Modelling of the Millenium Deposit with MultiLoop III

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The Millenium Deposit

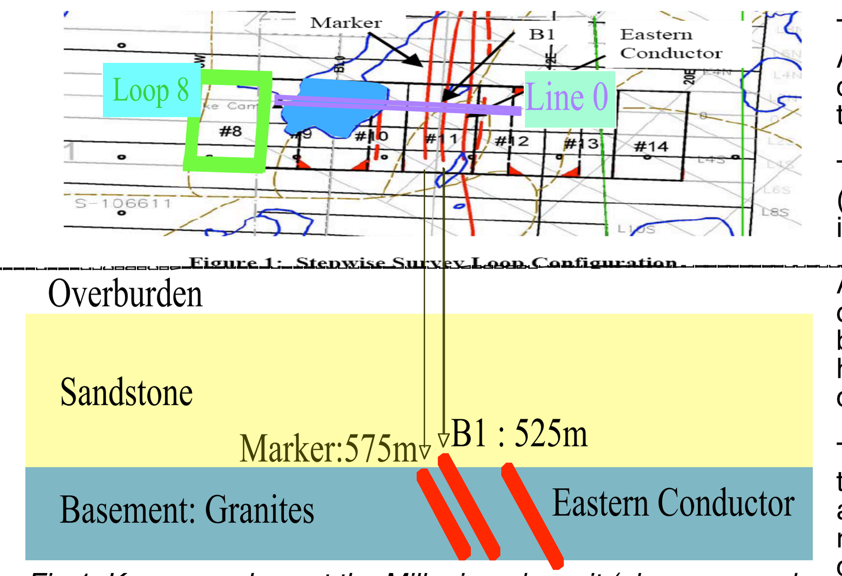


Fig.1: Known geology at the Millenium deposit (plan map and data are courtesy of Cameco Corp.).

The Millenium deposit is located in Saskatchewan's Athabaska basin under approximately 500 to 600 meters of sandstone. A step-loop EM-37 survey was conducted to better understand the geology.

This poster presents a model study of data aquired from (step) loop 8 (illustrated in green) along line 0 (illustrated in violet).

A schematic diagram of the geology at the Millenium deposit is illustrated on the left. The basement rocks below the sandstones are thought to host 3 conductive horizons (illustrated in red): the marker, B1 and eastern conductor.

The important electrical elements in this interpretation are the conductors (red), the sandstone (yellow), the lake (blue) and the overburden. Even though the sandstone is often resistive (4000 ohm-m), because of its thickness, the total conductance can be important.

Elements of MultiLoop III

MultiLoop III models the inductive response of thin conductive meshes using a rapid time-stepping solver. It extends the concept of thin-plate modelling to include more complex shapes. Finite meshes can be used to represent geologically realistic shapes such as synclines, folds, faults and contacts. Pseudo-infinite meshes can be used to represent extensive regional conductors and conductive horizontal layers. Meshes permit more realistic models than can be made from simple plates alone.

