High resolution 2D & 3D modeling of IP anomalies for various gold-bearing deposits in Peruvian mining exploration programs using the Pole-Pole array

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Introduction

Over the last five years many major developments have occurred in Geophysical data analysis and processing. In the late 1990s, 2D modeling of IP & Resistivity anomalies was first being presented with significant improvements from previous 1D sounding techniques; but it was not until around 2002, when 3D modeling of electrical methods started yielding some significant results over previous methods. These analyses are constantly improving and their applications are widening as time goes by. Our experience with all the standard arrays has led us to prefer the Pole-Pole array for its higher signal quality.

Sensitivity and Array Specifications

It is now possible to compute array sensitivities for various synthetic model conditions. Available commercial software such as Res2dmod, allows us to compute different sensitivity functions for various arrays. The following images show the array sensitivity for n=2 on the three main arrays.
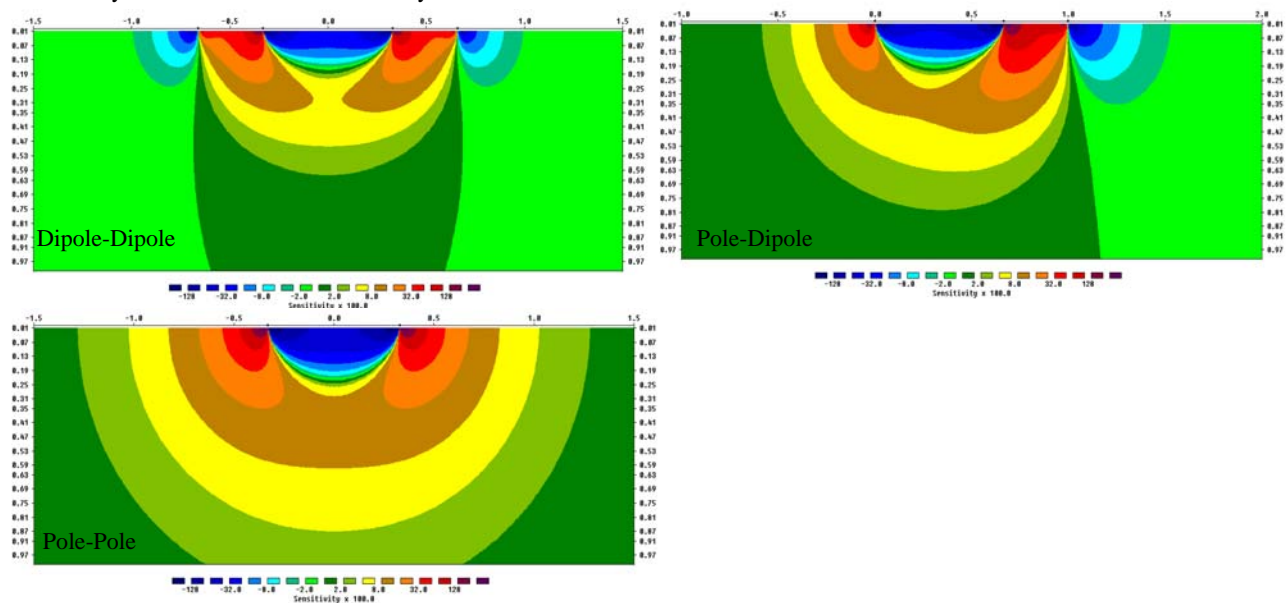
It is clear from the images shown above that Dipole-Dipole is the least penetrating of the three arrays, while it has the highest resolution for shallow responses; Pole-Dipole has an intermediate penetration but it is highly asymmetric which is best compensated by repeating survey lines surveys with two opposing movement directions with leading or trailing current electrode. Pole-Pole has least surface detection resolution but with significant depth reach improvement over the previous arrays. These figures were computed for a homogeneous environment with 100 ohm-m Resistivity, 1 Ampere of input current, 5 mV of minimum potential voltage and 0.33m electrode spacing. Taking these parameters under consideration it is clear that using a comparable energy source, Pole-Pole has the highest signal input which in turn guarantees high quality modeling of the data.

