Synthesizing 3D Time-Domain Electromagnetic Geophysical Forward Models for Uranium Exploration in the Athabasca Basin

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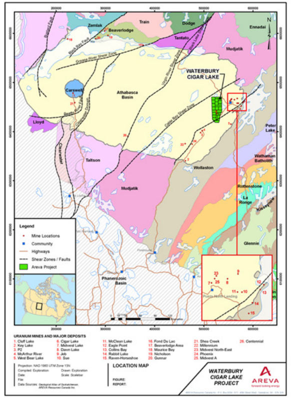
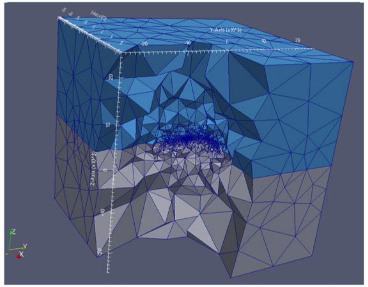
Background

Modern mineral exploration in the Athabasca Basin (northern Saskatchewan) is often undertaken in areas of deep sediment overburden, looking for small targets up to 500 metres or more below the surface. Due to the high conductivity of the ore bodies and related graphitic fault zones, time-domain electromagnetic (TDEM) surveys are an important geophysical prospecting tool and have led to the discovery of the majority of known uranium deposits in the region.



Model Construction

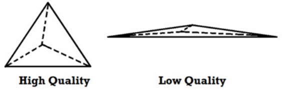
Recent advances in the 3D forward modeling of frequency-domain EM data using unstructured tetrahedral meshes have shown great promise in more accurately modeling anomalies of complex shapes. Methods also now exist for incorporating realistic structural geologic data into these unstructured meshes. A method of using many 3D frequency-domain forward responses in order to construct an accurate 3D time-domain forward response is being investigated in this study for its practical use in more accurately delineating complex, thin, near-vertical conductors and closely related sets of conductors.



Cutaway image of a 3D unstructured tetrahedral mesh with increasing refinement toward center of model, triangular facets are outined in blue.

Mesh Refinement

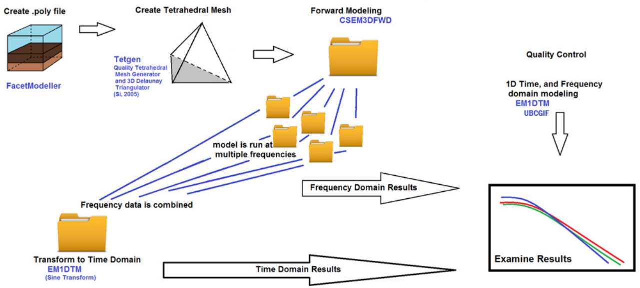
Obtaining a high quality mesh is of utmost importance in order to compute accurate values of the electric and magnetic fields. Mesh quality is dependent on the geometry of the tetrahedral cells and most importantly their dihedral angles. A variety of methods were tested to adequately refine models for the best results in both the frequency and time domain.

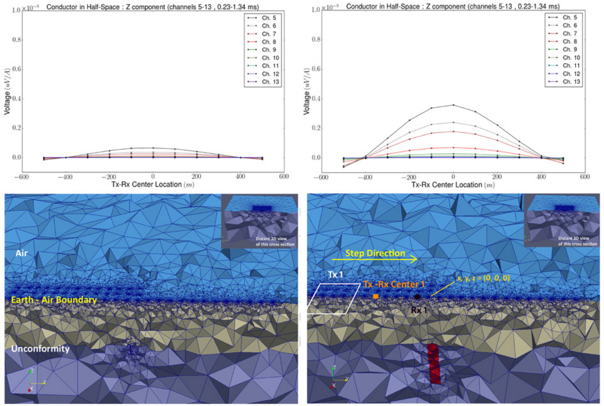


Forward Modeling

Forward modeling is carried out initially in the frequency domain using the 3D finite-element method of Ansari and Farquharson (2014). Models are computed for one frequency at a time, with the results for many frequencies then combined and transformed to produce a single 3D time-domain response.

Overview of Forward Modeling

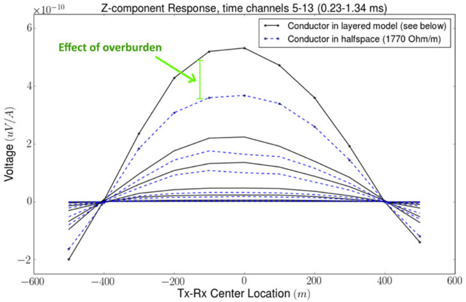


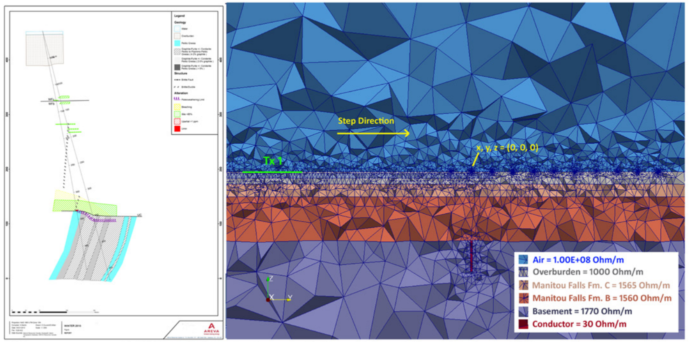


Two Slingram-style models and their z-component magnetic field results: at left a realistically sized conductor (strike length of 200m, width of 10m, 100m depth extent), at right a much larger conductor for comparison (strike length of 200m, width of 100m, 500m depth extent).

Current and Future Work

Current work is focused on creating a set of models that demonstrate a variety of simple conductors with varied thickness, dip, conductivity, shape and position. Work has also begun in creating models that reproduce realistic exploration situations like that seen below based on data obtained from Areva's Waterbury-Cigar Lake Property. Future work will be focused on incorporating a wider variety of relevant structural data obtained from drill logs, geologic maps/cross-sections, etc. in order to create models that are able to provide better understanding of the complex exploration challenges currently faced by Areva in the Athabasca Basin.





Z-component magnetic field results for a simple, geologically realistic model based on Areva drill logs and rock property data.

Citations

Ansari, S. & Farquharson, C.G., 2014. 3D finite-element forward modeling of electromagnetic data using vector and scalar potentials and unstructured grids. Geophysics, 79(4), pp.E149-E165.

EM1DTM; A Program Library for Forward Modelling and Inversion of Time Domain Electromagnetic Data over 1D Structures, version 1. Developed by the UBC-Geophysical Inversion Facility, Department of Earth and Ocean Sciences, University of British Columbia, Vancouver, British Columbia.

Si , H., 2007, TetGen: A Quality Tetrahedral Mesh Generator and Three-Dimensional Delaunay Triangulator, http://tetgen.berlios.de.

Acknowledgements

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