Paper 98

Electromagnetic Modelling of the Cree Lake Extension, Millenium Deposit, with MultiLoop III

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ABSTRACT

Step-loop EM 37 data have been acquired over the Cree Lake Extension (Millenium deposit)in the Athabaska Basin by Cameco Corp. The geology consists of a series of dipping basement conductors under the Athabaska sandstone, and the data reflect structures in the overburden, sandstone and the basement. Traditional modelling software using thin plates to represent the conductivity structures would be able to approximate the responses of the basement conductors, but modelling the entire conductivity structure using such methods would be difficult. MultiLoop III has been used to generate a detailed interpretation that is not possible with traditional approaches.

To model the data, the ground was represented in MultiLoop III by a set of pseudo-infinite and semi-infinite meshes with variable surface resistances. Horizontal meshes were used to represent the background response of the sandstones, while dipping semi-infinite meshes (half-planes) were used to represent the dipping basement conductors. Variable mesh resistances were used to represent conductivity variations in the overburden and the sandstone. Doing so allowed the effects of surficial conductivity variation on the data to be modelled so as to better reveal more subtle late-time anomalies. As a result, an anomalous conductivity zone in the sandstones above the basement conductors was revealed. This zone was modelled by assigning a variable resistance to the mesh representing the electrical structure of the deep sandstone beds.

INTRODUCTION

Much of modern electromagnetic (EM) interpretation relies on modelling software that represents the conductivity structure of the ground with one or more thin sheets. The thin sheet model is attractive because it executes quickly, is easy to compute and easy for the modeler to understand. The model has the disadvantage of a limited representation of the conductivity structure of the ground, and interpreters are often forced to limit the scope of their interpretative work to those parts of the data that fit the model. Accordingly, much of the potential of EM data remains unrealized.

MultiLoop III solves for the inductive response of a set of thin sheets that are represented by two-dimensional meshes. The meshes can be modified to accurately represent the shapes of conductors found in the ground, and so the model is not geometrically limited by the thin-plate assumption. Because the basic conductivity structures are two-dimensional, MultiLoop III maintains a substantial computational advantage over full three-dimensional solutions, while at the same time being able to represent the salient characteristics of the conductivity structures that the data respond to.

The interpretative capabilities enabled by MultiLoop III are a significant advance over present capabilities, and new methods for interpreting data must be developed to take advantage of them. Here, data from the vicinity of Cameco's Millenium deposit are interpreted using MultLoop III. The data are from the Athabaska basin in an area where the sedimentary rocks are approximately 500 meters thick. The data are interpreted first by modelling the background response of the sediments, and then the late time response of the basement conductors. Residual anomalies that persist after these major features are represented are then modelled, with the results used to infer the presence of anomalous conductivity at depth in the sandstones over the basement conductors.

DATA

A plan map of the survey, supplied by Cameco Corp (Garnet Wood, pers. comm.), is illustrated in Figure 1. The Figure illustrates the locations of the various loops employed, together with the locations of lakes (blue outlines) and the interpreted locations of various conductors, notably the Marker, B1 and Eastern conductor. The loops employed in the step-loop survey

In "Proceedings of Exploration 07: Fifth Decennial International Conference on Mineral Exploration" edited by B. Milkereit, 2007, p. 1077-1080

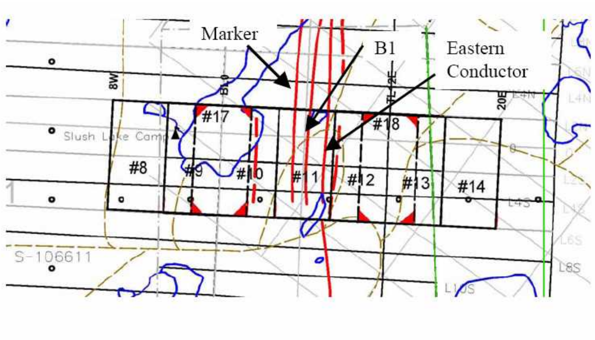

Figure 1: Survey plan map

are illustrated in black. The data used in this interpretation were acquired from loop 8, the western-most loop.

The electromagnetic data were imported into MultiLoop III and are illustrated in Figures 2 and 3. Figure 2 illustrates the full range of the data, with the early times (red) dominated by the response of the sandstone and overburden, while Figure 3 details the late time response (blue and violet shades) and illustrates the crossovers that reveal the presence of the basement conductors.

The data exhibit variation ranging from approximately 80 nT/sec/m2 in the early time to approximately 0.02 nT/sec/m2 in the late time. The model developed here will honour much of the data over this range.

