Airborne and Ground-Based TEM Methods in the Mining Industry: Advantages, Pitfalls, and Limitations

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Summary

How does one choose the best method when performing a geophysical survey? Every geophysical method can produce differing results, with certain advantages and disadvantages depending largely on the physical properties of the target and the scale of interest. Other factors that are not immediately obvious when survey planning may play a significant role in the final data quality – such as physical field conditions, nearby infrastructure, time of year, etc.
Perhaps one of the best, but least understood geophysical surveys used in Alberta resource management is the Time Domain Electromagnetic (TEM) method. This method can be used at a variety of scales. From airborne to ground-based TEM, this method can be deployed successfully and effectively for the exploration/delineation of potential water resources, near-surface geohazards assessment, delineation of mineable oil sands, and perhaps most commonly around the world, mineral exploration.

This presentation serves to introduce and explore the broad utility of TEM methods in a variety of scenarios, and to refresh or introduce the viewer on TEM usage in the energy and mining industry. Assumptions, advantages, disadvantages, pitfalls, and field implementation will be discussed to illustrate where these methods are most effective, and where they are not.

Finally, it will be shown where such methods can be combined with traditional methods, such as seismic, to constrain the results and produce an enhanced interpretation of the subsurface. One method alone cannot always detect important geological properties such as grain size, type of pore fluid, or other variations in the soil/rock layers; however, such information can be inferred with the use of combined methods.

Theory / Method

Time-domain Electromagnetics (TEM)

TEM incorporates Faraday's Law to induce a voltage within the subsurface. Faraday's Law implies that a measurable voltage is induced at any point where a change in the magnetic field through a coil occurs. In practice, this method uses a loop of wire, where a current is injected through it to induce a primary magnetic field (Figure 1). When the current is rapidly turned off, a change in the magnetic field is induced, creating a secondary voltage in the subsurface, which then decays rapidly with time, proportional to the chargeability of the subsurface. The electrical waveform propagates into the subsurface and creates secondary magnetic fields/eddy currents with a voltage that is proportional to the geological layers it travels through. These properties can be measured at the surface using a receiver coil, thus providing a time-dependent measurement of the subsurface.

Performing a TEM survey depends on a host of factors when considering the scope of the project. A solid understanding on the background theory allows us to better decide how to deploy the method that is most appropriate for the conditions/scope of work. Cost, depth of investigation, physical properties of the target, scale of the data, and physical field conditions all play a role in determining the feasibility of one method over the other, and ultimately to decide which method produces the best result, for the best value.

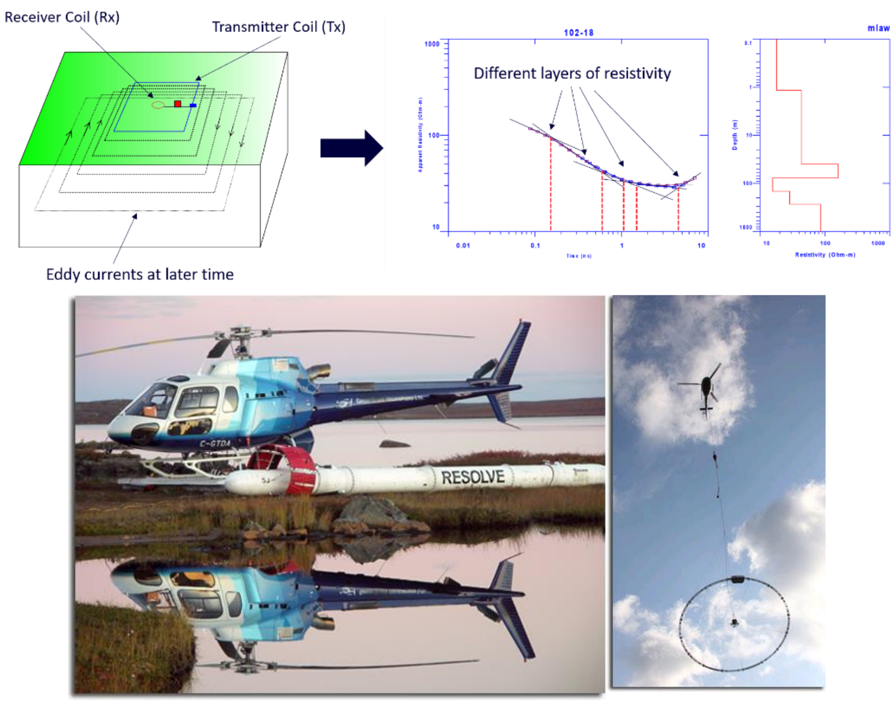

Figure 1: Top: Schematic of a ground-based Time Domain loop as deployed in the field, with the resulting apparent resistivity curve shown on the right. Bottom: Photo of the airborne EM (AEM) deployed in the field.

Results & Discussion

Shown in Figure 2 is a survey that was performed where an airborne EM survey allowed us to explore the character of sand channels, which are important for water resource management and to support resource development. As the figure shows, the airborne survey allowed us to target locations that were identified as probable sand channels, which then allowed us to plan strategic locations for ground-based Time Domain surveys. The ground surveys provided higher resolution subsurface results, allowing a thorough interpretation of the subsurface to strategize drilling operations based on variations in the subsurface stratigraphy that were not captured by the AEM survey alone. Finally, the TEM method can be used most effectively when combined with other more traditional methods in the mining and resource development industry. Figure X shows a TEM survey combined with seismic, which allows us to interpret the subsurface with much greater detail than we otherwise could with either method alone. TEM allows us to infer information about grain-size, mineralization, potential of saline water, and even more when existing drilling results are also incorporated.

