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A UTEM3 Case History at Neves Corvo, Portugal

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Introduction

The Neves Corvo deposit is located in the Iberian Pyrite Belt in southern Portugal (see Figure 1). This spectacular cluster of polymetallic sulphide deposits was discovered in 1977 with an estimated total reserves of about 200 million tons of massive sulphide and stockwork ores. More exploration work in the early 1990s resulted in the identification of two sulphide zones that were added to the cluster. The zones all lie at depths of 250 to 500m within a sequence of volcanic and sedimentary rocks that dip at shallow angles.

The Neves Corvo deposit has been generally considered a difficult geophysical target except for gravimetry (which was the method of discovery). This is mainly because of the large depths involved, the lack of useful magnetic properties, and the presence of conductive layers above the sulphide zones. As a result of these characteristics, the Neves-Corvo deposits have proven to be an interesting test area for many geophysical methods.

Figure 1: Neves Corvo location map.

The History of Exploration in the Neves Corvo Area

Exploration in the Neves Corvo area began in pre-Roman times and has continued to the present day. A gravimetric anomaly was drilled in 1973 to a depth of 250m and found no mineralization but the hole was deepened in 1977 and at 350m the drill entered a 53m thick intersection of massive sulphides. After this discovery, more drilling was completed delineating four zones (each tens of metres thick) of sulphide mineralization: Neves, Corvo, Graca, and Zambujal. Each is interconnected by thinner sulphide horizons and stockworks.

The Geology of the Neves Corvo Orebody

The main sulphide minerals are pyrite, chalcopyrite, sphalerite, and galena, with some cassiterite. The cluster of deposits generally dips to the North at an angle of less than 30^{o} and drill intersections range from 350 to 600m. The Neves Corvo deposits themselves are interbedded in a thick sequence of acid volcanics, tuffites, black shales, and beds of greywackes, siliceous shales, jaspers and limestones.

Past Geophysical Work and Borehole Petrophysical Surveys

The massive mineralization appears to have a high electrical conductivity compared with the moderate conductivity of the surrounding rocks. There were also three other zones of low resistivity above the massive sulphides, corresponding with a shear zone at a depth of 190m and some pyritized shales at a depth of 280m.

The sulphide mineralization saturates the instrument with indicated conductivity at least six times higher than that of the black shales (which lie above the main mineralization zone). The conductance is expected to be at least sixty times that of any of the shale zones since the sulphide mineralization is also ten times thicker than the anomalies on the shales.

Detecting the mineralization at Neves Corvo is difficult because it has the following characteristics:

- •there are no pyrrhotite nor any other magnetic minerals in the sulphides of the deposits
- •the target bodies are at an appreciable depth: i.e. At 250m depth in their shallowest part
- •there are unrelated nuisance conductors such as carbonaceous/graphitic shales and disseminated sulphides near the target and often above it

The UTEM3 Surface Test Survey

The UTEM3 surface test survey over the Neves Corvo massive sulphide deposit in Portugal was completed in July of 1991 by Lamontagne Geophysics. The plan view (Figure 2) shows the transmitter loops of the two survey lines which were each 2.5km long. The two test lines were separated by 275m and surveyed with loops on both the updip (Loop 31) and downdip (Loop 32) sides of the undeveloped Neves massive sulphide deposit and of the deeper Lombador deposit. The dashed line contours are isopach lines with a 10m contour interval and the continuous line is the outline of the deposits (as of 1991).

The survey lines were thus situated directly over the Neves and Lombador deposits and roughly 500m from the mine installations. On each of the two lines, the vertical component (Hz) of the magnetic field was measured at 50m spacings. Survey time, including loop layout and retrieval and wire loop repairs, totalled four days.