All Pole-Pole surveys conducted in Perú and discussed here have used an "a" electrode separation of 50 meters with 7 spacings allowing an average penetration of 290 meters. The use of modern multi-channel induced polarization receivers with input impedances of up to 100 megohms allows for quality readings even under difficult contact resistant conditions.

3D modeling of IP and Resistivity information may be obtained by means of full three dimensional measurements or by using closely spaced 2D survey lines. In the first case, survey procedures are quite complicated as readings need to be taken using all possible transmitter and receiver electrode locations, while the later option allows for a significant improvement from standard

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2D modeling of IP survey lines, provided line locations do not exceed 2 to 4 times the electrode spacing. This three-dimensional modeling of 2D lines compiled into an input grid is usually called 2D to 3D modeling.

## PODEROSA MINE, La Libertad, Perú

Compañía de Minas Poderosa is located in the Oriental flank in the Peruvian Andes, at elevations ranging from 2000 to 3000 meters above sea level, in the Precambrian Pataz batolith, which mostly consists of granodiorite and monzogranites. Quartz veins have phyllic quatz-sericite alteration and their thickness range from 0.3m to 2m. Mineralization in the veins is mostly gold-bearing pyrite, with traces of chalcopyrite and sphalerite. This Precambrian intrusive is extensive with over 50 km of exposed length and has high Resistivity, commonly above 3000 ohm-meters. The intruding quartz veins, including their alteration halo have Resistivities usually under 1000 ohm-meters. Chargeability responses depend mostly on sulphide occurrence which is not far from the structures, with varying concentrations along the vein axis as well as depth. Accurate target definition is surely difficult and may be best achieved by means of 2D and 3D modeling techniques. Difficult terrain conditions require accurate surface topography information to be included in the data processing and modeling.

Two dimensional views obtained from 3D modeling are commonly used for quick field result assessment. The following images show a typical 2D model obtained over the Glorita vein, which was mapped with this survey and is currently under production.
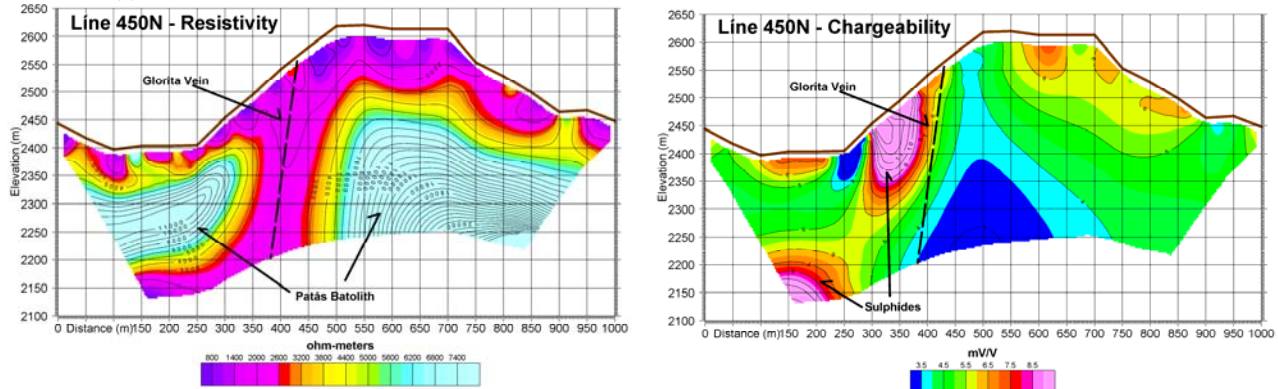
Sulfide presence in this line may be seen in two instances: near the surface and down to some 200 meters below associated to the Glorita vein. The second chargeable mass, located under 2250 meters above sea level is possibly pyrite in the intrusive related to low Resistivity faults and non economical structures.