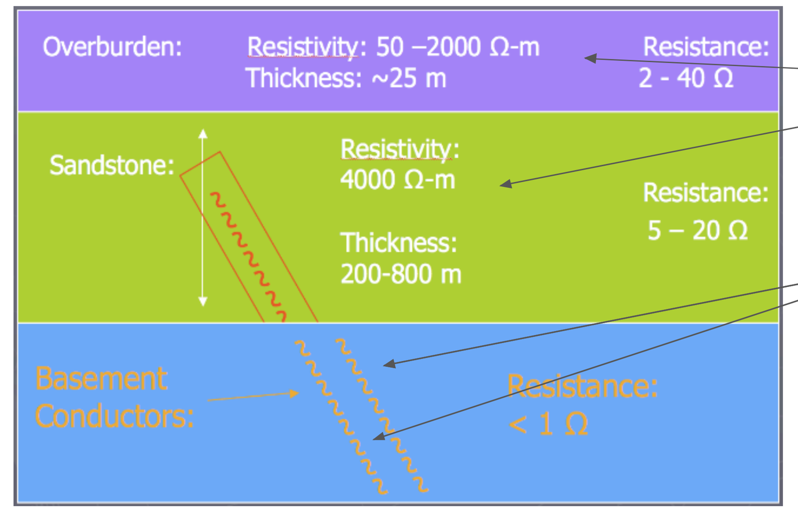
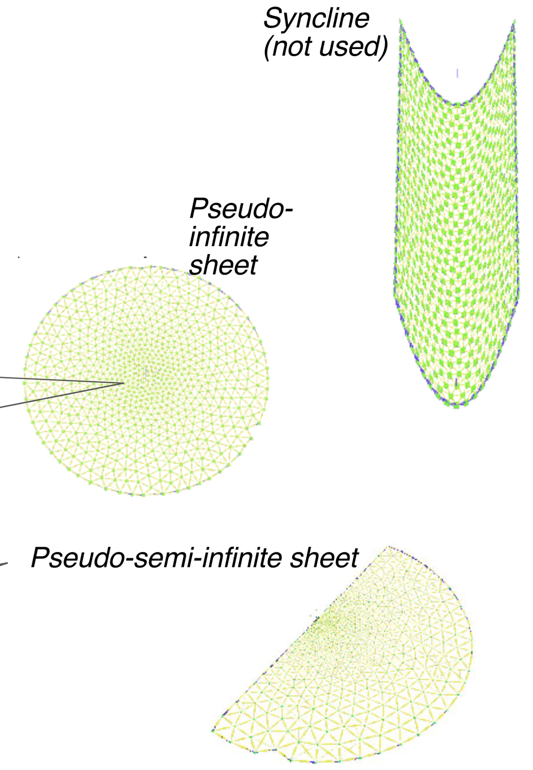


Fig. 2: Translation of the known geology at the Millenium deposit into mesh elements for use by Multiloop III.



Conductors are built-up from meshes, which may be selected from stock, or custom built.

In the Millenium model, the overburden and sandstone were represented by pseudo-infinite meshes, while the basement conductors were represented by pseudo-infinite halfsheets.

Importing the data

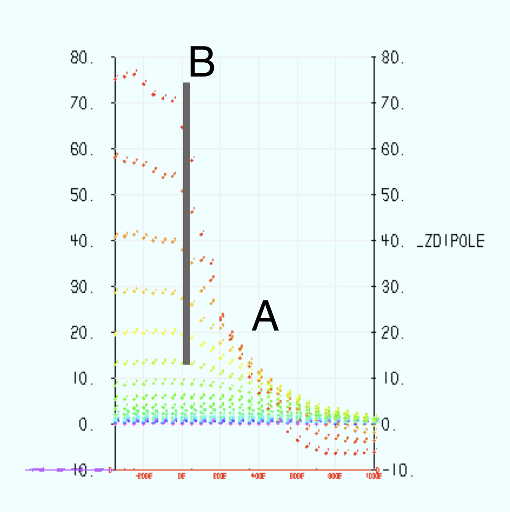


Fig. 3: Imported EM-37 Step Loop data from Loop 8 (full scale plot) in nT/sec

The EM data are illustrated in Figure 3 (showing the full scale data) and Figure 4 (detailing the late time channels). The early time data are plotted in red, the later time data in blue. The loop location appears in purple to the left of the line.

The early time data show a definite response associated with currents flowing either in the overburden or in the sandstone. Evidence of horizontal current migration is evident at the early time cross-overs (A). Nearer to the loop (B), the early time profiles have a platform shape, indicating support for the magnetic field in the proximity of the loop.

Although the response is small, the late time data show a consistent cross-over (C) response at late times, indicative of the conductors in the basement granites. Note the peaks at D, indicative of a potential lateral change in conductivity.