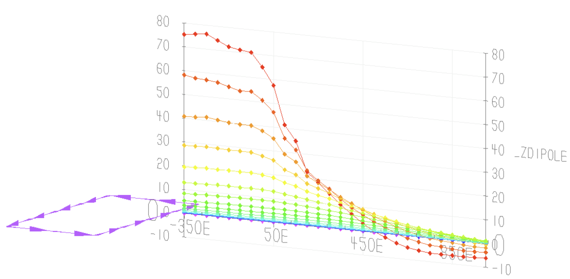

Figure 2: Full range EM-37 data (nT/sec/m2)

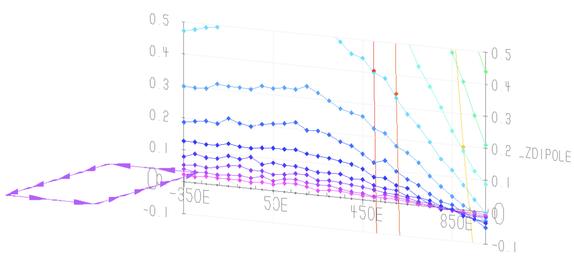

Figure 3: Late time EM-37 data (nT/sec/m2)

INTERPRETATION

The interpretation was undertaken using a two-pronged approach, the first being to approximate the early time response by using a pair of stacked pseudo-infinite meshes to represent the conductivity of the sediments, and the second being to locate the basement conductors by employing dipping pseudo-infinite meshes to simulate half-planes. Experience has shown that the response of the sandstones can be adequately represented by two or three horizontal meshes separated vertically by a few hundred meters. To obtain the correct late time responses for surveys in the Athabaska basin, the meshes should extend to at least 3 to 4 kilometres from the loop and the end of the traverse line. Doing so allows the currents to diffuse well away from the survey area before encountering the mesh boundaries, and mitigates the effect of the implied resistance caused by the edge of the mesh. After a bit of juggling with the mesh resistances and depths, a representative fit can be obtained to the early time data. An example of such a fit is illustrated together with the model in Figure 4 (early time), and in Figure 5 (late time). Meshes with 601 nodes were used to model the dipping conductors; a mesh with 1101 nodes was used to model the deep sandstone, while a mesh with 1501 nodes was used to model the near-surface conductivity. The complete model consisted of 3801 mesh nodes.

The modelled response (points) illustrated in Figure 4 only approximates the response of the data, and there is clearly a persistent source of induction that supports the magnetic field in

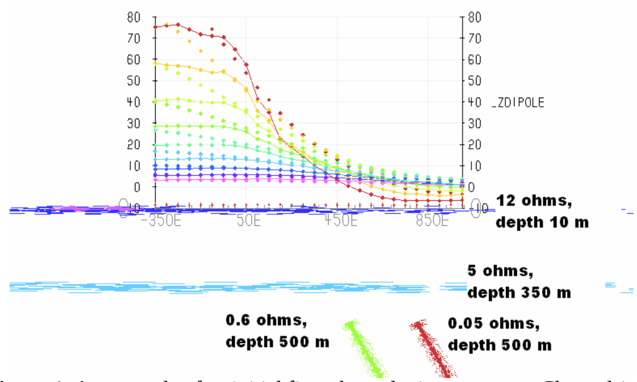

Figure 4: An example of an initial fit to the early time response. Channel 1 is shown red and channel 9 in purple. The mesh is plotted below the data.

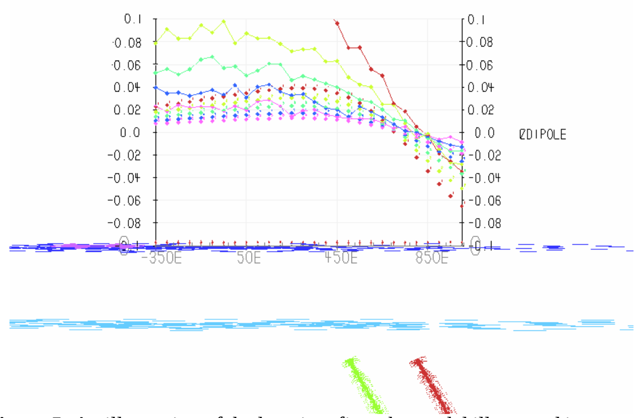

Figure 5: An illustration of the late time fit to the model illustrated in Figure 4. Channel 16 is plotted red, and channel 20 is plotted purple.

the vicinity of the loop (-350E to -50E) that is not present in the model. Initially it was hypothesized that a conductor in the sandstone, possibly a fault, was short-circuiting the current in the sandstone at approximately -50 E. Indeed, the model was modified to include such an effect, and the data could be replicated but there was little other evidence to support such a structure, and the fault did not fit well with the other components of the model as it evolved. A review of the physiography (Figure 1) shows a lake at approximately the same location, and so the model was modified to account for the probable anomalous conductivity associated with the lake sediments.

