# Botija Cu-porphyry deposit

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**Abstract**

Botija Cu-porphyry deposit is located in Panama. In 2013 it was surveyed with SkyTEM system for geotechnical purposes. The data were interpreted in order to map the thickness of weathered saprolite. In 2015 the data set was revisited and reinterpreted in order to extract additional geological information about alteration zones. The data set was further inverted in IP mode and results compared with ground IP survey.

**Introduction**

A SkyTEM survey was flown in 2013 over the Mina de Cobre project area (Panama) at request of First Quantum Minerals. The aim of the survey was to map the depth to bedrock for purposes of building infrastructure for an open pit mine. The survey included an area around the Botija deposit, which hosts porphyry style Cu mineralization within a granodioritic batholith with adjacent andesite volcanics (Figure 1). Abundant sulphides in the form of pyrite and chalcopyrite have been intensely weathered and precipitated the formation of clays in this tropical environment. The deposit has been subject to extensive drilling, which facilitated verification of all inversion results.

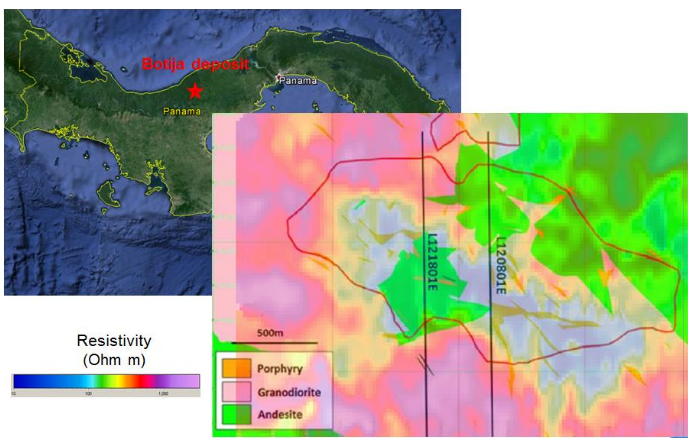


***Figure 1.*** *Location and simplified geology of Botija Cu porphyry deposit, Panama, showing SkyTEM flight lines 120801 and 121801and overlain by recovered electrical resistivty, gridded at 30-40 m below surface.*

In 2013 the SkyTEM data were inverted by Aarhus Geopysics using spatially constrained inversion (SCI) (Viezzoli et al., 2008) in order to map thickness of weathered saprolite, which was expected to show a relatively conductive response over consolidated bedrock composed predominantly of electrically resistive igneous units. The interpretation of the inversion results led to discovery of deeper-seated conductive zones within the bedrock and below the oxidation level. These conductive areas are either stratigraphically above (and directly adjacent to the mineralized zone) or situated within the mineralized zone, in both cases showing a positive correlation with the deposit outline in a plan view (Figure 1).

In 2015 the data set was reinverted with IP modelling (Fiandaca et. al, 2012; Viezzoli and Kaminski, 2016) in order to refine the recovered resistivity models and to apply reinterpretation of the data for geological mapping on the deposit scale. IP modelling was carried out using a Cole-Cole model (Cole and Cole, 1942). The newly acquired resistivity model confirmed presence of conductive zones below the oxidation level and adjacent to the deposit, as well as suggested some distribution of shallow chargeable material in the NE corner of the survey area, subject to further investigation.

**Spatially Constrained Inversion of SkyTEM data in non-IP mode**

The initial inversion attempts were made in non-IP mode and allowed successful mapping of depth to the bottom of saprolite, which is overlaying consolidated bedrock. The inversion converged to an average misfit of 0.85 (normalized by standard deviation). The inversion results were confirmed by multiple boreholes (Figure 2). In this figure the depth to bedrock derived from the inversion results is verified against the depth to bedrock derived from boreholes. Overall the inversion attempt was very successful in providing the areal mapping of depth to the bottom of the weathered oxidized material.

