geoconvention
Calgary • Canada • May 11-13 2026

Evaluating a 1D airborne electromagnetic inversion workflow using well-log-derived resistivity proxies

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Summary

This study evaluates the capability and limitations of 1D airborne electromagnetic (AEM) inversion to recover resistivity contrasts associated with oil sand–bearing intervals within the McMurray Formation at the Clarke Creek In-situ Property. Using borehole resistivity logs as synthetic proxies, we demonstrate a workflow that (1) constructs a realistic 1D resistivity profile (2) forward model AEM responses over this profile, (3) adds noise and inverts the synthetic data, and (4) compares the recovered model from each well with the original log to assess how well AEM could resolve oil sand-bearing intervals in principle.

Introduction

The AEM method is sensitive to changes in resistivity (or, conversely, conductivity) that reflect hydrogeology, such as lithology, permeability, and fluid composition. Thus, AEM is an applicable technique for oil and gas and aquifer delineation in sedimentary environments. During an AEM survey, electromagnetic waves are emitted from an airborne transmitter at a particular base frequency, and the resulting decaying magnetic field information is recorded by a receiver. An AEM survey is approximately 1/10th the cost of a 3D seismic survey, and it is effective at shallow depths (<400 m).

Oil sand–bearing intervals in the McMurray Formation are expected to be more resistive (100 – 1000 Ωm) due to high bitumen saturation, in contrast to more conductive (2 – 10 Ωm), clay-rich background lithologies (Zhdanov et al., 2013). Evaluating whether 1D AEM inversion can resolve these resistivity contrasts is the focus of this study.

To recover the earth's resistivity, an inverse problem is sought to find a resistivity model fitting the observed data. One-dimensional inversion of AEM data is widely used for subsurface resistivity characterization; however, the reliability and resolution of recovered models depend strongly on data quality and inversion methodologies, and prior knowledge.

Theory / Method / Workflow

Resistivity logs from two wellbores, sampled at 2 m intervals over comparable depth ranges, were discretized into layered 1D earth models and used to generate synthetic AEM responses representative of a VTEM-style survey. Forward modeling was performed using the SimPEG framework (Cockett et al., 2015), incorporating realistic transmitter geometry, waveform characteristics, and off-time gates. Gaussian noise (5%) was added to account for measurement uncertainty. The synthetic data were inverted using a smoothness-constrained 1D layered inversion with identical survey parameters, noise levels, and inversion settings for both wells.

Comparisons between true and recovered models were used to evaluate resolution, sensitivity, and repeatability of inversion behavior under controlled 1D conditions.

Results, Observations, Conclusions

The predicted data fits the observed data very well and the data misfit is randomly distributed (Fig. 1). For both boreholes, the inversion workflow successfully recovers major resistivity contrasts and shallow (~120m) subsurface structure, while deeper features (> 120m) exhibit increased smoothing and reduced resolution (Fig. 2). Although the two wells display differing resistivity distributions, similar depth-dependent inversion behavior is observed, including underestimation of peak resistivity values and smoothing of sharp layer boundaries. These results highlight the inherent non-uniqueness and depth-dependent sensitivity of 1D AEM inversion (Oldenburg & Li, 1999). Overall, the study demonstrates that well-log-derived resistivity serves as a useful proxy for evaluating 1D AEM inversion workflows before their application to real AEM datasets.

Outlook

The next phase of this study involves applying the validated 1D inversion workflow to field AEM data collected over the Clarke Creek property. A primary objective will be to integrate the inverted resistivity volumes with high-resolution seismic data to characterize point bar sequences, which are the major reservoirs within the McMurray Formation. By comparing the AEM-derived resistivity signatures against seismic facies and attributes, we aim to assess the reliability of the AEM method for distinguishing between sand-prone and mud-prone intervals in an in-situ setting.

Novel/Additive Information

This study provides a proxy-based, multi-well synthetic evaluation of a commonly used 1D AEM inversion workflow, demonstrating repeatable inversion behavior across differing resistivity profiles under identical survey and inversion conditions. The results offer practical guidance on the reliability and limitations of the AEM method in oil sands exploration.