In Figure 5, the modelled channel 20 response agrees well with the data over a range of approximately 800 meters from approximately 300 E to 1100 E. However the modelled responses for channels 15 to 19 decay too quickly relative to the data, an indication that the model requires more conductivity to support the fields at late times.

Effect of the Lake

The results so far indicate that the model requires additional conductivity near the loop to support the field at early times, together with additional conductivity at late times to support the decays measured in channels 15 to 19 over the basement conductors. A set of models was computed to account for the near-surface conductivity, and to determine if the missing near surface conductivity could account for the rapid model decays seen in channels 15 to 19.

To assess the possible effect of the lake, the resistance of the surface layer was modified so that its resistance was 1 ohm in the interval -300E to 100E, and 12 ohms otherwise. Only the near-surface mesh was used in the calculation. Results plotted in Figure 6 indicate the resistance of the lake was underestimated, and a better estimate is presented in Figure 7 where an anomalous resistance of 5 ohms was used.

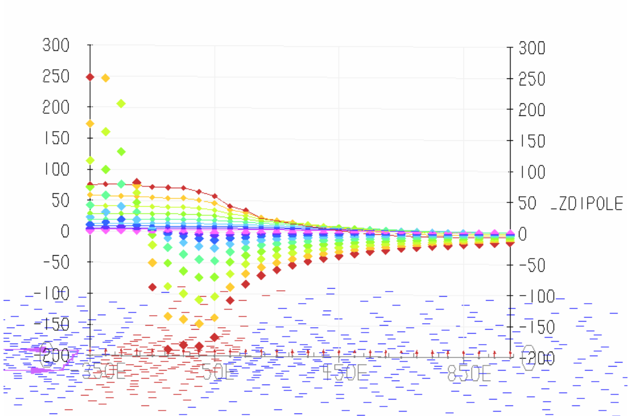

Figure 6: Computed response of the lake (points) based on an initial guess of the resistance. The location of the "lake" is illustrated with the red tiles.

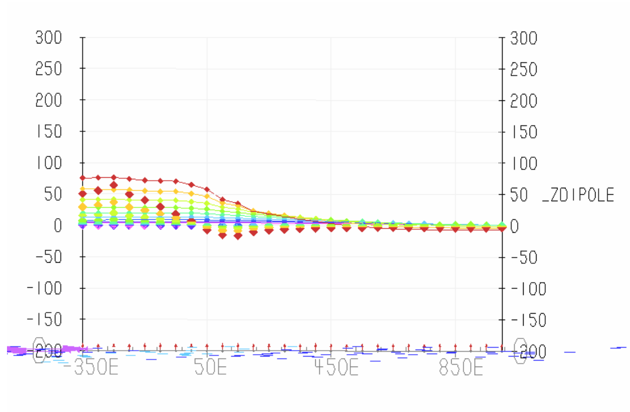

Figure 7: Estimate of the lake response using a lake resistance of 5 ohms.

The estimated lake response was then used as a basis for computing the effect of the lake. The lake parameters and the parameters of the horizontal layers were adjusted to produce the fit shown in Figure 8. The lake was modelled by assigning the upper mesh with the resistivity of 0.6 ohms between -200E and 200E, and north of 100N, and 20 ohms otherwise. The mesh at 350m was assigned a resistance of 6 ohms.

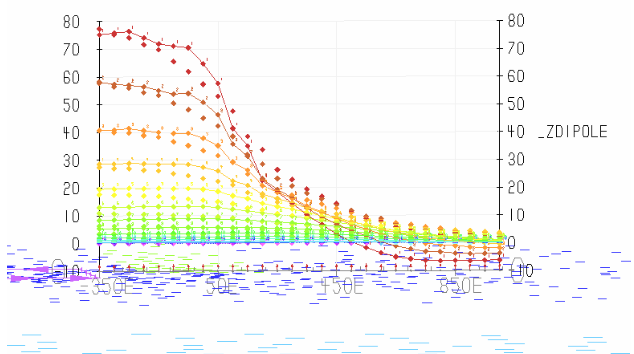

Figure 8: Calculated early time response (points) accounting for the effect of the lake.