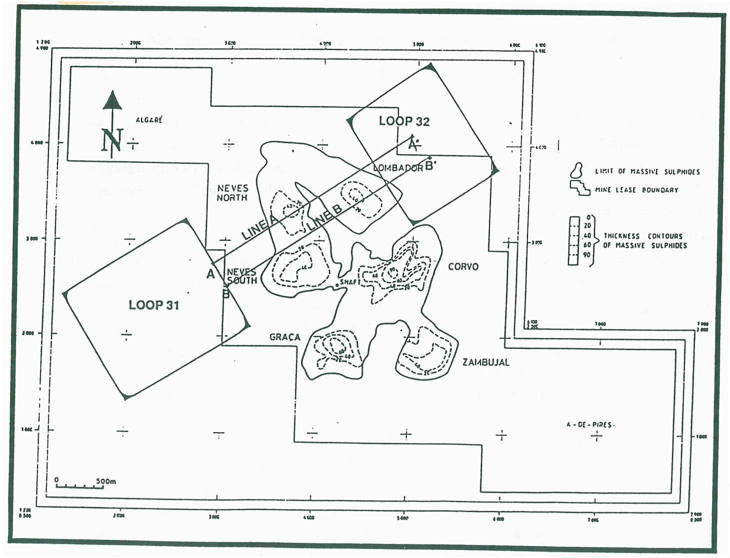


Figure 2: Neves Corvo Loop location map, showing Loop 31, Loop 32, survey line A and survey line B.

The UTEM3 profiles of lines A and B from both the southwest and the northeast loops are shown in Figures 3 and 4. A few data profiles from other loops in the area without the anomalous response have been included in Figure 5 in order to show what the background response alone would look like.

Because of the shallow dip to the northeast, the best responses were obtained using Loop 31, situated to the southwest of the deposit with its loop front located at 1250S. The lines were surveyed with this loop up to 2.5km from the loop front. Figure 3 displays the data of lines A and B from which the powerline responses have been stripped.

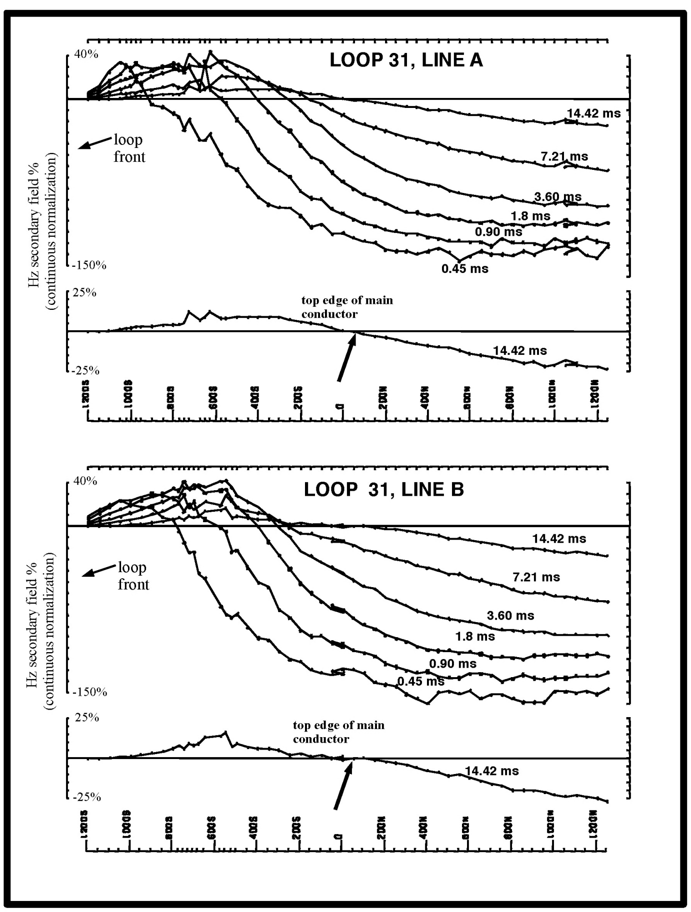


Figure 3: UTEM3 profiles from Loop 31 (powerline response removed). Ch. 1-6 are plotted on the top axis and Ch. 1 is plotted on the bottom axis.

