Modeling of airbone data (magnetic and electromagnetic) of Cristalino Cu-Au Deposit, Carajás, Pará, Brazil

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Abstract

The Cristalino Cu-Au deposit is located in Carajás Mineral Province. The area of the deposit was covered by an airborne survey (magnetic and time domain electromagnetic) in order to identify the most conductive areas. Six resistivity depth images were built for these data, using the software ImagEM and the magnetic data was processed and interpretation was based on the Analytical Signal. The ImagEM software is under development by the Electromagnetic Interpretation Research Group of Universidade de Brasilia. ImagEM showed very good results for the Cristalino area, where the low resistivity core has a good correlation with the deposit.

Introduction

The Carajás Mineral Province (CMP) is a highly mineralized metallogenic province in the southern part of the Amazon Craton in Brazil, located in the Carajás Neoarchean Domain between the Araguaia Belt at east and overlying Proterozoic sequences at west (Figure 1; Docego, 1988; Araújo and Maia, 1991; Tassinari and Macaimbra, 1999). To the north, it is concealed by Proterozoic and Cenozoic sedimentary rocks of the Amazon Basin (Pinheiro and Holdsworth, 1997) and the south, it is contact with the Rio Maria granitoid-greenstone terrain (Docego, 1988; Hunh et al., 1988a,b; Villas and Santos, 2001, Grainger et al., 2008).

The CMP comprises two Archean tectonics blocks, the southern Mesoarchean Rio Maria granitoid-greenstone terrain (3.0 to 2.86 Ga; Hunh et al., 1988a,b; Machado et al., 1991; Macambira and Lafon, 1995; Macambira and Lancelot, 1996; Althoff et al., 2000; Souza et al., 2001; Leite et al., 2004; Dall'Agnol et al., 2006), and the northern Neoarchean Carajás domain one of the best preserverd Archean volcano-sedimentary sucession of the world (2.76 to 2.54 Ga; Araújo et al., 1988; Machado et al., 1991; Huhn et al., 1999; Barros et al., 2004; Sardinha et al., 2006; Grainger et al., 2008). The later contains world-class Fe-oxide Cu – Au deposits and the most significant examples are: Salobo, Cristalino, Sossego and Igarapé Bahia-Alemão. The focus of this work is on the Cristalino.

Discovery of the Cristalino deposit was in 1998 through integration of geological and soil geochemistry data. The anomaly is associated with intense potassic alteration related to a magmatic brecciated/stockwork system. The magnetic, electromagnetic and induced polarization anomalies are the response of these hydrothermal zones (Huhn, 1999a).

The Cu - Au Cristalino deposit is located at the Serra do Rabo hill, in the southwest part of Carajás Domain and its mineralization is hosted by mafic to felsic volcanic rocks hydrothermally altered and interlayered with iron formation of the Grão Pará Group and was classified as a Fe-Cu-Au-U-REE deposit type (Figure 2; Docego, 1988; Huhn et al., 1988a,b).

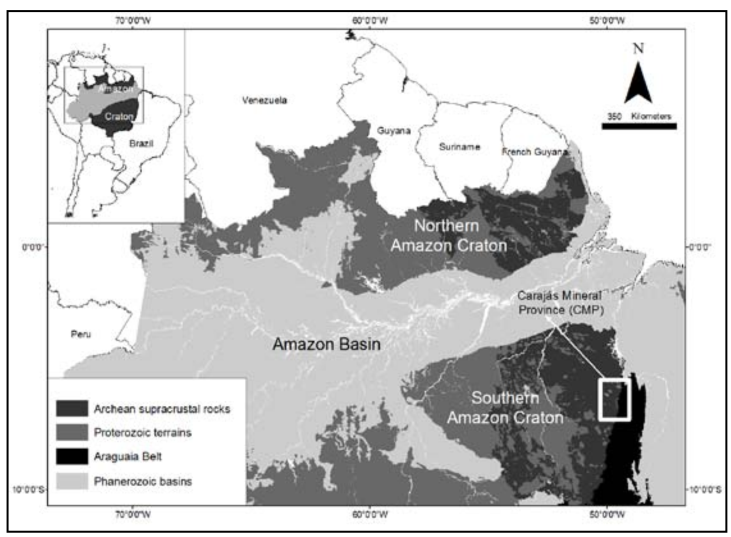

Figure 1 – Simplified sketch map of Amazonian Craton showing the location of Carajás Mineral Province (CPRM, 2001).