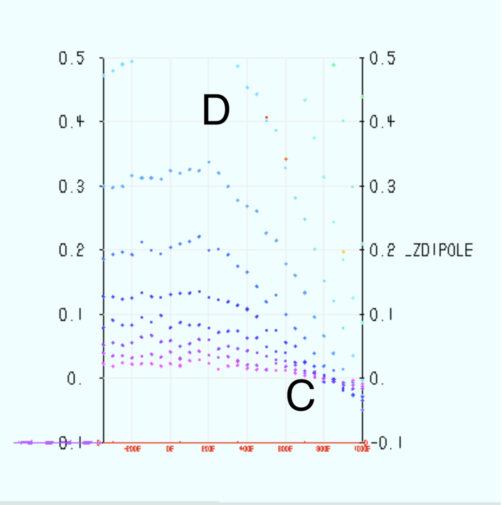


Fig. 4: Imported EM-37 Step Loop data from Loop 8 (detail plot) in nT/sec

A first try....

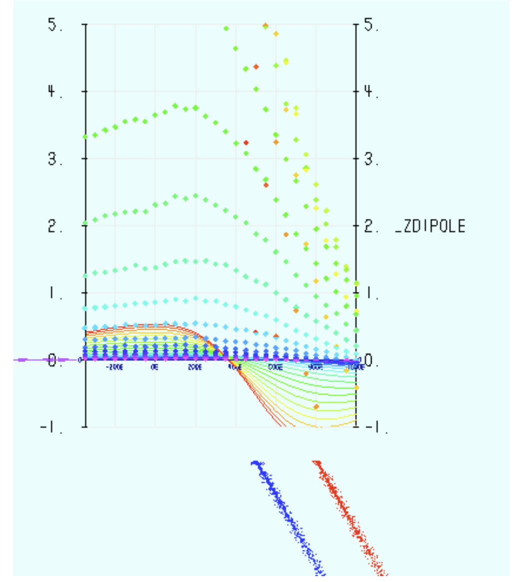


Fig. 5: The first step was to compute a simple two-conductor model. The result (lines) is plotted with the field data (points).

As a first step, a simple model using two semi-infinite half sheets to simulate the response of the basement conductors was run. The intent was to try to model the location of the cross-overs incorporating the a-priori geological information provided by Cameco.

The two conductors were both placed at a depth of 500 meters, dipping to the southeast with a dip of 60 degrees. Pseudo-semi-infinite meshes were used to represent the conductors with 601 points on each mesh. The meshes have a diameter of 4000 meters. The western conductor was assigned a resistance of 0.4 ohms (2.5 S) and the eastern mesh a resistance of 0.05 ohms (20S).

Results of the first model are shown on the right. The dipping conductors are coloured according to their surface resistance (the inverse of conductance), with red being the more conductive.

It is clear from the modelling that the response of the basement conductors is small relative to the response of the sediments, and a complete model should include the sediment conductiivity.

Assuming a resistivity of 4000 ohm-m, and a thickness of 500m, the conductance of the sediments can be estimated to be 0.12 Seimens.

The figures to the right illustrate the model results when a single semi-infinite mesh was used to simulate the sandstones. The far figure to the right illustrates that the response is under estimated. The figure immediately to the left illustrates that the response of the basement conductors is distorted by the sediments.

