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Resistivity modeling use in geosteering thermal development wells

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Resistivity inversion calculation, use in geosteering workflow, applications in thermal oil field development

Traditional correlation-based geosteering has limited applicability in reservoir navigation of estuarine deposits such as the McMurray. Inclined heterolithic beds, lateral variations, and breccia intercalation can throw off gamma readings. Resistivity measurements in a lateral well cannot be confidently or accurately correlated with measurements recorded in a vertical well, due to the way electric current flows through a formation, resulting in log separation or polarization horns. Resistivity inversion and modeling is an approach that overcomes these limitations by providing a method to correlate resistivity readings from vertical delineation wells to readings recorded in lateral development wells.

Theory / Method / Workflow

Fast and accurate forward modeling of various induction logs used while drilling is necessary for the rapid assessment of the quality of the current model and position of the wellbore. Combining the forward modeled curves with actual logged-while-drilling logs transmitted in real-time leads to proactive and more effective geosteering.

The technology developed by ROGII Inc. as part of their StarSteer suite of geosteering software provides such a method. Resistivity inversion, based on specific tool configurations is correlated with actual LWD readings to determine stratigraphic position, stand-off to fluid or lithological boundaries. As with all software based geosteering approaches, calculated apparent dip along the borehole leads to forward projections of formation trends. These elements combined allow for precise and confident reservoir navigation.

The technology allows users to make predictive or “forward models” of resistivity response for the majority of tools currently available on the market (most tool specifications are in the public domain). The approach has the capability of modeling response from tools with frequencies from 1 kHz up to 100 MHz, as well as transmitter/receiver spacings ranging from inches to the tens of meters across the length of the tool. Modeled resistivity logs range from the minimum recordable values up to 1000 Ohm.m (and depend on the measurement and tool specifications).

A semi-analytic 1D solver method is used for forward modeling, while the conjugate gradients method is used for inversion calculations. Those calculations are performed in real-time. Due to parallel processing, there is almost no lag in obtaining the up-to-date model.

Another application of resistivity modeling is well planning. SAGD producer wells are ideally placed as low as possible in a reservoir in order to minimize bypassed pay. Resistivity prediction along a borehole is achieved by calculating theoretical formation response in various geomodel

or geosteering interpretation scenarios. This information is then used in optimizing well placement.

Results, Observations, Conclusions

The approach is used to effectively steer wells drilled in heterolithic reservoirs, based on resistivity readings. Reservoir navigation is performed by geosteerers independent of LWD tool providers. Active geosteering leads to a significant decrease in bypassed pay and maximizes final recovery in SAGD field development.

Resistivity inversion is the only technology that allows for the identification of formation boundaries at discrete distances from the tool position. Coupling the strat-based geosteering method with resistivity inversion improves efficiency and reduces costs through more effective data usage.

In some cases, the transition layer between the oil water contact and the pure oil zone in a typewell may show a gradual change in the resistivity profile. In these scenarios, forward modeling is often a better solution for predicting the resistivity log responses at a certain distance from the OWC, rather than mapping a boundary when a resistivity contrast is not obvious. Selecting the proper method, inversion or forward modeling, best suited to the resistivity profile and data available is critical to successful operations.

Novel/Additive Information

This is the first approach of an independent resistivity modeling in the geosteering software package. It is done alongside strat-based or modeled-based correlations, and also takes into account the effects of the propagation resistivity measurements. Full processing of resistivity measurements was previously done by the tool vendors in their proprietary software. This new approach is vendor-neutral. The workflow done independently by in-house teams for pre-job modeling, during real-time operations by wellsite or remote geosteerers or on the post-job stage for evaluation and future planning.