The mineralization occurs in breccias and as stockworks, disseminations and fracture fillings in both the intrusive and metamorphic host rocks (Huhn et al., 1999a; Grainger et al., 2008). The main ore minerals are chalcopyrite, pyrite, magnetite, bravoite, cobalite, millerite, vaesite and gold. The resource is estimated at more than 500 Mt grading 1.0 % Cu and 0.3 g/t Au (Huhn et al., 1999; Grainger et al., 2008).

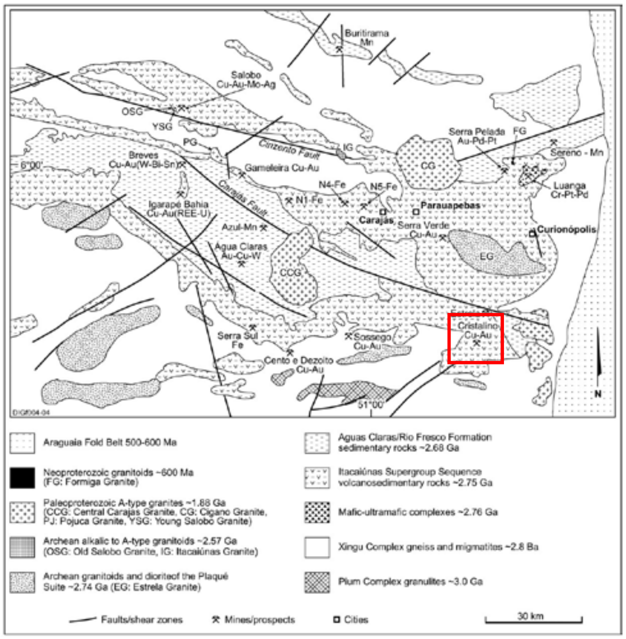

Figure 2 - Simplified geological map of the Neoarchean Carajás Domain, showing the study area (Docegeo, 1988; Araújo and Maia, 1991; Barros and Barbey, 1998; Grainger et al., 2008).

Method

The eletromagnetic time-domain (TDEM) method is very important for exploration of massive to semi-massive sulfide related deposits and magnetometry can be very useful if it is related to magnetite. An airbone GEOTEM and magnetic survey was flown by Geoterrex-Dighem on behalf of Companhia Vale do Rio Doce over the Cu-Au Cristalino deposit aiming to identify the conductive and magnetic anomalous zones. Eletromagnetic data were acquired using the GEOTEM eletromagnetic multicoil system, in time domain, base frequency of 90 HZ, current of 700 A. receiver multicoil system (x, y and z) recording 20 channels for each component, the first five channels are on time. Magnetic data were acquired using the Scintrex CS-2 single cesium vapor towed-bird, sensitivity of 0.01 nT, sample rate equal to 0.1 s and range of 20,000 to 100,000 nT. The flight direction was N-S, line spacing of 250 m (Figure 3) and tie line spacing of 6000 m.

The Analytical Signal (ASA; Figure 4A) was created using the Geosoft TM 7.2 software. The GEOTEM channels 7, 10 and 14 images are shown in the figure 4B, C and D. The channels 5 to 20 were considered for the Resistivity Depth Image (RDI) processing in the software ImagEM, which is under development by the Electromagnetic Interpretation Research Group of Universidade de Brasilia.

Initially, the ImagEM was based on the RAMPRES software (Sandberg, 1988; Von Huelsen, 2007; Von Huelsen et al. 2008). The new software calculates the apparent resistivity, using the potential difference in the receiver coil that is concentric to the transmitter coil. It does a simplified inversion, applying the secant method (Von Huelsen et al., 2011).