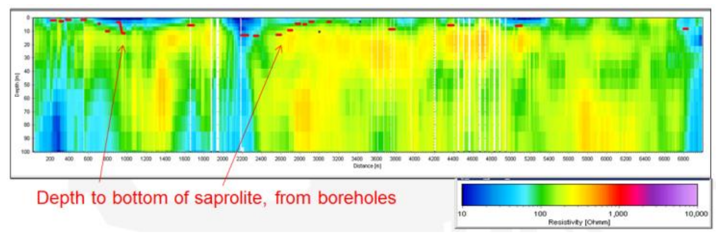


***Figure 2.*** *Example of the inversion results verified against the existing boreholes.*

**Spatially constrained inversion in IP mode**

The most recent inversion attempt was carried out with implementation of Cole-Cole model for the TDEM inversion. This inversion converged to an average misfit of 0.75 (normalized by standard deviation). It was anticipated, that high concentration of pyrite and chalcopyrite in and around the deposit will result in measurable AIP effects in the data space. Although such effects were not immediately evident, the inversion in IP mode allowed recovery of better fitting model, which was then verified against the boreholes (Figures 3 and 4). As it can be seen in both figures, the top saprolite layer is distinctively mapped as a conductive layer, which is in agreement with borehole data. In general the resulting resistivity model was very similar to the model recovered in non-IP case. In addition to the conductive areas near-surface, which are interpreted to map the extent of the weathered zone, there are conductive areas in the bedrock, which are either hosted within the deposit (Figure 3) or directly adjacent to the mineralized zone (Figure 4). It is anticipated that the bedrock (granodiorite and andesite) would be electrically resistive and the preliminary interpretation of abnormal conductivity distribution may be due to presence of intense clay alteration from pyrite weathering above the ore zone (Wijns, 2016). The continuous conductive zone at the bottom of the cross-section appears to be below the depth of investigation (DOI) and does not yield viable geological interpretation.

There is an open question with regards to absence of evident AIP effect in the data space at a first glance, while AIP effect was observed in a similar setting over the Mt. Milligan deposit (Viezzoli and Kaminski, 2016). Our interpretation of the absence of this phenomenon may be attributed to low frequency constant (c) values, high time constant ($\tau$) values or to chargeable material being emplaced too deep to be detected with this TDEM system. There is historic ground IP coverage over the area, which will be examined and corroborated with the airborne TDEM data in our follow-up study.

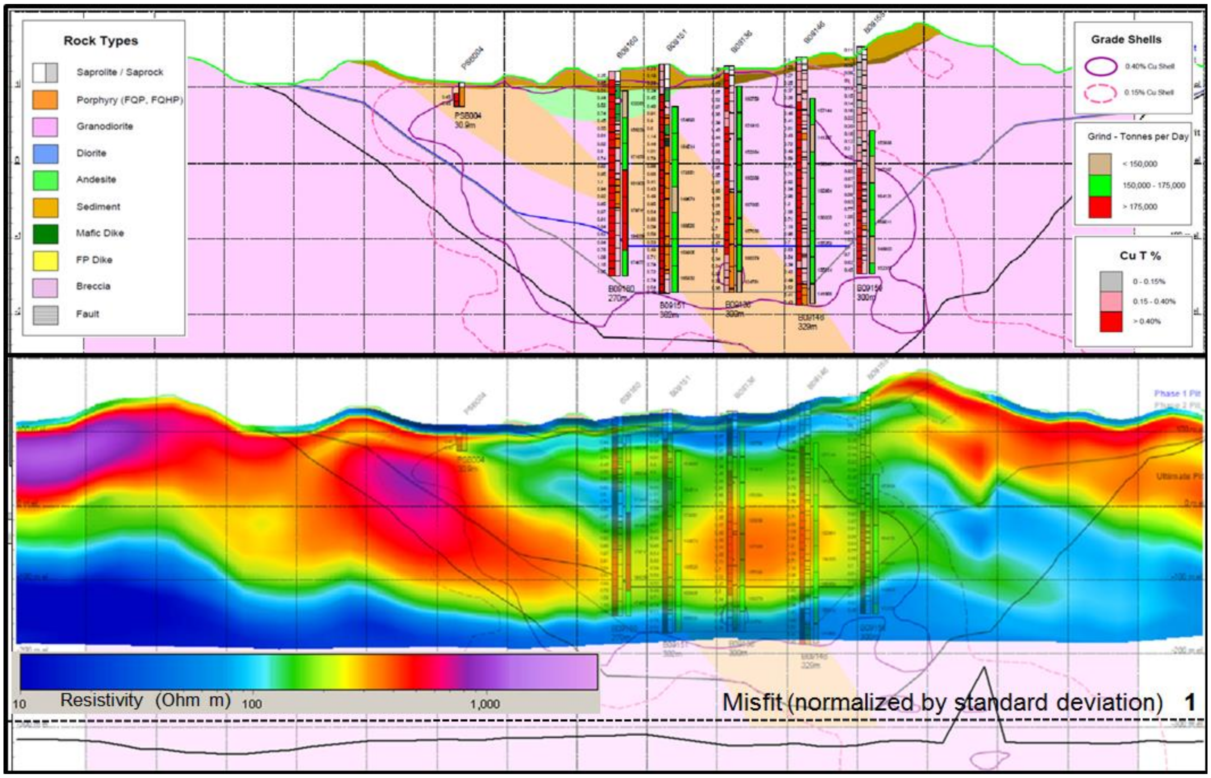


***Figure 3.*** *Inversion results over SkyTEM line 121801/121802. Top: geological model constructed based on drilling information with contours of projected open pit mine; bottom: resistivity depth section derived from SCI inversion.*