References

1. Mogilatov V.S., Potapov V.V. Universal algorithm for induction logging – 2014
2. LWD Resistivity Tool Survey, compiled by John Zhou (Maxwell Dynamics), Nov. 2016

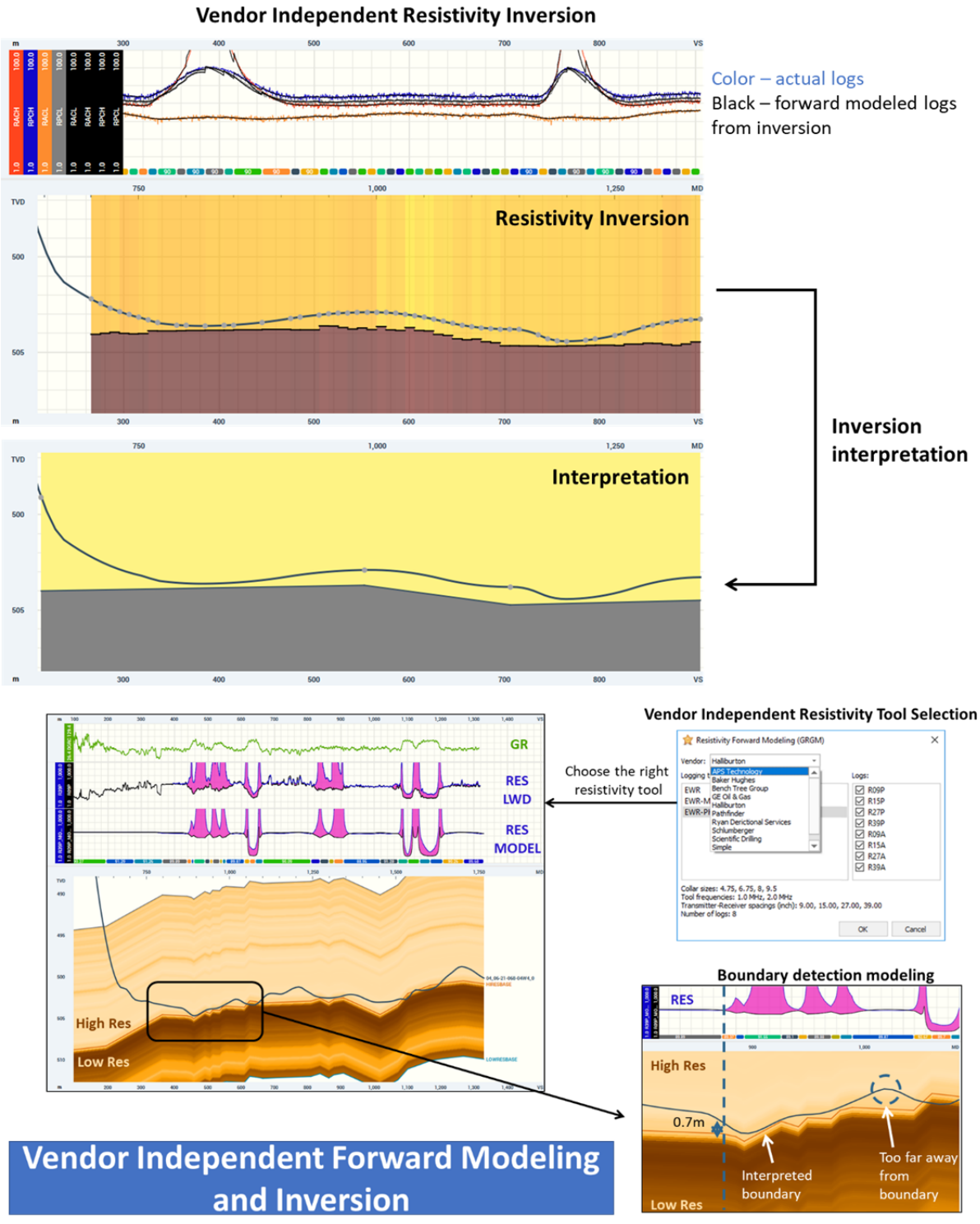

Fig. 1. Vendor independent resistivity inversion and forward resistivity modeling examples.

