Defense Announcement

Evaluation and Exploration of Complex Subterranean Formations Using Numerical Modeling: Azimuthal EM Deep Resistivity Applications

Hsu-Hsiang Wu

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Committee Chair: Dr. Ji Chen

Committee Members: Dr. David R. Jackson
Dr. Driss Benhaddou
Dr. Jiefu Chen
Dr. JinJuan Zhou

It is always important but challenging to accurately evaluate subterranean formations in the oil and gas exploration. Precise knowledge of geological structures and rock properties is essential to assist geophysics and petrophysicists in wellbore placement optimizations. With proper understanding of reservoir geology, it would help design better wellbores' positions relative to desired targets, enhance oil production, and further reduce overall operational cost.

Over the last few years, ultra-deep electromagnetic tools equipped with multi-component sensors were proposed in logging-while-drilling (LWD) applications. This technology is a game changer in the market, providing better resolution, as compared to seismic tools, and deeper depth of investigation, as compared to existing LWD tools. Because of geology complexity over such deep detection range and large amount of data used in this deep reading application, conventional one-dimensional (1D) inversion technique is not sufficient and a new inversion process consisting of many layers is required for better interpretation of these ultra-deep measurements. Furthermore, forward modeling may have to include higher dimensional variations in formation structures for such ultra-deep reading applications.

This dissertation aims to evaluate a 1D hybrid inversion performance on ultra-deep EM signals from various realistic 1D and two-dimensional (2D) formation models. A 2.5D finite difference (FD) modeling capability was developed during the research. Simulation accuracy of the 2.5D code has been significantly improved by two main approaches, including non-uniform auto meshing and effective electrical properties calculation, to minimize numerical errors from rectangular conformal meshes in complex geometries. Synthetic responses of various 1D and 2D formation models cases from commercial software, HFSS, has verified and demonstrated great performance of the 2.5D FD modeling. The 1D inversion scheme is thereafter tested with 1D and 2.5D FD modeling responses of 1D and 2D geological structures over long distance range. This evaluates the 1D hybrid inversion performance in both 1D and non-1D formation models. The study further identifies the cases where 1D inversion is not adequate and a 2D or 3D inversion algorithm is crucial for such deep reading applications. In the end, the dissertation highlights several areas for advanced development in the future.