Three dimensional modeling of the previous data results in the two figures below, where a slice at 100 meters of depth has been selected. Line 450N has been also highlighted. The resistivity model clearly shows the structure while the sulphide presence is shown along the structure and on locations away from it. Chargeability was used here merely to confirm the location of the lower Resistivity vein and pointed elevation ranges within Glorita where drilling should be targeted. The three dimensional model slices provide better interpretations between lines and measured geophysical properties are better correlated, as electrical fields are considered as 3D masses instead of linear responses. This is why in the slices shown below the chargeability responses have some what lower values. It should also be noted that a common problem in 2D and 3D modeling chargeability measurements provides results somewhat displaced perpendicularly to line direction.
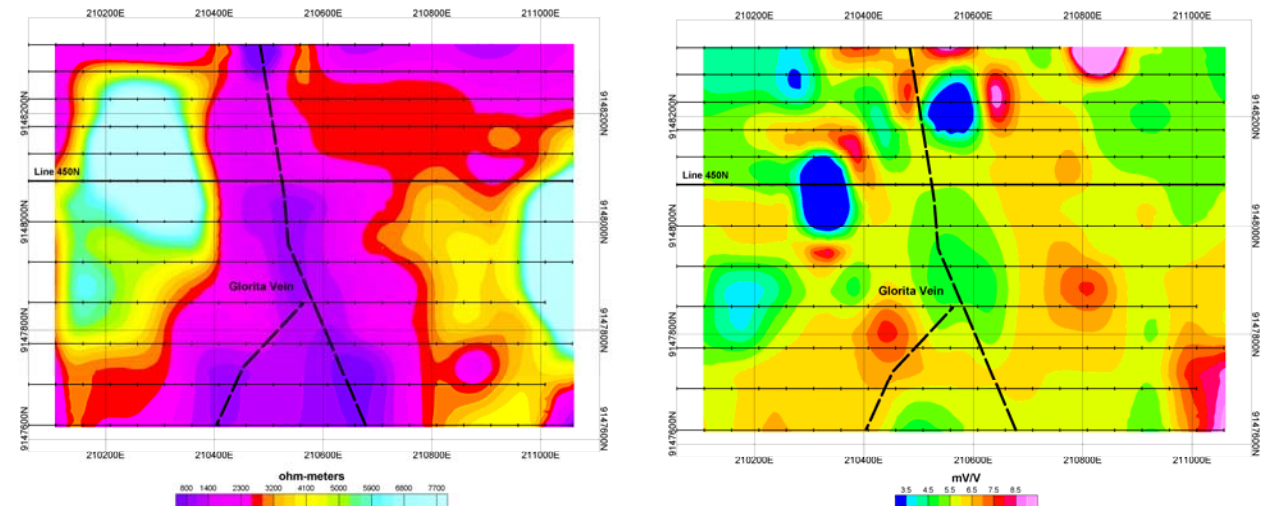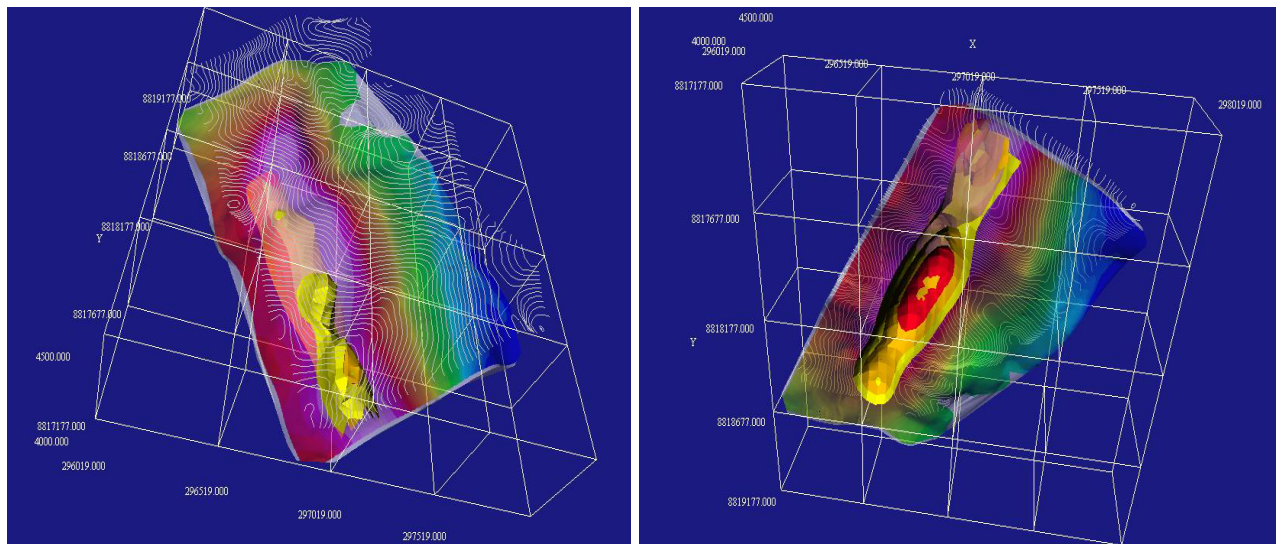
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MALLAY, Ancash, Perú