Acknowledgements

The author acknowledges the use of the SimPEG open-source inversion framework; thanks Imperial Oil for financial and technical support.

References

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Oldenburg, D. W., & Li, Y. (1999). Estimating depth of investigation in DC resistivity and IP surveys. *Geophysics*, 64(2), 403–416.

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FIGURES

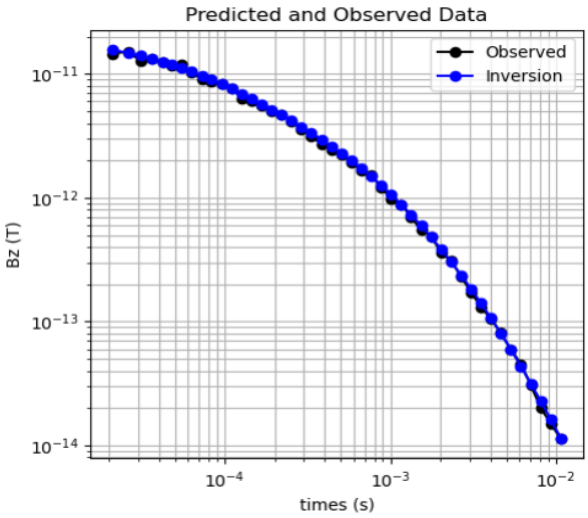


Figure 1: Plot of Observed data and Predicted data at Well 1.

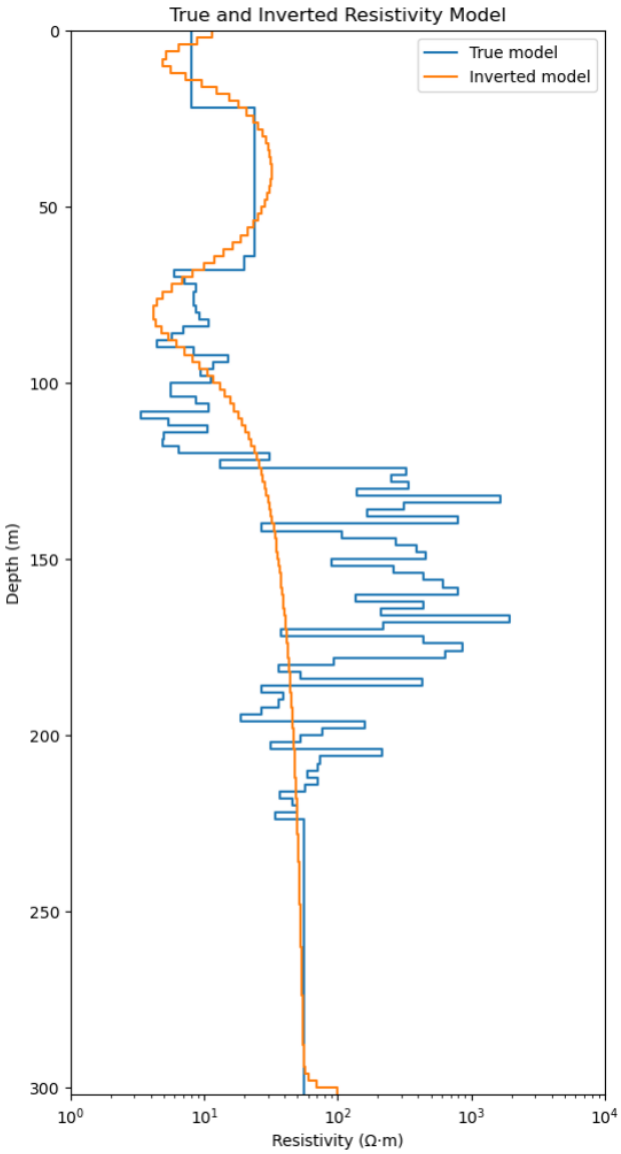


Figure 2: Plot of Observed data and Predicted data at Well 1.