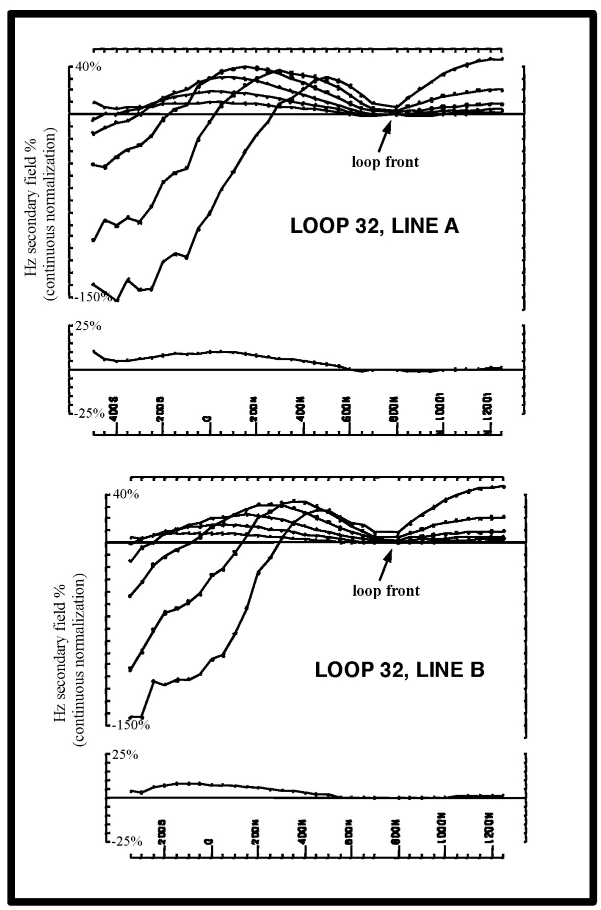


Figure 4: UTEM3 profiles from Loop 32.

The response of the deposits is a broad prominent negative anomaly developing from about 500S that may be seen in the latest time channel (Ch. 1). It is easily discernible in spite of the two power lines that cross the lines: PL A and PL B, which both produce sharp anomalies characteristic of long cultural conductors. The stripping of the PL responses was done using a least-squares fitting routine (Polzer and Miura, 1990) to fit and strip away the power line anomalies. It is obvious that the deposits produce a large, long (15-25ms) decay response which can be seen quite clearly in Channel 1, the latest channel. Some migration in the cross-over can be seen which may be due at least in part to the effect of PL B.

The responses on lines A and B (275m apart) are virtually identical, indicating that the conductor has a strike length much greater than the line spacing. The powerline anomalies, n the other hand, are displaced between lines. A large conductor size is inferred from the large anomaly amplitudes and widths.

The data from lines A and B of Loop 32 are presented in Figure 19 (see below). The south wire of the loop was located above the deep art of the Lombador deposit to avoid null coupling, and the lines were stopped short of the power lines because of the increasing noise level and survey time constraints. The positive response observed is qualitatively the response expected from a deposit located deep under the survey line and dipping under the loop. The migrating early channel crossovers indicate that the rocks overlying the deposit have low resistivities, particularly at shallow depths. The migration on the later channels may be due to the expanding eddy currents in the sulphide horizon.

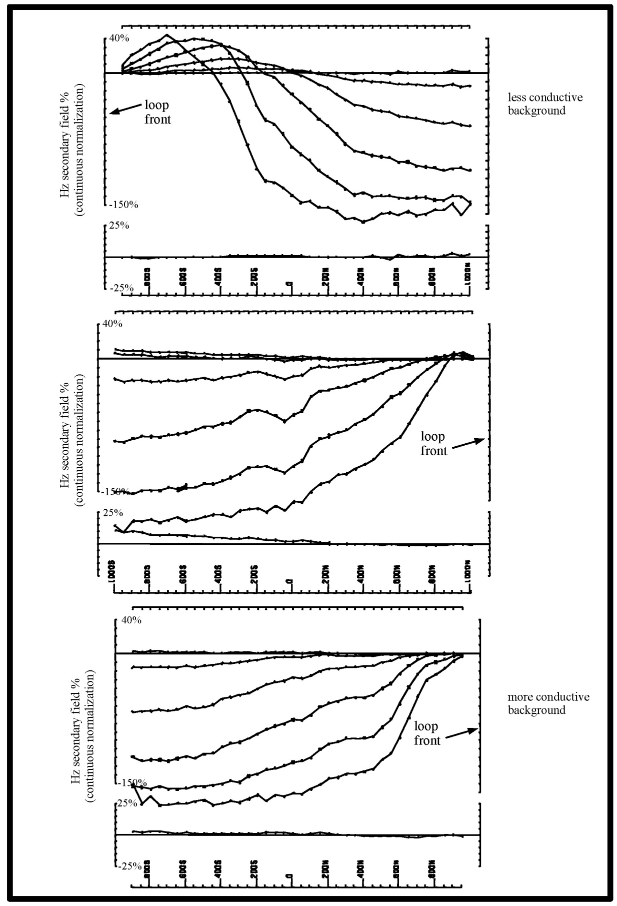
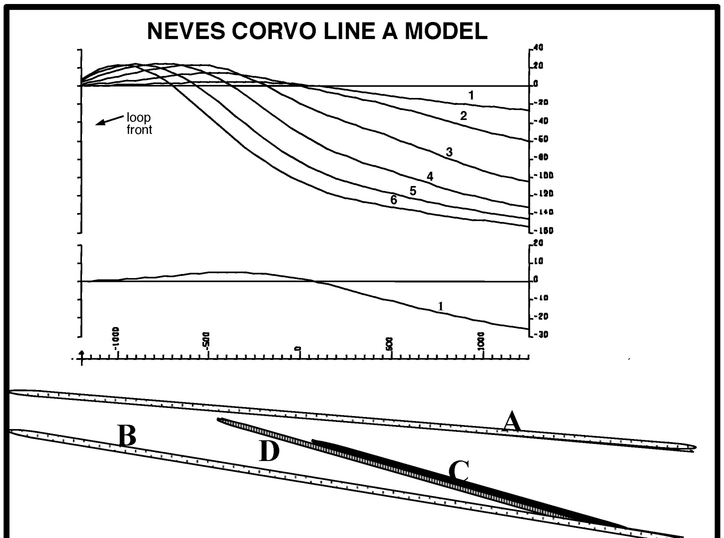