The Mallay project is located in the Oyón Province, Ancash Department, in the Peruvian Central Andes and is part of the exploration programs of Compañía de Minas Buenaventura S.A.A.. Surface topography in this project had also very difficult access and a a high resolution survey was completed to help compensate for the topographic effects. The target body is located in the contact of the high Resistivity Pariahuanca limestone formation (upper Cretacious) and the Farrat formation quartzites (lower Cretaceous). Mineralization in the contact contains up to 9% Zn, 7% Pb, 6 oz Ag, over 20% Fe and Pyrite and Arsenopyrite masses. The survey layout was done with lines mostly spaced by 100m but with some intermediate in-fillings at 50 meters. Lines were perpendicular to the formational trend. The 3D modeling of the survey area yielded some very clear results. The following images represent Resistivity and Chargeability modeled at 300 meters below surface.
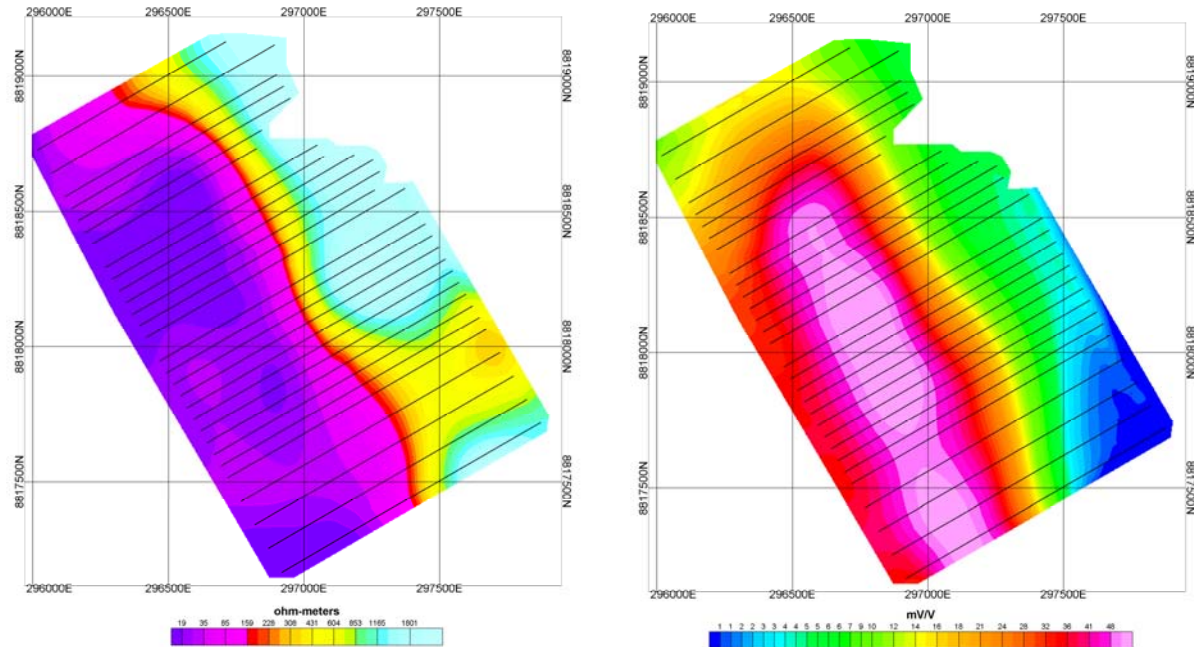
Prior to our arrival several drill holes had been completed with very encouraging results. Right now an underground tunnel is being completed to fully analyze the results and possibly to start this new mining operation.

