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Accessing Potash Inflow Hazards

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Summary

Potash mining in Saskatchewan has made extensive use of geophysics for a variety of engineering and environmental purposes. One of the applications for geophysics in potash mining is the location and quantification of near mine geohazards that are known to cause inflows. The source of these water inflows are anomalously porous sedimentary formations located either above the potash evaporate layer or within the salt itself. For a broad overview of this subject, see Funk et al. (2019). The use of surface 3D seismic has proven to be a highly effective tool in identifying many geohazards; however, in order to better quantify these features other geophysical tools have been brought into use. These tools have ranged from DC resistivity to frequency- and time-domain electromagnetics. This project focuses on the use of time-domain electromagnetics (TEM) to delineate an area of anomalously porous carbonates near a potash mine; this effort was pursued through both analysis of survey data and computer modelling. In-mine TEM survey data was collected in a pair of profile lines that extended from normal to abnormal conditions under one such anomaly in a potash mine and was provided to the Butler Research Group by Nutrien Ltd. as part of a Mitacs Accelerate project with the author. Computer modelling required a full-space environment to account for the diffusion of current in both directions above and below the mine layer. This forward modelling was performed in COMSOL Multiphysics and sought to quantify the relationship between the change in the environment and the expected response from the TEM signal.

Theory / Method / Workflow

The carbonates that are the focus of this project reside in the Dawson Bay formation. In general, the large lower portion of the Dawson Bay carbonates are tight and non-porous, serving as a strong seal against other aquifer layers above. However, this member has been known to become porous itself under specific geological conditions. The Dawson Bay formation lies just above the Prairie Evaporite formation which contains the potash ore zones. The target carbonates vary in thickness depending on the mine site but are 30-40 metres thick and reside around 40 metres above the potash seams.

Time-domain electromagnetics was selected for this project both for its superior depth sounding capabilities when compared with frequency-domain EM and because of the difficulty in injecting direct current through the highly resistive salt of the mine. Computer modelling of in-mine electromagnetics required the implementation of a full-space modelling environment with variation in the electromagnetic diffusion occurring both above and below the transmitting layer. Forward TEM modelling was performed in COMSOL Multiphysics using the AC-DC magnetic fields module and 2D-axisymmetric geometry. Rudimentary inverse modelling was performed in Matlab using the in-built simplex minimization algorithm and tied to COMSOL Multiphysics via LiveLink for Matlab. This simple inverse modelling technique was performed using several different parameter sets and weighting controls.

Results, Observations, Conclusions

Figure 1 shows the decay view results from one of the surveyed profile lines. Station 01-01 represents the westernmost station on this profile line and resided in a geologically normal area of the mine. Station 01-11 represents the easternmost station on the profile line and resided in an area with abnormal geological signatures. The stations on this surveyed line were 100 metres apart. The decay response showed a large and repeatable conductive response beginning around 0.1ms for both the inline horizontal (radial) and the vertical fields toward the eastern end of the profile line. This conductive response coincided with the expected extent of the anomaly. A set of inverse models were constructed on this dataset in order to constrain the depth of this conductive anomaly. One set of inverse models included a large parameter set and was weighted to keep the values geologically appropriate. The other inverse model set included a limited 2-parameter inversion with no weighting controls applied. The results can be seen in Figure 1.c. The weighted parameter set showed that only the two Dawson Bay carbonate layers had a conductive relationship with the location of the anomaly. The weighted and non-weighted inverse model values assigned to the Dawson Bay layers agreed with one another very well. The full set of parameters used and their results in the weighted 1D inverse model sets are shown in Figure 2. The results of this project suggest that the resistivity contrast in the anomalous area of this study seem to predominantly reside in the Dawson Bay formation and that their resistivity change is almost by an order of magnitude. More broadly, the project shows that TEM can be used effectively in conjunction with other geophysical tools to assist with the detection and quantification of anomalous geohazards near potash mines.