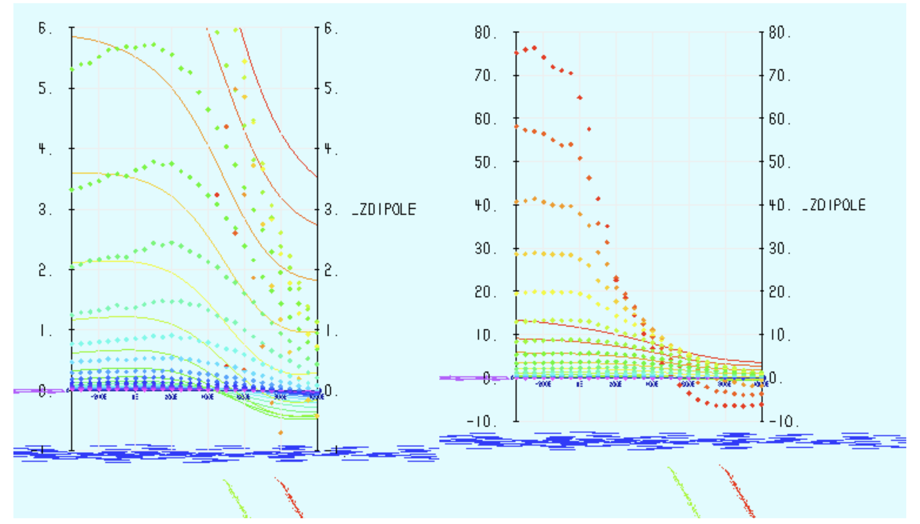


Fig. 6: Initial models that include the effect of the Athabaska Sandstone indicate that its background effect cannot be neglected.

Accounting for background conductivity

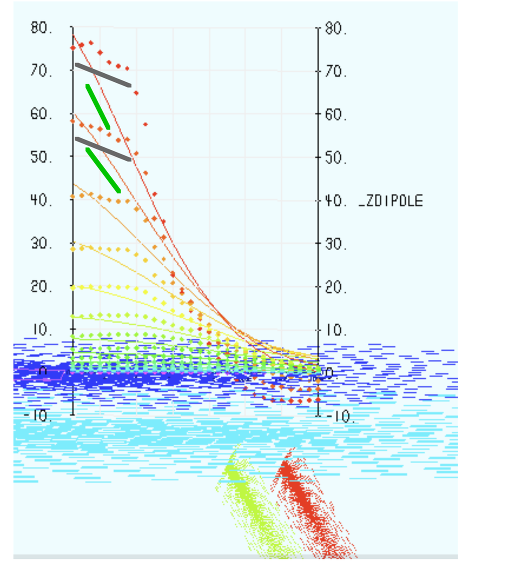


Fig. 7: The background response was simulated with two pseudo-infinite sheets.

A fairly good fit to the background was obtained by modelling the sandstone with two pseudo-infinite meshes. The top mesh had 1501 nodes, a diameter of 6 kilometers, a resistance of 20 ohms and a depth of 10 meters. The lower mesh had 1101 nodes, a diameter of 8 kilometers, a resistance of 5 ohms, and a depth of 350 meters. The model consists of 3404 nodes.

The resulting model is plotted in Figure 7 to the left. Note that platform-like response in the data (gray lines) differs from the modelled linear drop-offs (green lines). This indicates support for the early time magnetic field

A detail of the computed background is plotted in Figure 8. Note the anomalous responses seem to continue into late time, (gray line) and so may be overprinting the much smaller responses of the conductors.

Often, to understand the response of a deep conductor, it is necessary to understand and remove the effects of surface noise. Once surface noise is understood, it is possible to model deep structures with greater certainty.

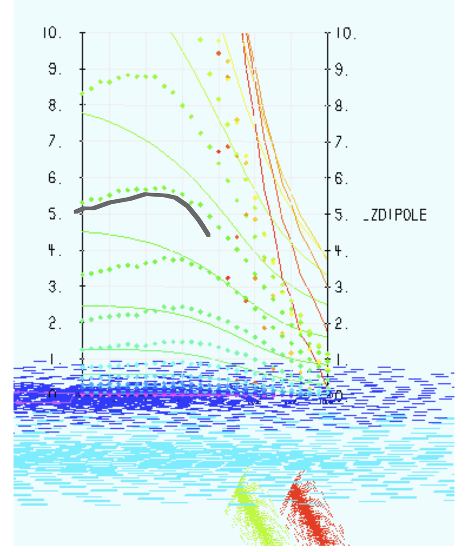


Fig. 8: Modelled background (detail).

Modelling (stripping) the near surface effects

There is a conductor near the loop that has not been accounted for. A review of the plan map shows that a lake is present. Lakes can contain conductive sediments, and so the lake / lake sediment may be the unknown conductor.

