published resource (2018) is >15Mt and the underground operation has a mine life to at least 2037 (Miningdataonline.com, 2022). Drilling campaigns since then have extended the CDMS deposit producing further resource growth. Underground development for both CDMN and CDMS commenced in 2018 with production from CDMS commencing in 2021. DHEM and soil geochemistry demonstrate that the resources could potentially extend southeast for at least another 500m.

Interestingly, the DHEM has also shown that the ore has a strong 60Hz AC electric field that generate signals up to 20nT(!) in boreholes that penetrate the ore. The source is hypothesised to be current channelling from the local powerline which may be using the earth as the earth-return wire, similar to the single-wire earth return systems in Australia. This current channelling is a result of the long strike length of the deposit.

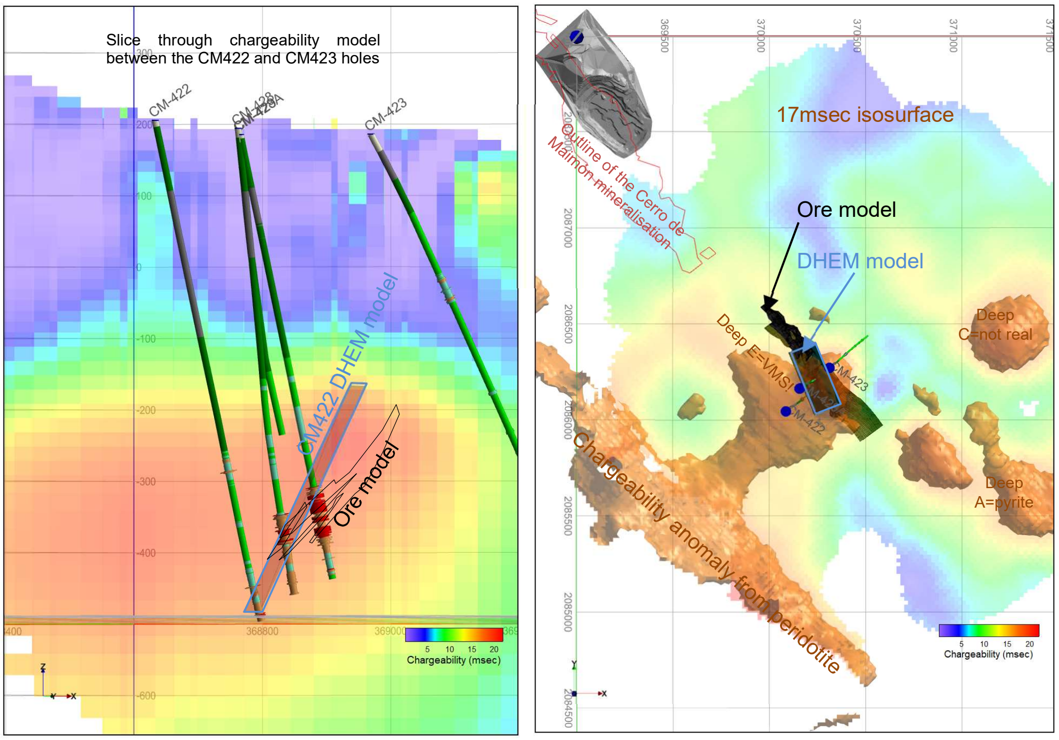

Figure 11. Section through one of the IP models at the location of CM-422 and depth slice at -250mRL through the same model. Also shown is the plate model (outlined in blue), preliminary ore model (black) and 17msec chargeability isosurface. Note that the IP anomaly is much broader that the sulphide zone due to the disseminated pyrite halo. This halo was the target of CM-422: the 'central' massive sulphides were close enough to be detected by the DHEM because of the large size, planar geometry and relatively high conductance.

