Geophysics for Sediment Hosted Copper and Gold Mineralisation, The Role of 3DIP

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SUMMARY

Sediment hosted copper mineralisation involves redox precipitation of copper sulphides where oxidised basinal fluids interact with in situ organic material or migrated hydrocarbons. This is a common process in sedimentary basins so it is important to find fast and cost-efficient methods for their exploration. Airborne magnetic/ electromagnetic and ground gravity and electrical resistivity-induced polarisation (IP) methods are commonly used to explore for these types of deposits. The application of IP methods can be utilised as a direct targeting tool in the sediment hosted environment.

Multichannel receivers, large transmitters, improvements in processing capacity has led to more confidence in inversion results and the recent popularity of the 3D IP technique. Examples of the application of large 3D IP surveys for sediment hosted copper deposits from Zambia and Alaska show that high grade copper mineralisation is associated with an IP response. Sedimentary textures associated with mineralisation compromise the inductive conductivity and resistivity response (anisotropy). An integrated exploration approach using geology, geochemistry and geophysics helps alleviate pursuing responses from digenetic pyrite, graphitic shales and specular haematite.

Key words: copper, IP, sediment-hosted, Alaska, Zambia

INTRODUCTION

Sediment hosted copper mineralisation involves redox precipitation of copper sulphides where oxidised basinal fluids interact with in situ organic material or migrated hydrocarbons. This is a common process in sedimentary basins so it is important to find fast and cost-efficient methods for their exploration. Airborne magnetic/ electromagnetic and ground gravity and electrical resistivity-induced polarisation (IP) methods are commonly used to explore for these types of deposits. The application of IP methods can be utilised as a direct targeting tool in the sediment hosted environment.

Double-offset Pole-Dipole Induced Polarisation (PDIP) was acquired over and adjacent to the Chimiwungo Deposit at Barrick Gold's Lumwana Copper Mine in north western Zambia. Lumwana produced 271 million pounds of copper in 2016, with proven and probable copper reserves of 207.6 million tonnes at 0.586% Cu at the end of 2016 (Barrick Gold Corporation, 2017). IP was acquired over a strike length of 6km and defined known mineralisation and targets in adjacent areas of sparse drilling.

Terra Resources Pty Ltd commissioned a double-offset PDIP survey over Coventry Resources Ltd's Caribou Dome Copper Project area in Alaska. Nine lenses of sediment-hosted copper mineralisation were outlined in surface mapping. Economic grades and thicknesses of mineralisation have been intersected over the entire 800m of strike drill-tested to date. IP has now been acquired over 7km of strike and defined known mineralisation and targets that have recently been proven to be mineralised.

ZAMBIA

The Lumwana Copper Mine is hosted within Proterozoic basement of the Mwombezhi Dome of the Domes Region, adjacent to the Central African Copperbelt. The Mwombezhi Dome is comprised of gneisses, schists and granites. Copper mineralisation at Chimiwungo is hosted by the Ore Schist, a metamorphosed, poly deformed, intensely mylonitised and then recrystallised kyanite, muscovite, phlogopite, quartz schist. Sulphides are disseminated and dominated by chalcopyrite and bornite, with carrollite also present. The hanging wall is comprised of gneiss while the footwall is comprised schists and gneiss.

An IP survey was undertaken in 2011 and 2012. A total of twenty blocks of double-offset PDIP were surveyed. Each block was 400m in width and approximately 2.5km in length and consisted of receiver electrode lines located 200m either side of a central current injection line (Figure 1). Current and receiver electrode spacing was 100m. Current injection lines were located 400m apart, allowing for each receiver line to be read from two adjacent current injection lines. A common receiver electrode was used, allowing for the derivation of 100m, 200m and 400m dipole spacing responses. Data was acquired at 0.125Hz in time-domain.