By examining the difference of the models with the lake present and removed, it was possible to determine that the resistance anomaly associated with the lake could not account for the scattered fields seen in the late time channels. Accordingly, this part of the measured response must be due to an unaccounted for conductor within the sediments or the basement.

Modelling the conductivity of the sandstone

The model accounts for many of the features seen in the data, but Figure 9 shows there is a significant difference between the modelled response and the data at mid-times Because the differences occur in mid-times, their effect is likely due to a conductor deeper than the near-surface mesh, and shallower than the basement conductors which account for the late time crossovers.

In particular, both the slight peak in the data and the eastward extension of the anomalous response, marked by of the horizontal line in Figure 9, is not replicated. To account for this effect, the conductivity of the lower horizontal mesh was adjusted to be 2 ohms in the interval -50E to 350E. This adjustment did not produce the desired results. An adjusted model, shown in Figure 10, in which the anomalous zone was centred on 700 E with a resistance of 1 ohm in a background of 5 ohms produced a superior result. This result shows the anomalous conductivity lies over the two vertically dipping conductors.

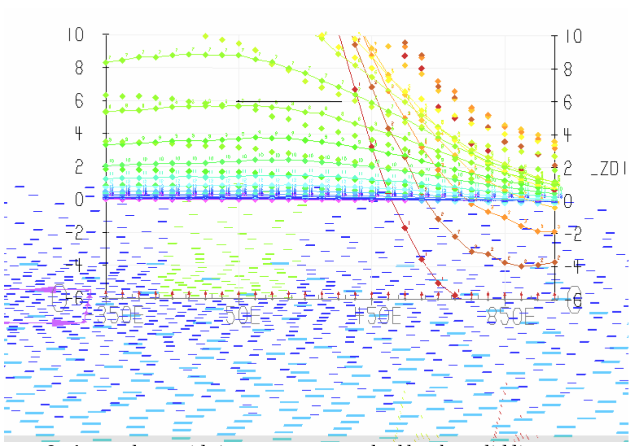

Figure 9: Anomalous mid-time response marked by the solid line.

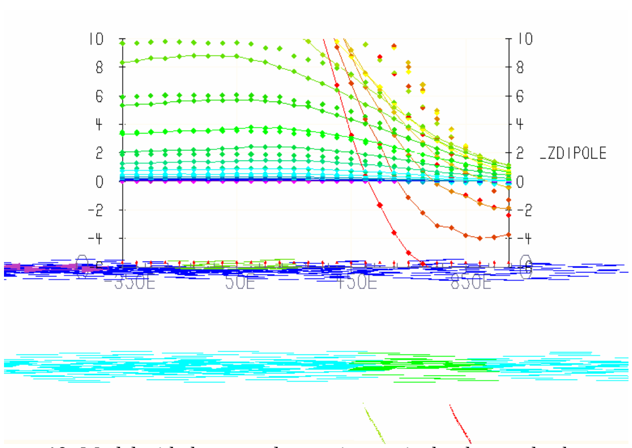

Figure 10: Model with the anomalous resistance in the sheet at depth 350m. The anomalous zone is plotted in green.

CONCLUSIONS

A detailed model of the electrical structure of the Cree Lake Extension has been developed using MultiLoop III. The model was created by incrementally adjusting the properties of the meshes until a good fit between the model and the data were obtained.

Success in building a representative model of the ground from electromagnetic data depends on two competing requirements: 1) the capability of the modelling algorithm to adequately represent the conductivity characteristics of the ground that are responsible for the observed response, and 2) the time required to conclude each calculation as the interpretation progresses. MultiLoop III, with its mesh based thin-sheet formulation, avoids the massive computations required by a fully three-dimensional approach while maintaining the ability to represent complicated conductivity structures in the ground: It embodies a good compromise between the two competing requirements of electromagnetic interpretation software.

For the data examined here, it was possible to show that while surficial conductivities were important in the early-time data, their effects would be small in the late time data. It was also possible to model the response at intermediate times to show that the response in those channels could be attributed to an anomalous conductivity in the mesh at 350 meters depth. This resulted in identifying a possible conductivity anomaly in the sediments associated with the basement conductors. More modelling, however, would be required to fully tease out the relationship between the sedimentary and the basement conductors.

ACKNOWLEDGEMENTS

The authors would like to thank Cameco Corp., and in particular Brian Powell, Garnet Wood, Lawrence Bzdel and Claire O'Dowd, both for providing the data, and also for their comments, both of which were essential for developing the interpretation techniques presented here.