

Athabasca Oil Sands Exploration and Development Investigation Using the Helicopter-Borne Transient Electromagnetic Technique

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Summary

Airborne electromagnetic (EM) geophysical surveys have been performed in the Athabasca oil sands area since 1996. Improvements in technology since the first surveys were performed have increased the resolution and depth of investigation, improving accuracy and expanding the goals that can be met with this technique. Furthermore experience in a variety of environments with a variety of systems has led to an understanding of where this technology can and can not be effective. Data from a demonstration survey in an area which already has a subsurface understanding is presented here.

Introduction

Helicopter-borne transient electromagnetics (HTEM) is a relatively new classification of airborne EM systems which combines the depth of exploration achievable with time-domain EM with close to the spatial resolution of helicopter frequency domain systems. The resulting resistivity measurements are similar, but with lower vertical resolution, to electrical and inductance logging in that they provide useful information about geo-electrical contrasts between the geological horizons of interest where sufficient contrast exists. The airborne data set comprises continuous measurements at intervals along line of 3 – 6 m, from depths of 0 m to about 300m. HTEM is most effective when combined with the higher resolution measurements from borehole and ground geophysical methods.

Typically the goals of airborne geophysical surveys in the Athabasca oil sands area are:

- thickness and lateral extent of bedrock stratigraphic units such as the shale seal of the hydrocarbon reservoir for SAGD evaluation
- location of inter-till, bedrock aquifers and basal water sands
- classification of soils and overburden into sand, gravel and clay for environmental investigations and land use planning
- delineation of rich surface mineable oil sands

- heavy oil reservoir quality
- baseline surveys prior to infrastructure development

Figure 1 shows typical resistivity values of the various geological units in the Athabasca oil sands area. Figure 2 depicts typical sand and gravel filled, inter-till, glacial fluvial channels. These paleochannels commonly have high permeability, high electrical resistivity and are often fresh water aquifers and in some cases contain biogenic or migrated thermogenic methane gas. Figure 3 is a typical geological section in the Athabasca oil sands area.

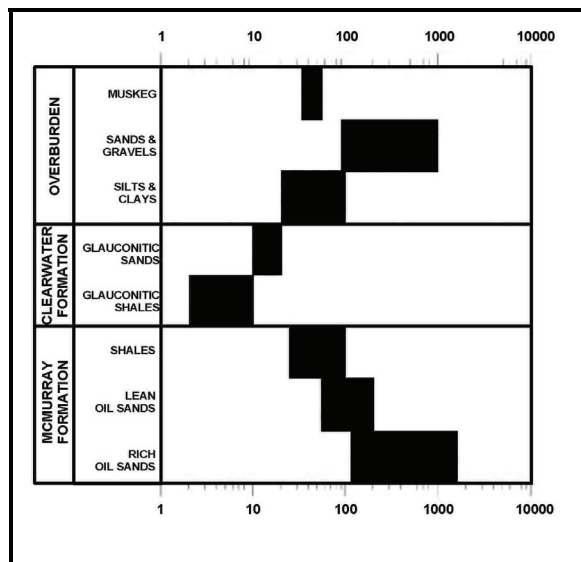


Figure 1: Typical Soil and Rock Resistivity, Athabasca Area (from Associated Geosciences Ltd.)

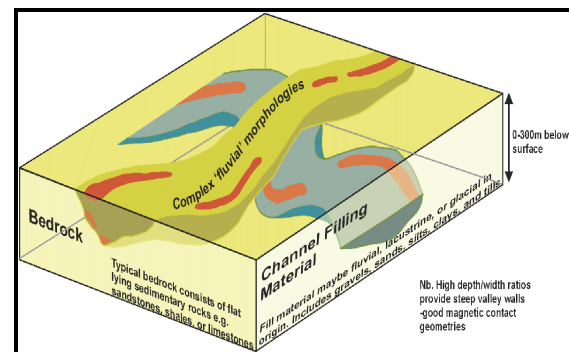


Figure 2: Paleochannel Morphology (from Jim Davies, IIT Inc.)