To model the effect of the lake, the overburden layer was given a variable resistivity specified by the formula:

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IF (ABS(E) < 200, IF (N – 100 > 0, 0.6, 20), 20)
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The formaula consists in this case of two nested "if" statements and was used to assign a patch of ground with a resistance of 0.6 ohms within the uniform mesh resistance of 20 ohms. Figures 9 and 10 illustrate models with a 1 ohm and 0.6 ohm lake respectively. The 0.6 ohm lake model fits the early time data reasonably well.

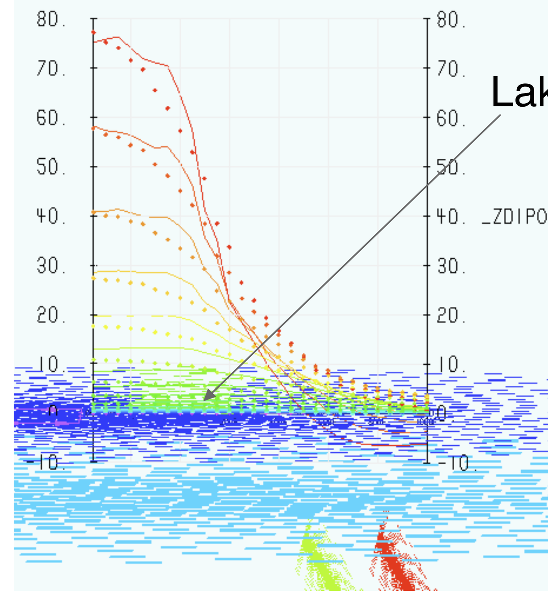

Fig. 10:The effect of a 0.6-ohm resistance lake.

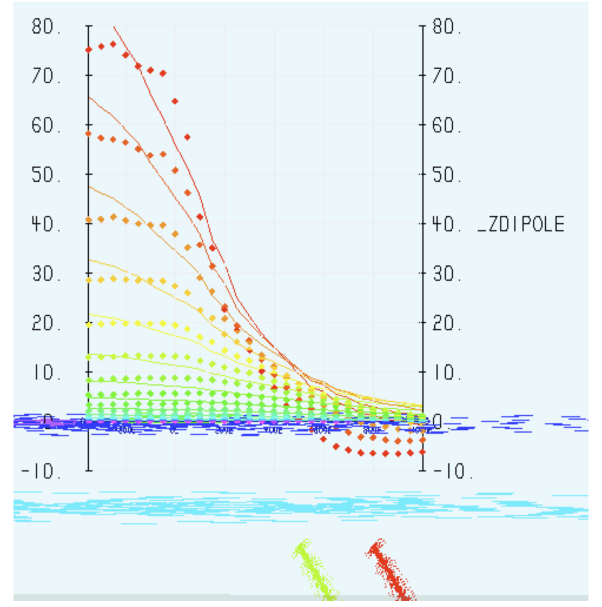

Fig. 9:The effect of a 1-ohm resistance lake.

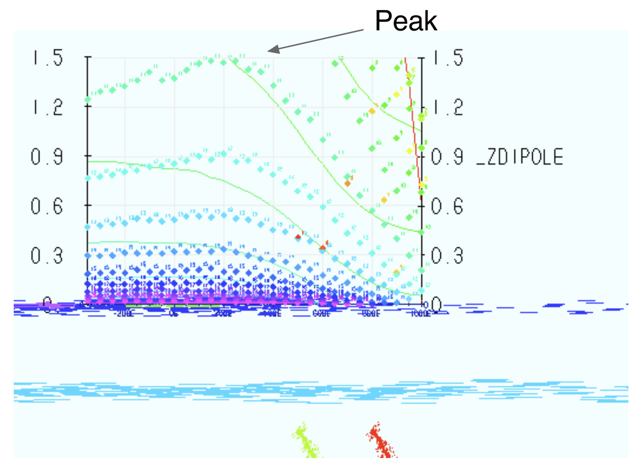

Fig. 11: While the lake response fits the early times, there is a mid-time response peaking at approximately 200 E that is not accounted for.