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Three dimensional modeling allowed accurate display for drill hole and underground mining planning. The two views shown above represent the target chargeability response as solid masses (yellow-orange-red for 50, 55 and 60 mV/V, respectively) and the chargeability depth slice for 300-meter depth. The left image is a view from above ground and the right image is a view from a deeper reference point than the anomaly.

QUICAY, Pasco

The Quicay mine operation is located in the mid Peruvian Andes at elevations above 4000 meters. Mineralization is mainly free gold in a silicified mass. The high Resistivity anomaly marks the entire mineable area at shallow depths. Below 150 meters from surface the high Resistivity response narrows downsizes forming a mushroom-shaped high-Resistivity cap. Chargeability provided only negligible results as almost no sulphides are found in the area. Two dimensional section planes were obtained from the 3D inversion results at locations coincidental with the initial survey lines.
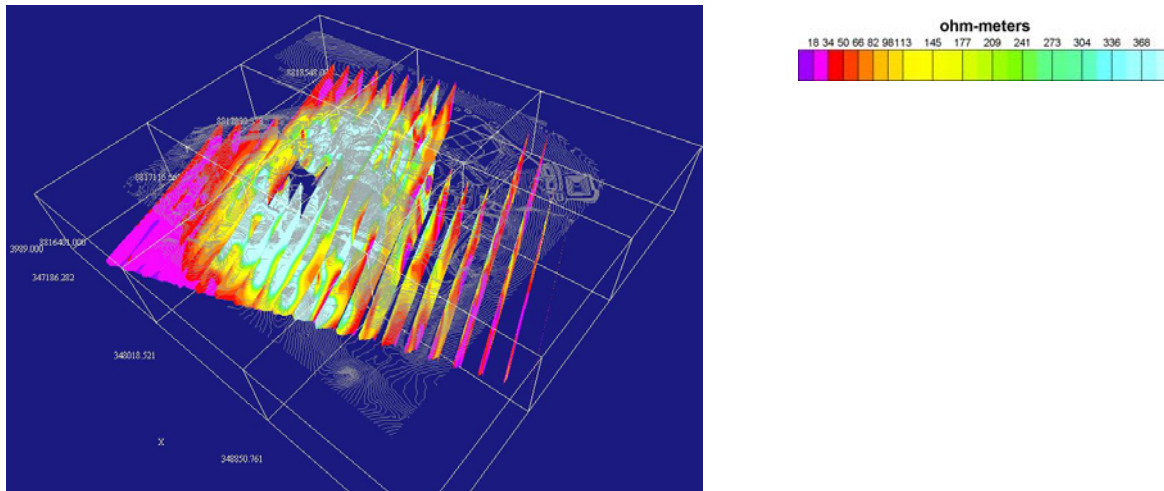
CONCLUSIONS

3D IP and Resistivity modeling from 2D data collection along lines provides a significant increase in the quality of the model, provided line spacing does not exceed a maximum of four times the minimum electrode separation. The use of a high-input array as Pole-Pole permits a very high signal input compared to other standard arrays, which will allow a higher quality resulting model. The 3D modeling of Pole-pole data provides accurate and reliable results which have a much higher degree of accuracy to be used to program drilling and subsequent mining programs. The use of a high input impedance IP receiver is of utmost importance to guarantee a high degree of reliability in field readings.

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ACKNOWLEDGMENTS