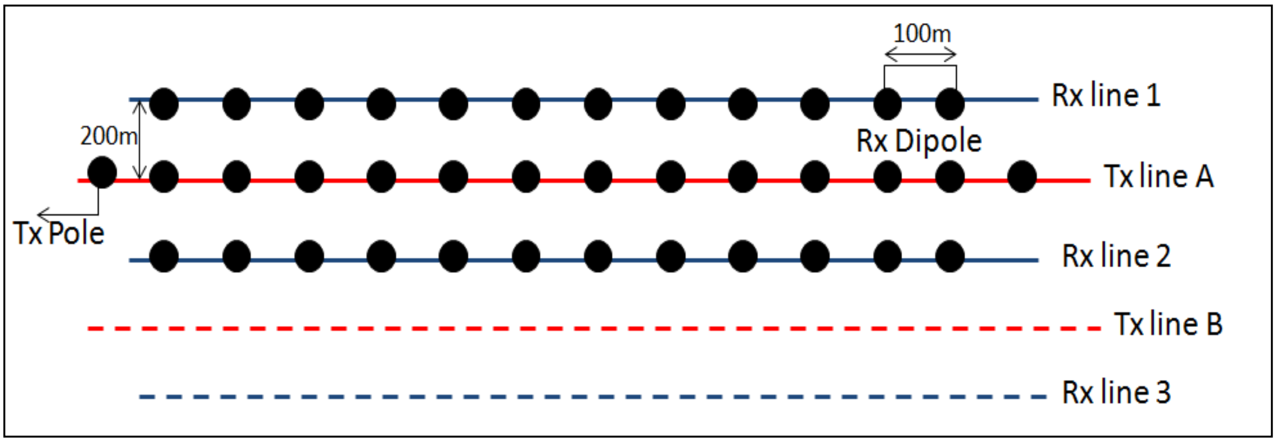

Figure 1: Schematic diagram of double-offset PDIP survey setup.

Processing involved: 1) correcting for transmitter and receiver station locations; 2) checking input currents and voltage potentials; 3) reviewing measured resistivity and chargeability values. Poor data (based on repeatability and decay) were removed before being averaged into Newmont Standard time windows (450-1100ms) to perform 3D modelling. The large amount of data redundancy allowed for the removal of poor data without any effect of the quality of the modelling results. Numerous 2D and 3D models were undertaken order to choose the most optimal parameterization in terms of the following: 1) Resistivity % error and error floor; 2) IP % error and error floor; 3) Cell/mesh definitions; 4) Length/Alpha scale: 5) Regularisation mode and Chi-factor and; 6) Number of iterations. Modelling was undertaken on three overlapping blocks due to the large size of the survey.

Analysis of petrophysical data from drill core at Lumwana shows that ore schist is associated with chargeability greater then 16msec while chargeability less than 10msec is dominantly hanging/footwall gneiss, Figure 2. Chargeability between 10 and 16msec can be due to either ore schist or hanging/footwall.