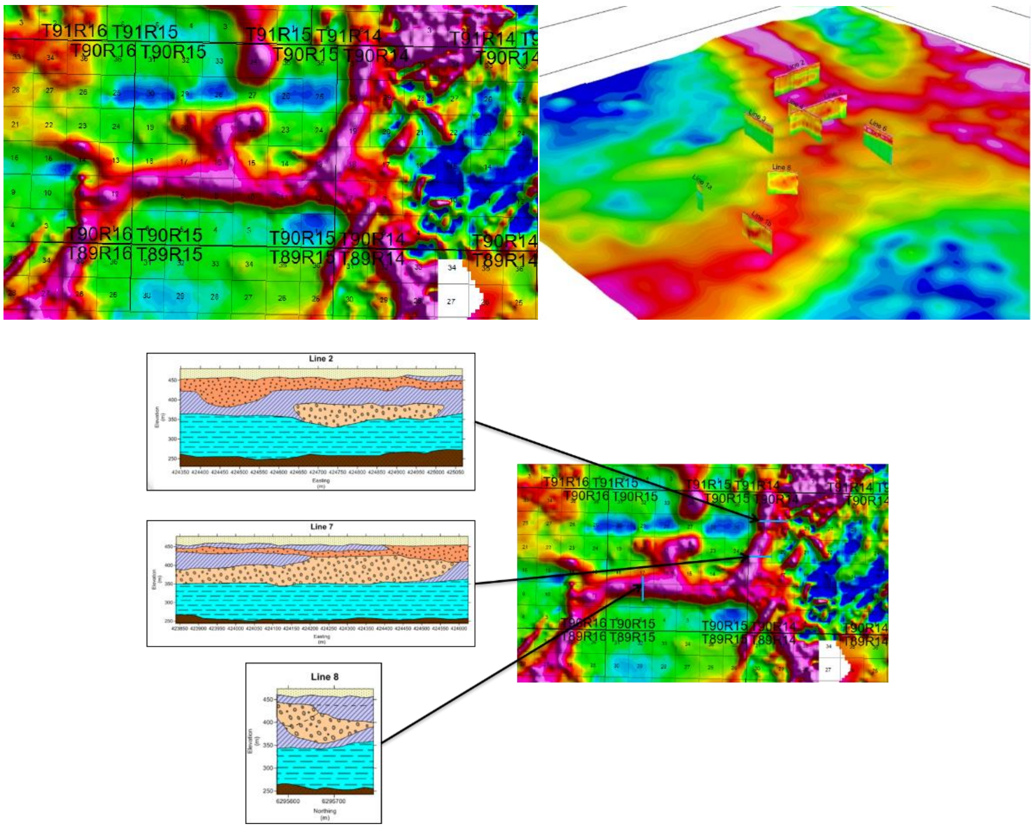

Figure 2: Comparison of Airborne EM (AEM) and Ground-based Time Domain EM (TEM) results over an area in Northern Alberta. AEM results show good regional coverage to identify locations of interest, while ground-based TEM allows for much higher resolution delineation of features of interest.

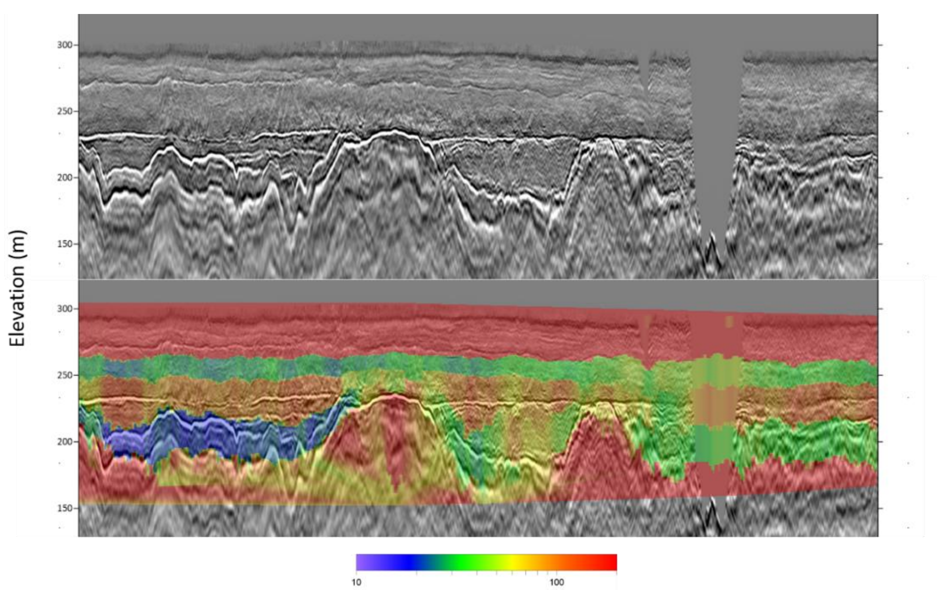

Figure 3: Top: Example of a 2D seismic reflection survey. Bottom: Overlay of TEM resistivity on seismic section.

Conclusions

The purpose of this paper was to introduce the Time Domain Electromagnetic (TEM) geophysical method, and provide a thorough background on the physics, the methodology, and the advantages/disadvantages of its implementation in airborne and ground-based surveys. While not used as often as it could be, the TEM method can provide a wealth of information about the subsurface that is otherwise completely unknown before drilling occurs.