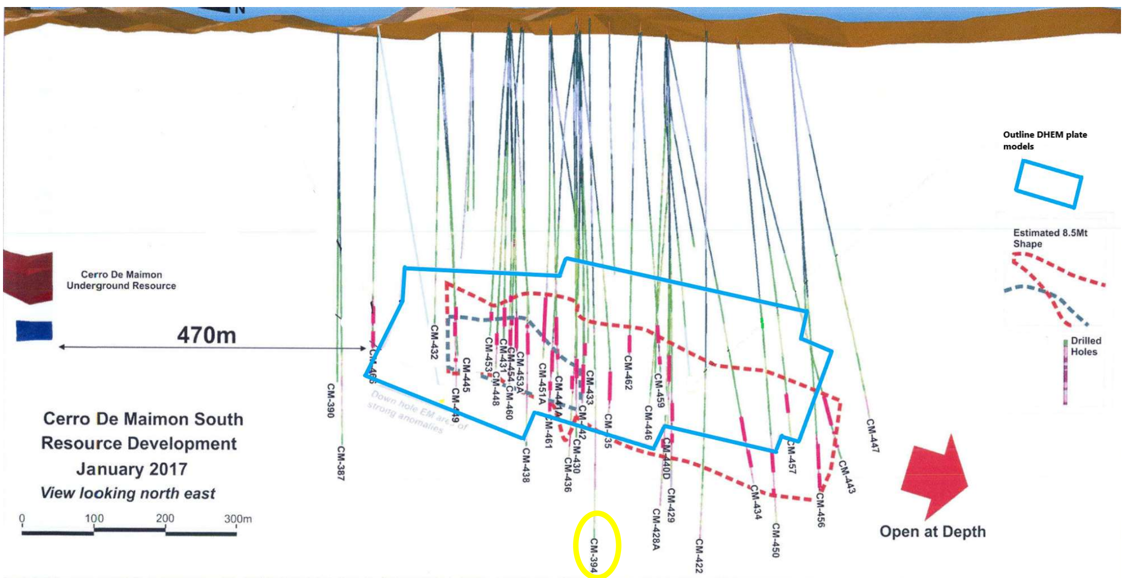

Figure 12. Long section comparing the preliminary ore model (as of 2017) for Cerro de Maimón South and DHEM plates generated from the DHEM surveys during the resource drill out. There is generally a good correlation, though the paucity of DHEM from the southeast end (right) limits the accuracy of the DHEM models in this area. The figure was modified from the 2017 corporate presentation about the discovery (available at Minedocs.com). Note that if hole CM-394 (circled in yellow, drilled before the discovery was made) had been surveyed with DHEM the ore zone could have been discovered much earlier.

Deposit description

The subsequent drilling has showed that the CDMS massive sulphide deposit is located along the southern margin of the Maimón Formation, about 150m below the thrust-faulted contact with the Peralvillo Formation. The deposit consists of massive to semi-massive sulphide lenses which collectively can extend up to 60 m thickness, from 350m to 1km below surface. At the north-western end the sulphide horizons dips 60° to the southwest (which is steeper than CDMN), and at the south-eastern end they dip about 35° to the southwest. The horizons plunge at 18° to the southeast. The deposit is hosted by the hydrothermally altered metavolcanic assemblage of the Maimón Formation. At 350m below surface it hasn't been exposed to oxidation or other associated secondary mineral processes (in contrast to CDMN). The CDMS deposit currently has dimensions of 2,500 meters (NW-SE) long by 200 meters wide with an average true-width thickness of 40m. It is open down-plunge.