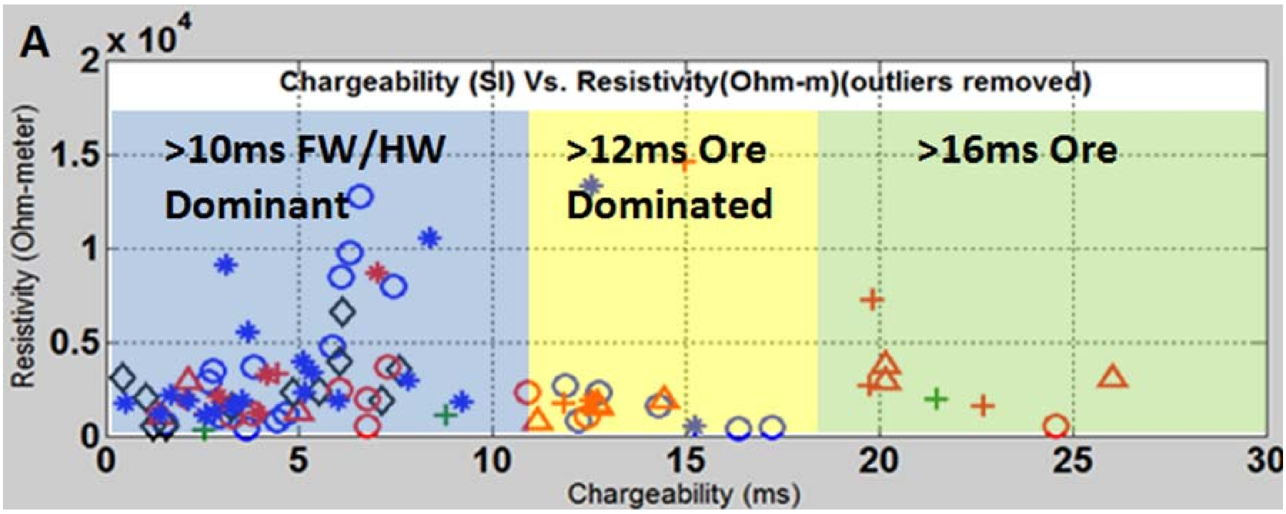

Figure 2: Chargeability and resistivity data from Chimiwungo Copper Deposit.

To the east of Chimiwungo a high chargeability trend occurs in an area of very little drilling, in close proximity to the active mining area (Figure 3). The resistivity data proved useful for mapping major lithology and structure.

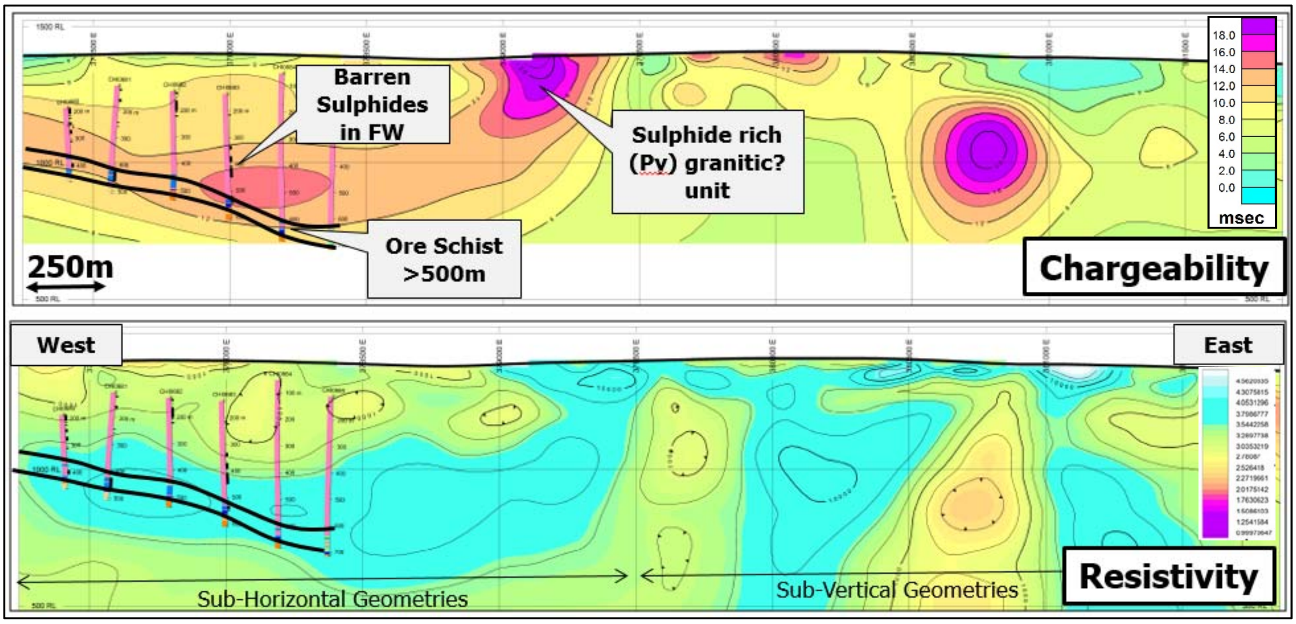

Figure 3: Chimiwungo resistivity model with chargeability section from 3D IP survey