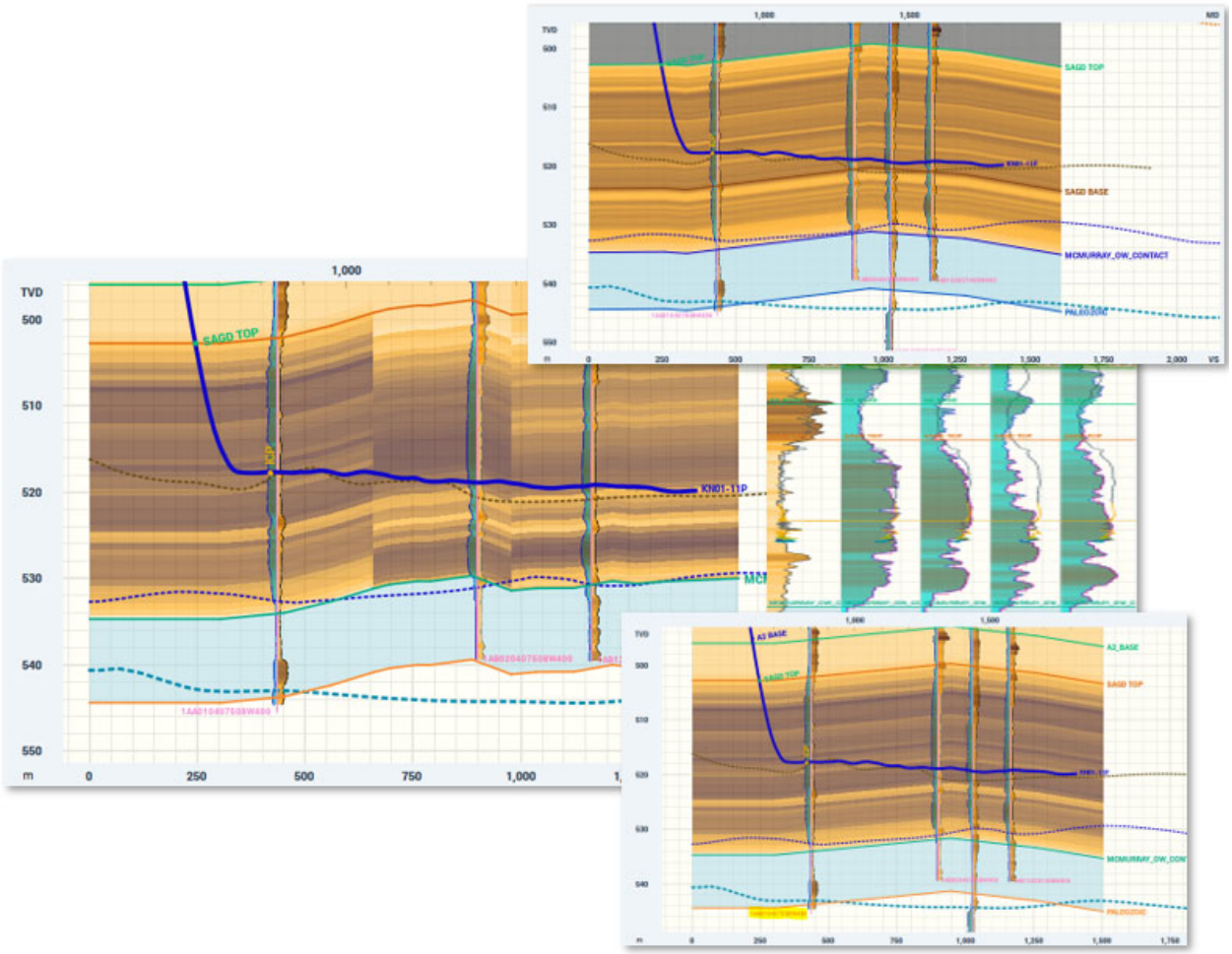

Fig. 2. Multi-well resistivity inversion vs correlation based geosteering.