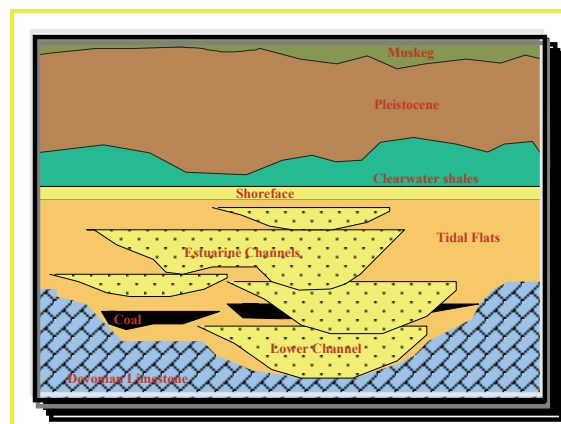


Figure 3: Geological Section (from Associated Geosciences Ltd.)

Demonstration Survey

The examples presented below are from a HeliGEOTEM HTEM survey of a heavy oil lease north of Fort McMurray Alberta. Of particular interest in this area:

- classification and thickness of soil and till for environmental assessment
- groundwater assessment, location of aquifers
- verification of the presence and thickness of the Clearwater shale to provide a reservoir seal for reservoir steam injection
- depth to the top of the McMurray oil sands reservoir
- characterization of the petroleum reservoir in the estuarine McMurray channels

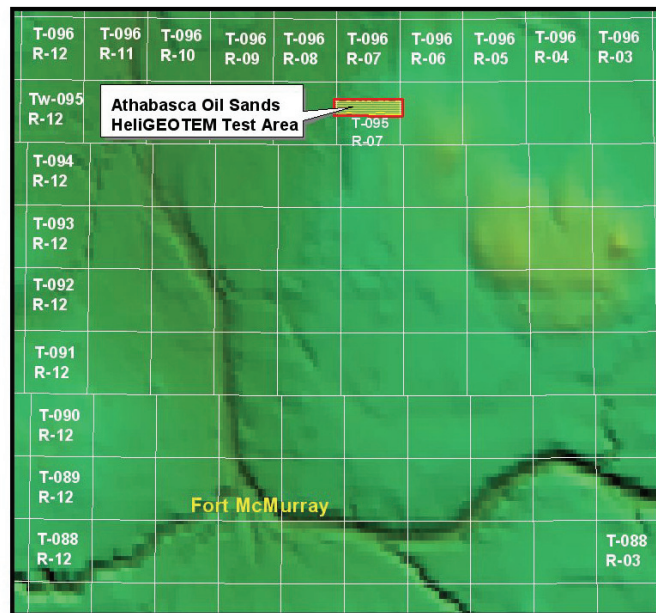


Figure 4: Location map

Data acquisition of a 100 line-km test area (see figure 4: Location Map) took place in September of 2007 during one flight of approximately 3 hours duration. The products shown in this example were prepared with the resistivity/conductivity depth image (CDI) technique, which yields 128 resistivity values at three metre intervals over a depth extent of 384 metres. Actual depth of exploration is controlled by the conductivity of the subsurface geology. This information is presented as both resistivity depth sections and plan images.