Figure 5: Background EM responses in the Neves Corvo region.

Modelling

The main parameters of the conductive structure which could cause the distinct Channel 1 anomaly observed from the Loop 31 survey were determined with the assistance of the MultiLoop modelling software. This software can model the response of conductive tabular bodies and overburden with multiple rectangular plates. A wide range of models were used in our attempts to obtain a response that closely matches the field data and to determine the outer limits of the parameters describing the conductors. The arrangement of plates that best fit the response shown for both loops include two large sheets (conductors A and B) centred under the loop, with conductance of 1.5 and 5 Siemens (S) respectively, and simulate the response of the layered conductive cover. The massive sulphides and the sulphide horizon that bridges the deposits are best modelled by the addition of conductors C and D with conductance of 125 S and 65 S respectively. The details of the parameters describing the conductors, the chosen model and its calculated response may be observed in Figure 6. The parameters of the overburden and the orebody seem to agree very well with the information from the geological section. Conductor B is likely not representative of any real tabular conductor, but is used with conductor A t render the overburden and host response.



Conductor Parameters

A:	conductive cover layer dip = 5 degrees conductance = 1.5 siemens strike extent = 8000m dip extent = 8000m	**C:**	location = 60N depth = 450m dip = 16 degrees conductance = 125 siemens strike extent = 800m dip extent = 1800m
B:	conductive cover layer dip = 9 degrees conductance = 5 siemens strike extent = 8000m dip extent = 8000m	**D:**	location = 450 S depth = 320m dip = 16 degrees conductance = 65 siemens strike extent = 1100m dip extent = 2100m

Figure 6: MultiLoop model of Neves Corvo Line A.

Discussion of UTEM3 Results

The response measured with the southwest loop would have been considered exceptional in any routine coverage, and that measured with the northeast loop would have called for followup work using additional loops located to the southwest.

The UTEM3 survey was considered very successful because it managed to detect the massive sulphides as a very clear, broad response with a 15-25ms time constant in spite of two major power lines that crossed the lines in the area of the target. Not only were there no difficulties with the depth of the target or the presence of other, shallower conductors, but the UTEM3 data and MultiLoop modelling also provided generally accurate information about the characteristics of the conductor and the conductive layers above it.

It is estimated that a deposit such as Neves Corvo would be detectable to much greater depths in this environment, or at a similar depth in a more conductive environment. The most characteristic feature for direct detection of these deep massive sulphides is a clear, strong negative response on late channels. On any suspected long decay response, the survey geometry should be adjusted in follow-up work to promote such a response.

Conclusions

The surveys at Neves Corvo have demonstrated that an exploration target like this can be a very difficult one for most geophysical techniques. While gravimetric data has proven to be very useful, it is essential that a complementary survey using the conductivity contrast between the massive sulphides and the host rocks be utilized as well, in order to discriminate between the gravity anomalies and to search beyond the depth range of gravimetric measurements.

Magnetic surveys have not successfully detected this exploration target. UTEM3 appeared able to provide reasonable depth and conductance estimates as well as giving accurate lateral locations of the orebody. The UTEM3 survey did not have difficulty with the depth of the target, nor the presence of conductive layers above the target. The UTEM3 data, together with modelling, provided accurate estimates of the dip, depth extent and strike extent of the orebody.

These results show that the UTEM system can be a useful tool for both detection and evaluation of large conductive deposits at depth in the Pyrite Belt environment.

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