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Airborne Electromagnetics in Oilsands Mining: Subsurface Characterization and Applications to Mine Planning

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Summary

Airborne electromagnetics (AEM) is an established tool in groundwater and mineral exploration and is increasingly valuable in the oilsands mining sector. At Kearl, AEM provides a cost-effective, spatially continuous geophysical dataset that complements drilling and seismic data, enabling improved delineation of geologic bodies critical to mid- and long-range mine-planning decisions. Strong conductivity contrasts within the stratigraphy allow key geobody boundaries to be mapped in plan view. Multiple AEM surveys acquired over the Kearl lease (76 km NE of Fort McMurray) successfully imaged McMurray Formation channel abandonments, collapse features related to Devonian dissolution, and the geometry of underlying reef structures. In areas with thin overburden, AEM also differentiates high- and low-net-to-gross point-bar deposits, providing qualitative insight into shallow ore-body variability. These results show how AEM can be integrated with well logs, core, and seismic to strengthen geologic interpretation and guide mine-planning workflows.

Geologic Background

The Kearl oilsands deposit comprises Early Cretaceous fluvial to marine strata unconformably overlying the Devonian Waterways Formation. Pre-, syn-, and post-Cretaceous dissolution of Prairie Evaporite units imparted significant structural and stratigraphic complexity across the lease. The primary ore body resides within the McMurray Formation, where point-bar deposits reach up to 45 m thick and channel-abandonment features are commonly ~500 m wide. Locally, marginal-marine Wabiskaw Member oil sands overlie the McMurray and form an additional mineable interval. Marine mudstones of the Clearwater Formation are variably preserved along the southeastern lease margin. The Cretaceous section is overlain by Pleistocene deposits, including deep glacial-outwash channels that locally incise through the entire Cretaceous succession.

Method

Two AEM surveys were acquired over the Kearl lease. The initial survey targeted a major Pleistocene channel system that determines the western limit of the current mine advance and lease boundary. Inverted resistivity volumes revealed fluvial geometries that were

subsequently confirmed with core, 2D seismic, and mine-face observations. Recognizing the technique's broader applicability for mapping internal stratigraphic architecture, a second, lease-wide AEM survey was collected to support long-range planning, data-collection strategies, and geologic modelling.

Results

AEM resistivity volumes illuminate Devonian structural features and shallow reef buildups in areas where well control is sparse (~400 m spacing). The data clearly delineate McMurray Formation channel abandonments, point-bar boundaries, and contrasts between mud-rich inclined heterolithic strata and more sand-prone bar deposits. Pleistocene incisions are also locally mapped. Infrastructure-related acquisition artifacts (e.g., pipelines, power lines, pumping wells) pose interpretation challenges, underscoring the value of early AEM acquisition in developing mine areas.

Conclusions

AEM provides a continuous, low-resolution subsurface mapping tool and enables proactive recognition of stratigraphic and structural complexities that influence mine design and execution. AEM is best complimented with an integrated subsurface dataset including seismic and well data.

At Kearl AEM data have supported:

- Targeted core-hole placement and seismic program design for long-range development
- Siting and design of out-of-pit structures such as overburden disposal areas
- Early understanding of pit geometries to improve pit continuity, mine-advance sequencing, and road-building efficiency
- Development of aquifer-management strategies adjacent to major Pleistocene channels

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