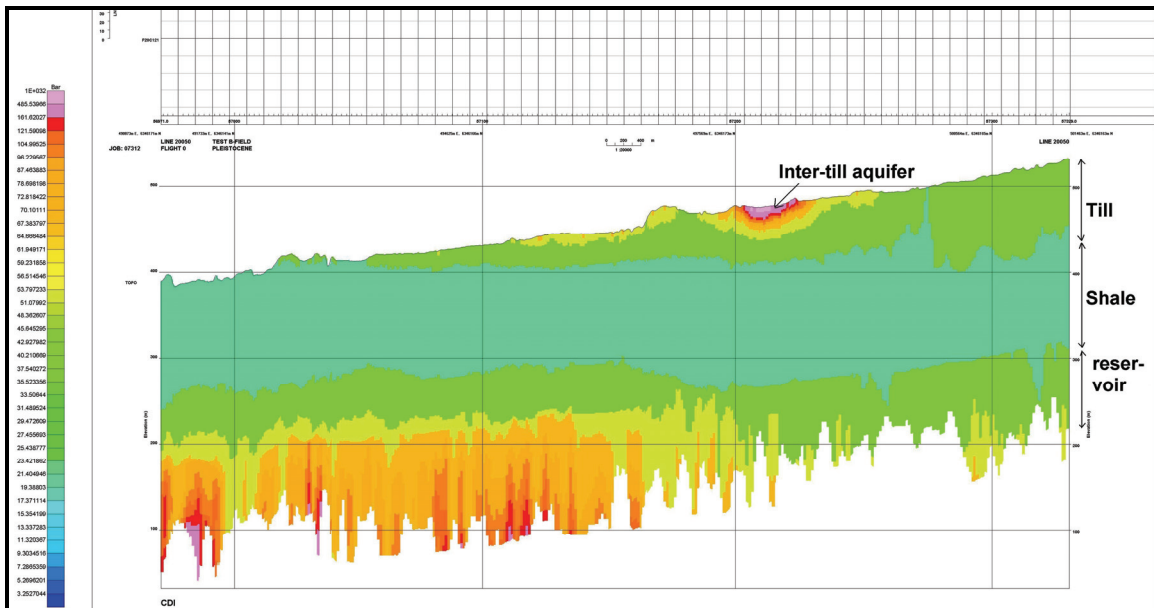


Figure 5: Resistivity Depth Section

Figure 5 is a typical Resistivity Depth Section product from the CDI technique from the Athabasca oil sands HTEM test. High resistivity values are hot colours and low resistivity cool colours. A proven fresh water inter-till aquifer is identified in the top 50 metres. This aquifer is a Pleistocene channel not obvious on surface and is likely covered by a clay rich soil layer that is too thin to be resolved with the airborne geophysics. Figure 6 is a plan view of a 15 metre RDI depth slice. Cooler colours, apparent on both the depth section and depth slice, surrounding this aquifer are relatively more clay-rich till.

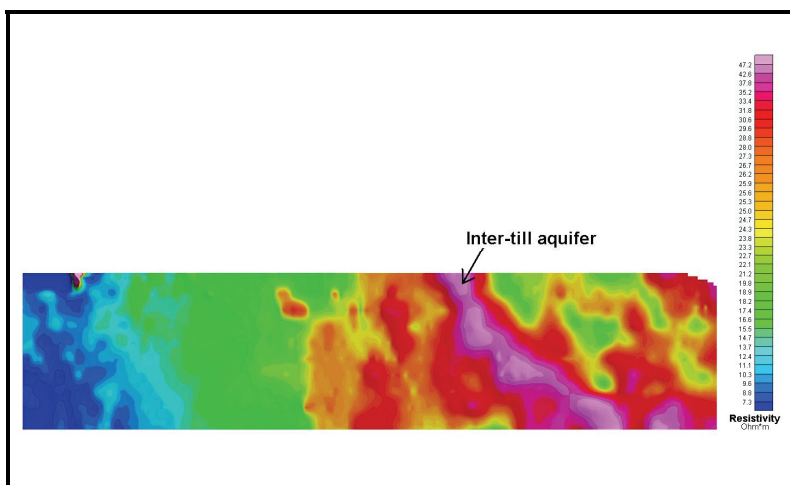


Figure 6: 15 Resistivity Depth Slice

On Figure 5. beneath the till, a horizontal conductive layer is indicated. This conductive layer is predominately a shale member of the Clearwater Formation. There is possibly some clay till on top and shale and in the top of the McMurray formation which can not be differentiated

from the Clearwater shale on the basis of resistivity. The Clearwater shale acts as a seal on the McMurray formation estuarine sands which contain the hydrocarbons. A specific minimum

thickness of the Clearwater shale is required in order to facilitate steam injection to produce oil. The thickness of Clearwater determined from the airborne geophysics can be refined by constrained inversion combined with some borehole information. However fewer boreholes are required for the project when using the airborne geophysics reducing project costs. The Clearwater thickness derived from AEM should be verified using boreholes.

The warmer colours at depth reflect sands of the McMurray formation. It is inherent in the electromagnetic technique that overlying conductive layers tend to absorb energy and reduce the signal from deeper resistive layers. This has the effect of reducing the useful information from these deeper layers. The relative high power of some HTEM systems maximizes the information available in this case.

Conclusions

The HTEM method is useful to develop an understanding of the subsurface stratigraphy, from surface to approximately 300 metres below ground surface, to identify soil and rock types, geological units that influence groundwater and contain the hydrocarbon reservoir.