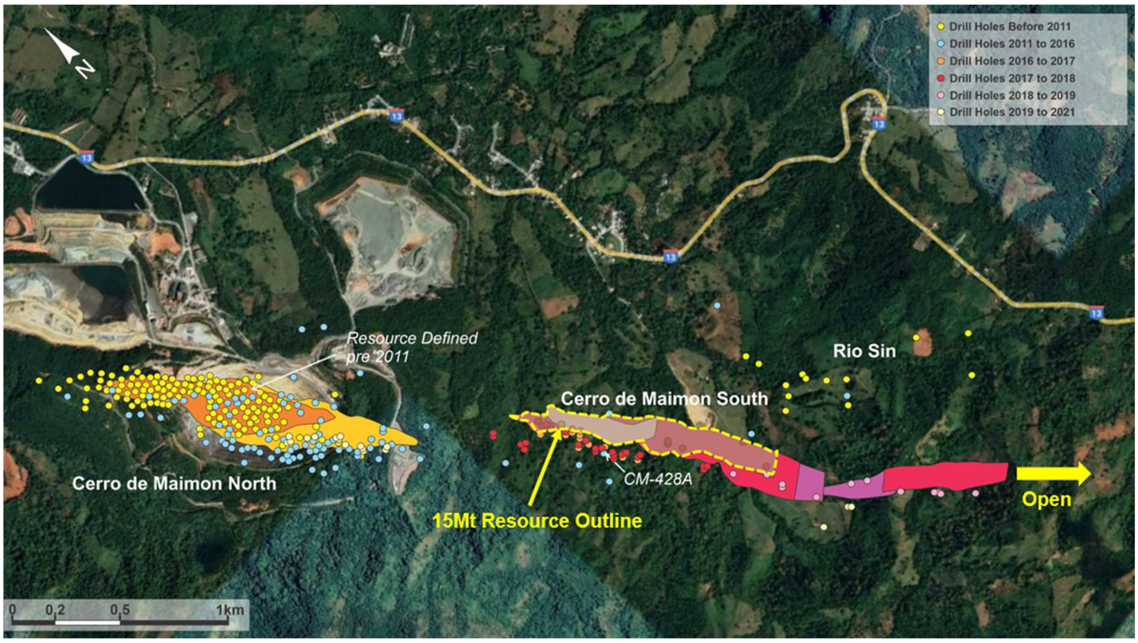

Figure 13. Map view showing location of Cerro de Maimón North and Cerro de Maimón South on the aerial photo. Drill holes are coloured according to year. Note that, prior to the discovery, the narrow widths of copper intersected at Rio Sin had attracted most of the exploration efforts.

DISCUSSION

The success can, in the greatest part, be attributed to the fact that the Perilya's exploration team had good knowledge of how to integrate geophysics, geochemistry and geology into exploration targeting. Mitre contributed our knowledge of what type of geophysics might be suitable for a given application, at what stage it should be considered (not too late, not too early), what it could/could not map, geophysical processing/modelling, and the nature of geophysical uncertainty and ambiguity. The last of these is particularly important because it enabled the exploration team to push for thorough testing of all the IP anomalies with DHEM even after the IP drill results had proved so disappointing.

There were also several other factors in the success. First was reprocessing the IP data. The 'Deep E' anomaly was not present in any of the initial models, and only revealed itself as a robust target after the data had been carefully filtered, re-modelled, and then modelled some more. This is partly a result of the data quality, but good data quality is exceedingly difficult here. Just completing the survey was a significant achievement. Secondly, the DHEM response was quite indistinct because of the great distance to the source (it was nearly 200m away from the nearest DHEM survey station), and this meant the resultant model was poorly constrained which, in turn meant that drilling a good test hole was both more important and riskier. Thus, persistence was key. The first hole collapsed and the second showed only moderate mineralisation. It was only the third hole, that went through the middle of the model conductor, that truly highlighted the potential tonnage

At 400m below surface, the 2007 HeliGeotem survey did not detect the mineralisation, despite its large size, relatively high conductance (time constant about 8-15msec) and lack of conductive overburden. This is not surprising to any geophysicist familiar with early-generation helicopter borne EM data but might be a surprise to many non-geophysicists. In other words, not all geophysical methods are created equal. Modern FLEM detects the mineralisation, but the high voltage powerline lines generate exceedingly high noise levels in these data which means it is hard to recognise a response without prior knowledge of where to look. It is worthwhile mentioning again that CDMS could have been discovered in 2012: CM-394 goes close enough that if DHEM had been used, it should have detected it. However, at that time, downhole geophysics was not routinely employed and, in hindsight, too much attention was given to the narrow weak copper intercepts at the Rio Sin prospect.

CONCLUSIONS

This discovery, at over 350m below surface for the initial ore zone, starkly illustrates the importance of downhole geophysics, particularly when following up diffuse targets. The success can be attributed to four factors. Firstly, the exploration team understood the different roles of geology, geochemistry and geophysics in 'cutting down the search volume' and thus were able to winnow a 56km prospective trend down to just a few primary targets. Secondly, they did not just test one or two of the geophysical anomalies, and then get discouraged by 'just pyrite', but systematically drilled all of them. Thirdly, they persisted with the DHEM on those holes even though none of them had intersected significant metal. Finally, and most importantly, they made sure to test not just the edges of the DHEM target but the centre, and thus showed that it had significant thickness and metal content.

The world class CDMS deposit now extends to over 2,500m in length and is still open to the southeast.

ACKNOWLEDGMENTS

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