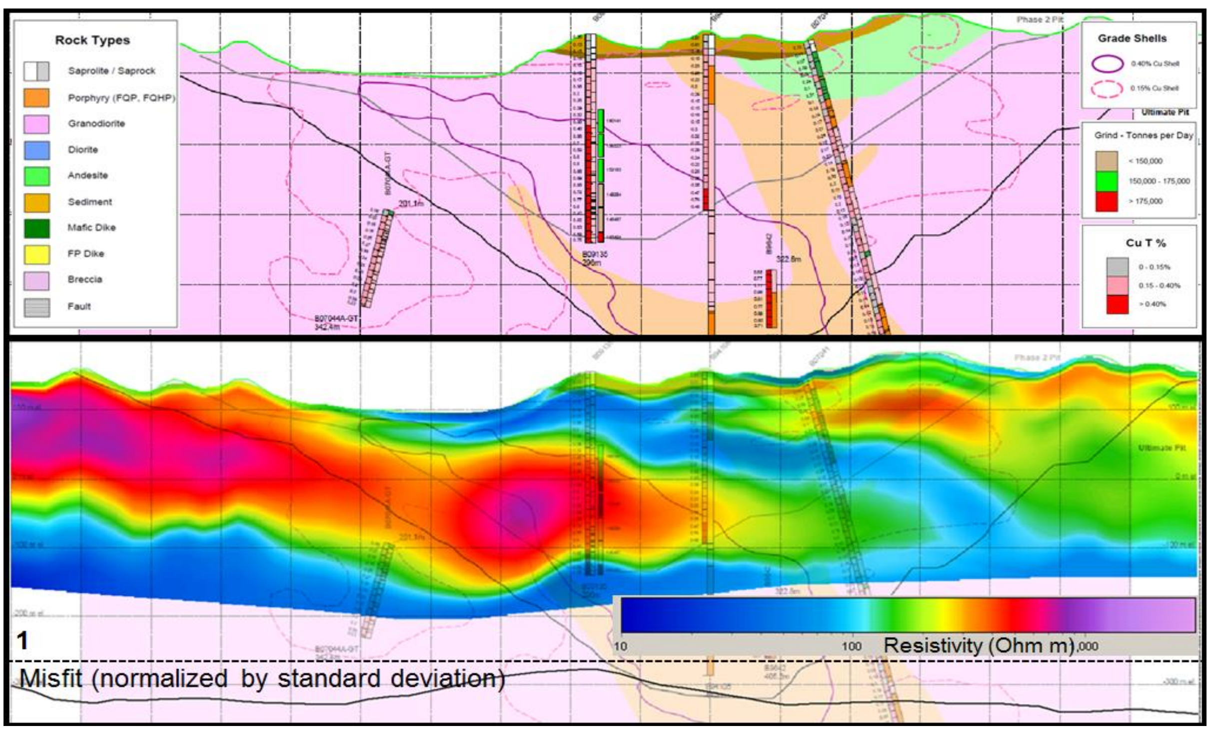


***Figure 4*** *Inversion results over SkyTEM line 120801. Top: geological model constructed based on drilling information with contours of projected open pit mine; bottom: resistivity depth section derived from SCI inversion.*

**Conclusions**

In is conclusive from the undertaken study that in this case, the airborne survey's value is not limited to its initial purpose and gave rise to follow-up study of geological relevance and potential for follow-up work in the future, which can have relevance for mining as well as for R and D. The correlation of bedrock conductive zones with intense clay alteration will be verified and the reinterpreted TDEM data may become a valuable tool in adding to existing knowledge about geology of Botija deposit.

The question of airborne IP remains opened and will be addressed in the follow-up work. It is however encouraging result, that both inversions with and without IP modelling recovered a very similar resistivity model, which allows to conclude that multiparametric Cole-Cole inversion is stable in absence of obvious IP effects and does not result in erroneous chargeable targets in absence of such.

**Acknowledgments**

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