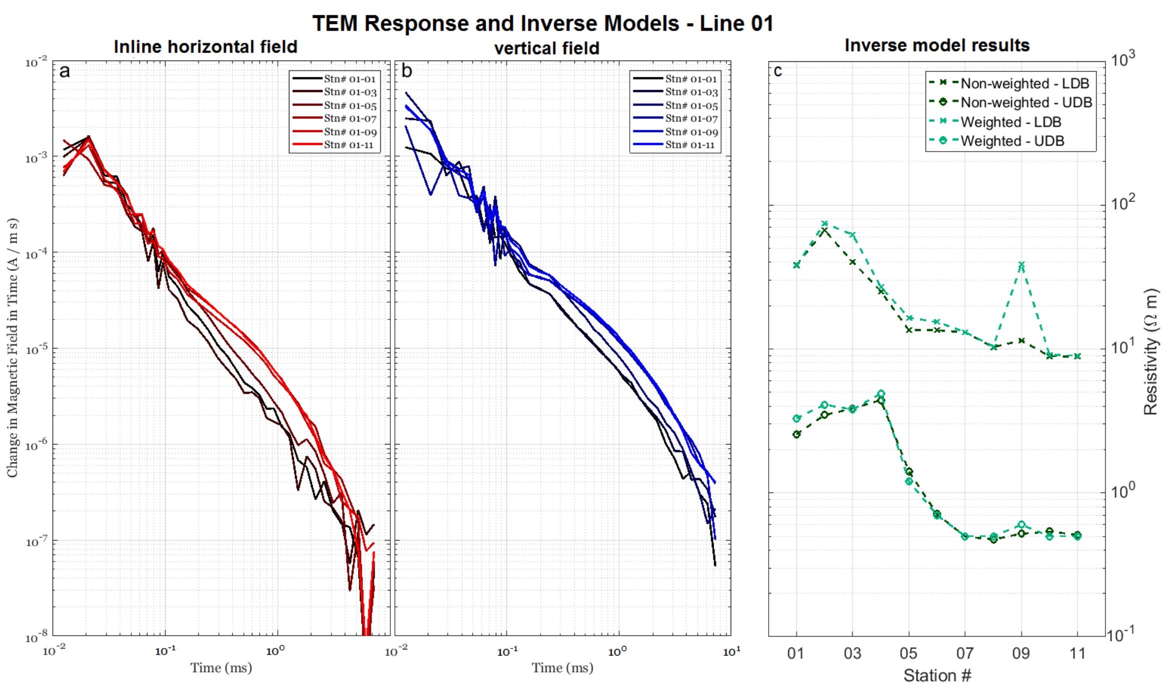

Figure 1: In-mine TEM survey data from one of the profiled lines. The time decays from various stations are plotted (stations ranged from 1 to 11). Also shown are the inversion results for this dataset (c). The terms "LDB" and "UDB" stand for the Lower and Upper Dawson Bay carbonates respectively.

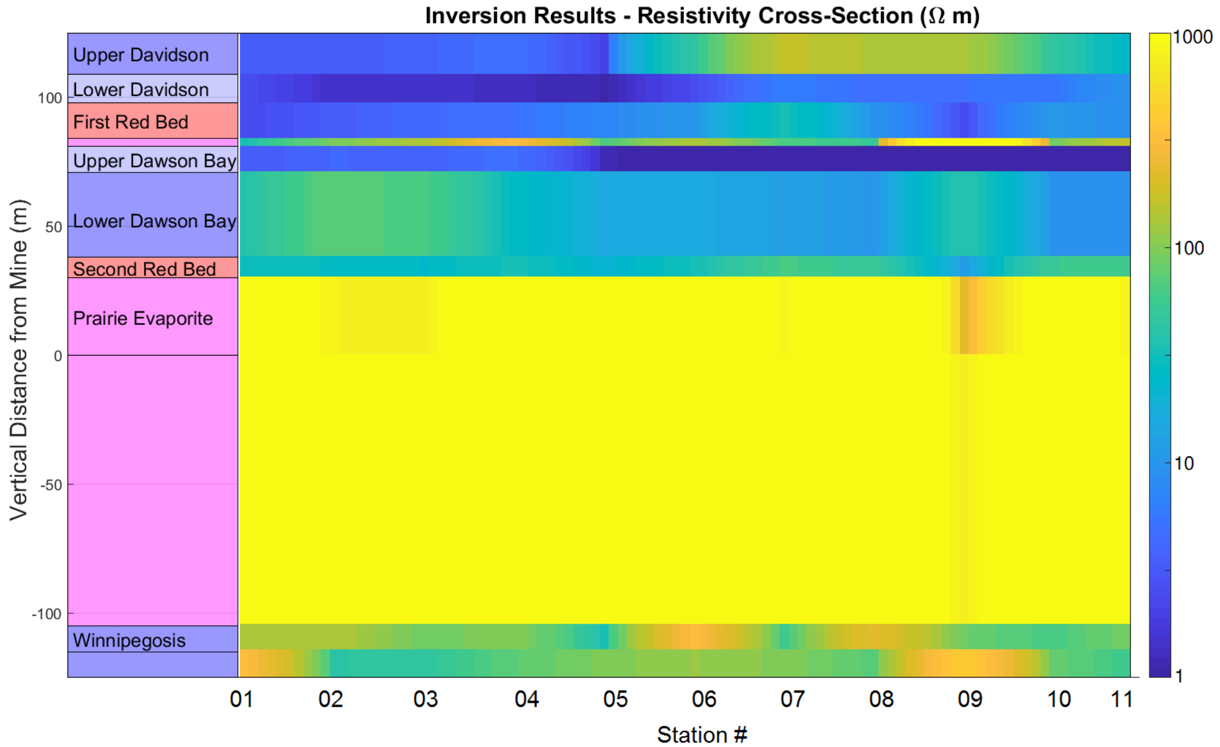

Figure 2: Results of the set of 1D weighted inverse models. The resistivity values are interpolated between data points.

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