ALASKA

The Caribou Dome Project is located on the transition zone between a belt of volcanic rocks and a sequence of sedimentary rocks. The volcanic belt consists of andesites and associated pyroclastic rocks. The sedimentary rocks include argillite, blue-grey and black limestone, and tuffaceous sediments (Roberts and Stevens, 2015). Roberts and Stevens (2015) describe the Caribou Dome stratiform sulphide deposits being formed in a marine basin where abundant organic matter and sulphate reducing bacteria created a strongly reducing environment. Copper derived by weathering of the nearby copper-rich volcanic rocks entered the basin and chalcopyrite precipitated as the sulphide ion was produced by the sulphate reducing bacteria.

A double-offset Pole-Dipole Induced Polarisation (PDIP) survey was completed in 2016. The survey comprised a total of 96 lines (157 line km) acquired in 34 blocks over approximately 2.5 months. Each block comprised of current injection sites on the same and adjacent lines to receiver array on 100m dipole spacing with 200m between lines of receiver electrodes (Figure 4). Some current injection sites were off-end from the potential electrode line to achieve greater depth investigation. All data was acquired at 0.125 Hz in time-domain.

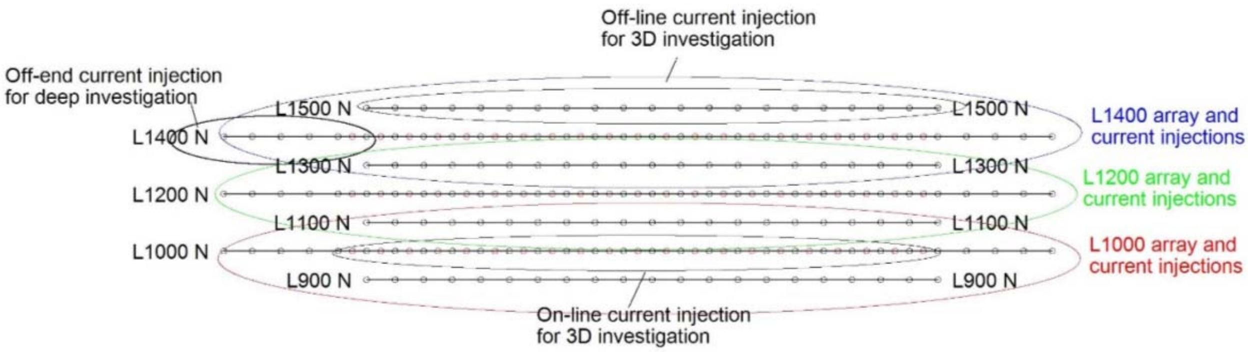

Figure 4: Illustration showing IP surveys lines and transmitter and receiver station locations.

Processing followed the same process as for the Zambian survey. Due to the nature of the survey, several repeats and sufficient data redundancy, the removal of poor data had minimal effect on the overall modelling results. Due to the size of the survey a 3D model was completed over two large areas with 400m overlap so that the two modelled results were consistent with one another and could be merged together.

Several potential targets were identified based on the following characteristics: 1) chargeability and resistivity response; 2) proximity to known zones of mineralisation; 3) trending nature and; 4) copper content seen in soil sampling. These targets can be seen in Figure 5. Most known mineralisation is associated with a high chargeability (between 10ms to 30ms) and is within a moderately to high resistivity zone. Overall chargeability response appears to correlate well with known locations of mineralisation and occur within anomalous copper zone seen in soil geochemistry. Highest-priority IP anomalies are located at or near the contact between the magnetic volcanic sequence of rocks and the non-magnetic sedimentary sequence of rocks.