Modelling alteration in the sandstone

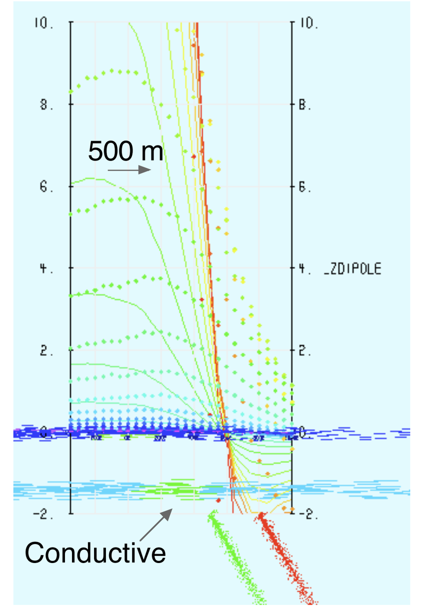

Fig. 12: Initial model of the alteration zone

Figure 11 shows there is a residual at approximately 200 E that was not simulated by the lake model. To account for this, a conductive 1-ohm band centered at 200 E was inserted into the resistance of the deeper horizontal mesh (located at 350 meters depth). Figure 12 illustrates the result. Note the modelled peak is offset from the peak in the data by 500 meters.

The conductive zone was then shifted by 500 meters to the east to (Figure 13), with the result that the fit to the mid-time peaks was significantly improved. Note that the location of the conductive zone now overlies the two conductors. This may be an indication that alteration occurs in the sandstones which is associated with the basement conductors.

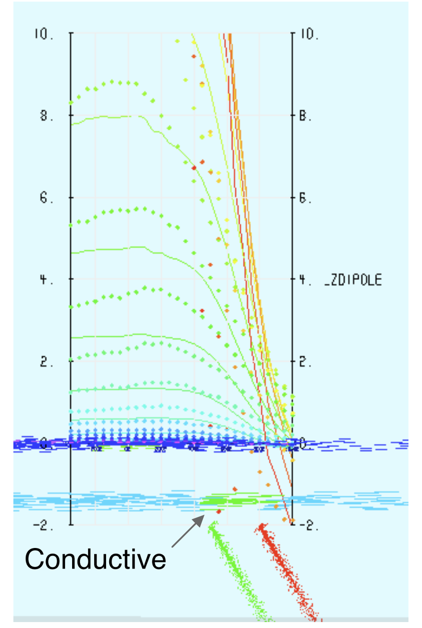

Fig. 13: Final model of the alteration zone

Summary

Electromagnetic data can contain a wealth of under-interpreted information. While a comprehensive interpretation such as the one presented here can take time, the insights offered can be quite rewarding. In this particular case, a possible alteration zone in the sediments above the basement conductors has been identified. This in-turn has significance in terms of selecting target priorities.

In this interpretation, early, mid and late times have been modelled to simulate overburden variation, conductivity variation in the sandstone, and the basement conductors. The interpretation honours the data over a large range in times.

Some insights into interpretation are:

- Conventional modelling software based on the thin plate or similar representations undoubtedly has its uses, but the use of such software tools is unlikely to furnish the insights afforded by more comprehensive models.
- All modelling software must oversimplify the "true" conductivity structure of the ground for pragmatic purposes, and the process of simplication can lead to "shape" biased solutions. With the ability to incorporate more shapes into the models, MultiLoop III is less susceptible to shape bias than are methods that rely on a single shape.
- Experience has shown that modelling conductors in isolation without considering the interaction with the "background" can lead to modelling errors. This occurs because the "background" can distort the response of target conductors, altering the electrical properties that would otherwise be measured in free-space.
- To correctly model the effect of horizontal layers, such as the Athabaska Sandtone, meshes several kilometers in extent are required. Smaller meshes cause the currents to "pile up" at the edges, causing the modelled late time decays to be distorted. This in turn can affect the interpretation of the basement conductors.
- Electromagnetic data are sensitive to subtle variations in the conductivity of the Athabaska (and other) sediments, perhaps to a greater degree than was previously believed. This in turn has implications for mapping and identifying alteration.