The RDI of six survey lines (Figure 4 C) were gridded in a 2D grid, generating a image of 20 m cell size, using the software Geosoft TM 7.2 (Figure 5).

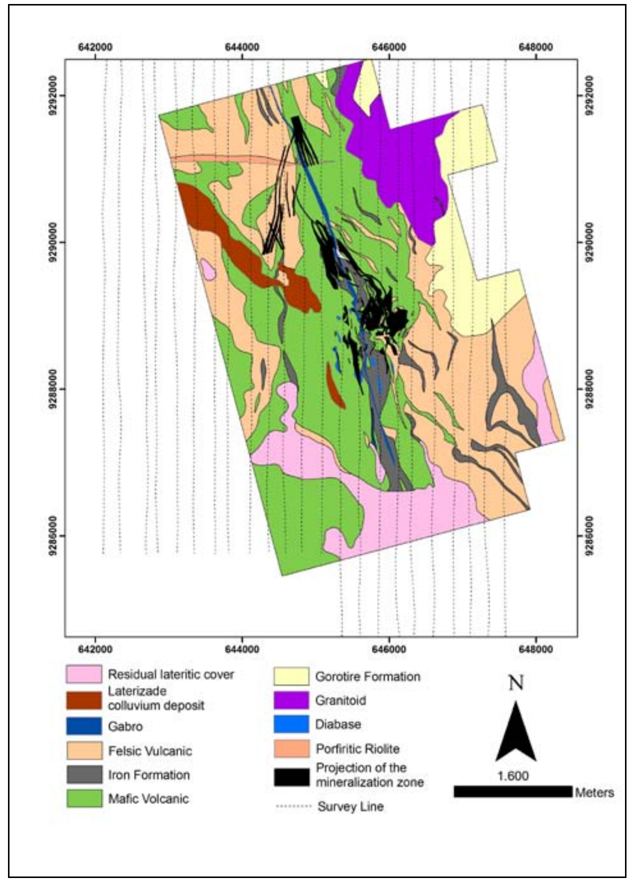

Figure 3 - Geological map of the Cristalino Deposit, showing the survey lines (modified after Huhn, 1999).

Results

The high magnetic signal in the Analytic Signal image is mainly due to the iron formation of the Grão Pará group. This iron formation has an amplitude of 1.2 to 3.6 nT/m and is well defined in this product (Figure 4A).

The EM images of channels 10 and 14 showed a conductive body with amplitude superior to 15000 pV/m2, with concentric shaped and well defined in channel 10, where are possible to identified a second condutive body near the principal body, also showed in channel 14 (Figure 4C and D).