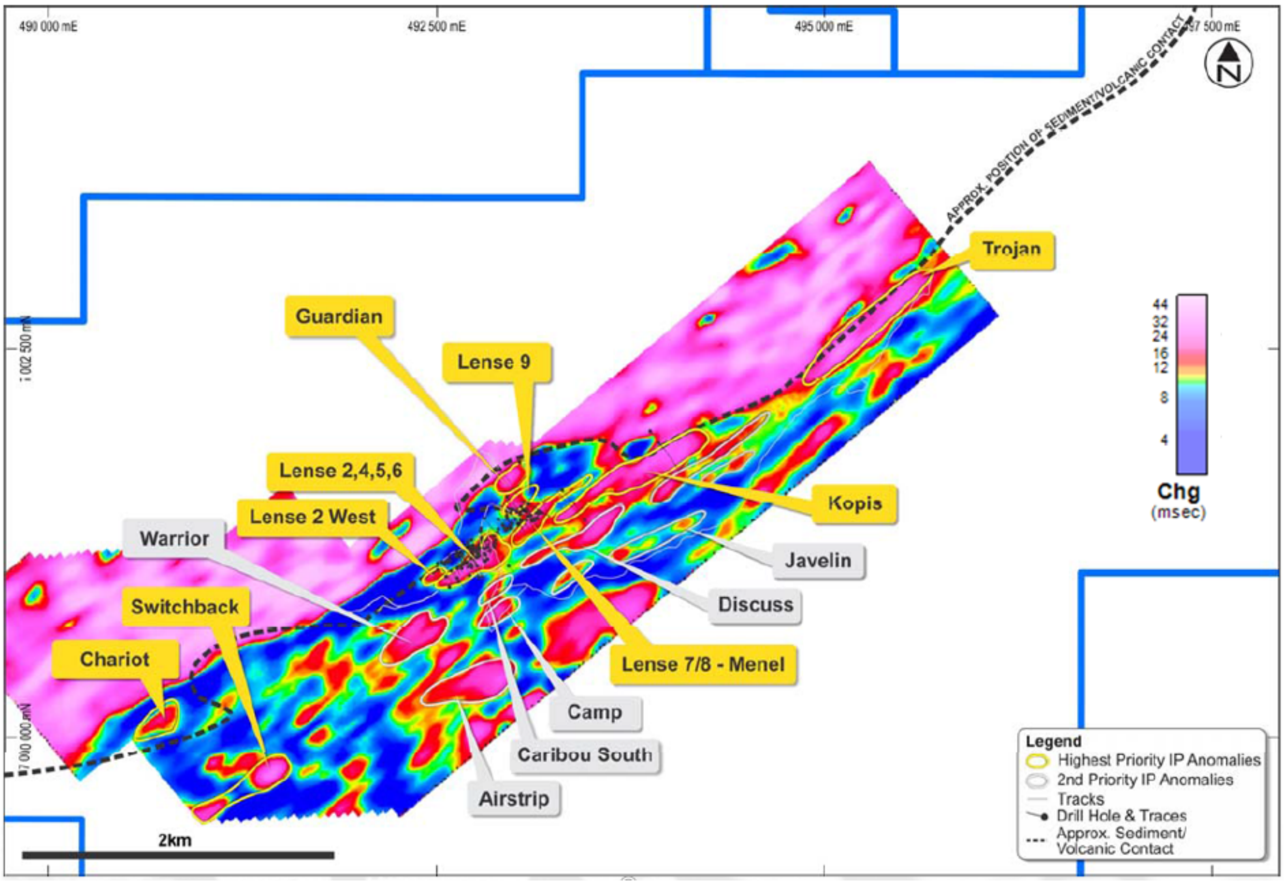

Figure 5: Map of survey area showing location of potential IP targets at -100m below surface. High drilling density shows location of known mineralisation.

CONCLUSIONS

Multichannel receivers, large transmitters, improvements in processing capacity has led to more confidence in inversion results and the recent popularity of the 3D IP technique. Examples of the application of large 3D IP surveys for sediment hosted copper deposits from Zambia and Alaska show that high grade copper mineralisation is associated with an IP response. Sedimentary textures associated with mineralisation compromise the inductive conductivity and resistivity response (anisotropy). An integrated exploration approach using geology, geochemistry and geophysics helps alleviate pursuing responses from digenetic pyrite, graphitic shales and specular haematite

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