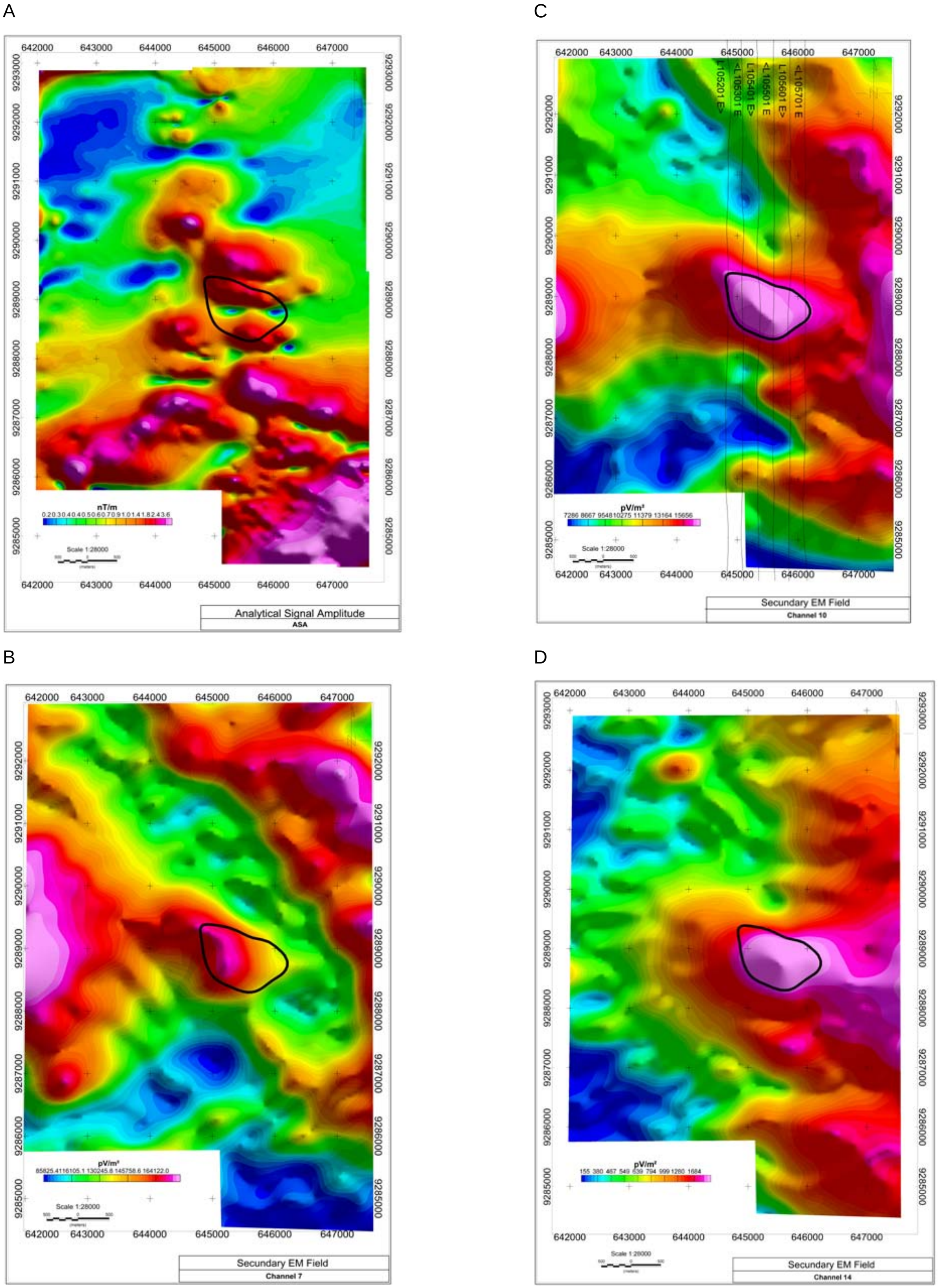

Figure 4 – A) Image of mag Analytical Signal; B) Image of EM Secondary Field (channel 7); C) Image of EM Secondary Field (channel 10); D) Image of EM Secondary Field (channel 14). The black trace in all images is the contour line of the low resistivity body, its calculated value is 15000 pV/m².

The high magnetic anomaly in the Analytic Signal image is mainly due to the iron formation of the Grão Pará group. This iron formation has an amplitude of 1.2 to 3.6 nT/m and is well defined in this product that shows that it is not a continuous layer (Figure 4A).

The EM channel 7 shows the NW-SE trend of the conductive body that is coincident with the deposit location (Figure 3 and 4B). This body does not show a strong response in the Analytic Signal image, but seems to be located between iron formation layers.

The EM images of channels 10 and 14 show the same conductive body of amplitude value greater than 15000 pV/m2. Both channels show the response of a smaller conductive body located at south of the main body area.

Figure 5 show the ImagEM Resistivity Depth Images (RDI) of the survey lines from west to east (Figure 4C). It shows a very conductive overburden that has approximately 150 meters thickness. The RDI 105201 and 105301 shows the top of the main low resistivity body between stations 3600 and 5200.

It is possible to identify the southern low resistivity body in the RDI 105201 to 105401 but it shows its better response in the RDI 105301 between stations 6400 and 7600. In the RDI 105401 to 105701 the overburden is more conductive and it is not possible clearly identify the mineralized zone.

Conclusions

The Analytic Signal was important to characterize the main geological features, as the iron formation layers of the Grão Pará group that occurs in the area. The EM channel images clearly show the deposit response but is affected by the geological background noise.

The RDI images map the top of the deposit very well, but the very strong signal of the overburden act as a filter of the mineralization signal. As consequence, it is not possible to estimate the low resistivity body depth.

Acknowledgments

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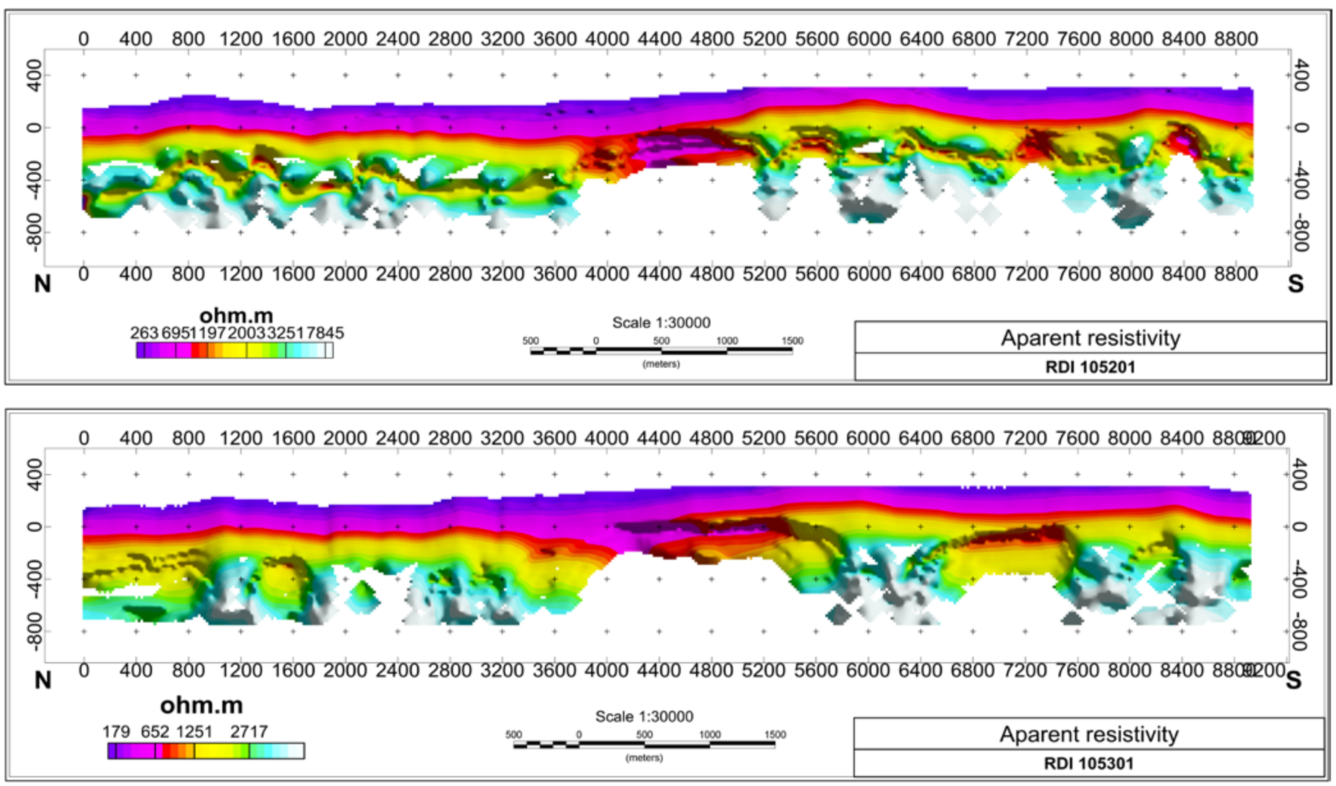

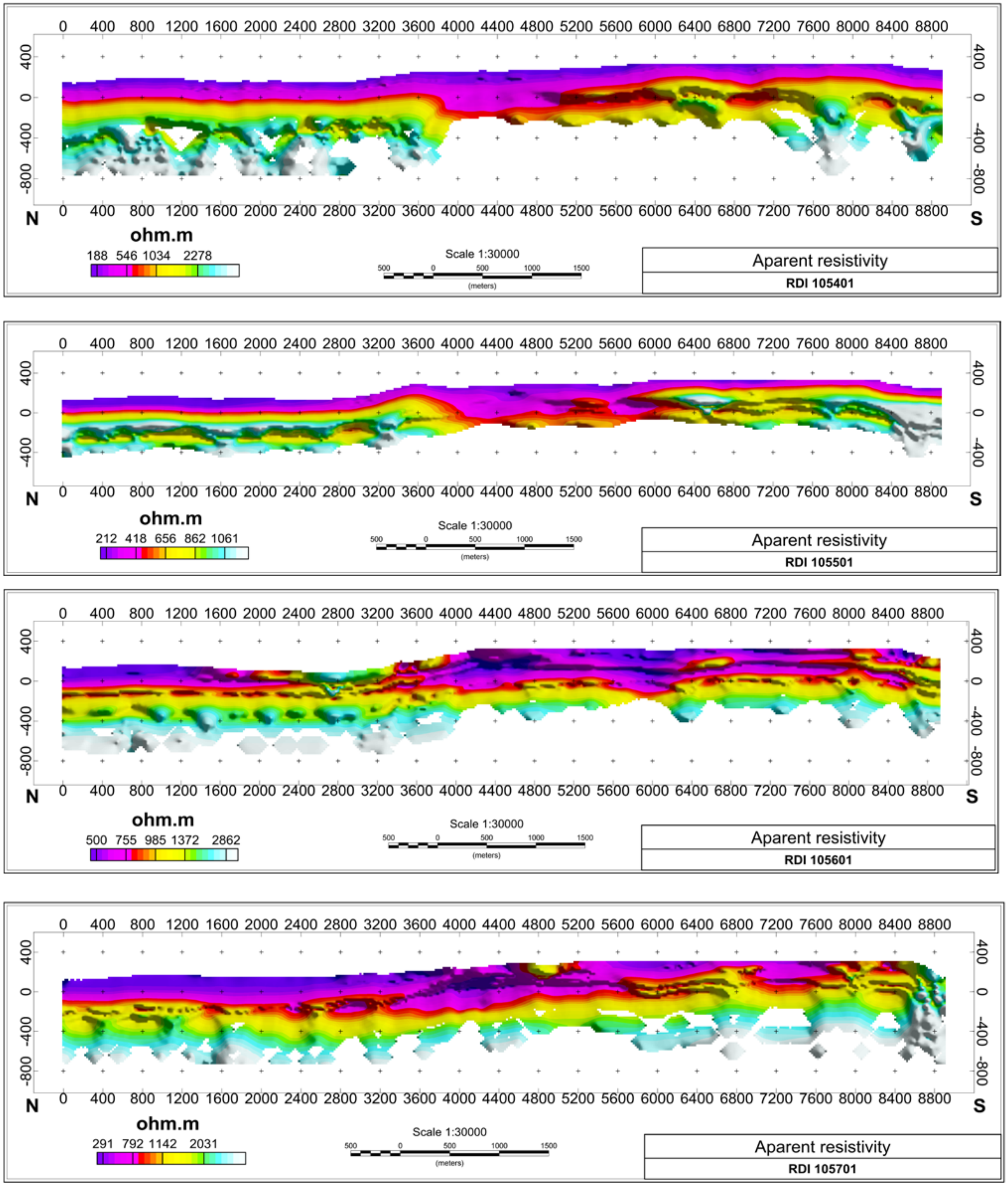

Figure 5 – RDIs of 105201, 105301, 105401, 105501, 105601 and 105701 lines, y -axis is the depth and x-axis are station.

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