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Errors in Petrophysical Interpretation in Deviated Wells Leads to Errors in H-C Reserves

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Summary

Conventional Log Interpretation techniques are still applied to deviated wells when evaluating Petrophysical properties. Both wireline conveyed and logging while drilling (LWD) logs are affected by the relative dip angle between the borehole and the formation. Petrophysical evaluation in deviated wells is challenging due to effects of shoulder beds, formation anisotropy, di-electric constant, borehole geometry, mud invasion on resistivity logs. Understanding how this affects the resistivity logs is key to solving errors in petrophysical interpretation and hydrocarbon (H-C) reserves.

In this case study examples will be shown of how one-dimensional (1D) (Figure 1) and two-dimensional (2D) (Figure 2) resistivity modeling can be used to solve the problem discussed above.

Introduction

The whole science of Petrophysical Log interpretation since the early days are based on the fact that wells were drilled vertically and the formation were assumed to be perpendicular to the bore hole. Now when the petroleum industry is drilling more and more deviated wells, a petrophysicist analyzing the logs looks at them through the assumption of vertical well and applies those techniques for deviated wells. Petrophysical evaluation in deviated wells is challenging due to effects of shoulder beds, formation anisotropy, di-electric constant, borehole geometry, mud invasion on resistivity logs. The well logging service companies have characterized the effects of deviated boreholes on log responses under various drilling conditions. There is wealth of information in the logs and proper use of it can give good petrophysical interpretation and reserves analysis.

1-D (Figure 1) and 2-D (Figure 2) resistivity modeling techniques were used to analyze log data and the results were used to solve for H-C saturation.

One-Dimension (1-D) Resistivity Modeling

The 1-D Rt inversion is applicable to ARC* family of LWD logs. The four effects the 1-D Rt solves for are

1. Anisotropy of formation resistivity
2. Invasion effects
3. Borehole Geometry
4. Formation Di-electric constant.

Two Dimension (2D) Resistivity Modeling

The primary effects that are solved by 2-D modeling are shoulder bed and anisotropy effects. The 2-D Rt uses log response functions to simulate the observed log response. In order to do the log response simulation also called as forward modeling, information such as structural dip, true vertical depth & thickness of beds, relative angle between the borehole and the beds and representative nearby wells logs data is used.

Once the simulated logs are optimized and constrained to the observed logs then the simulated model is used for petrophysical analysis

Examples

Figure 3. Shows the logs for wells drilled in the same formation. Using typical deep resistivity method to solve for saturation will lead to serious errors in interpretation. Using 1-D Rt modeling process and correcting the data for anisotropy effects which results in proper petrophysical evaluation as shown is figure 4.

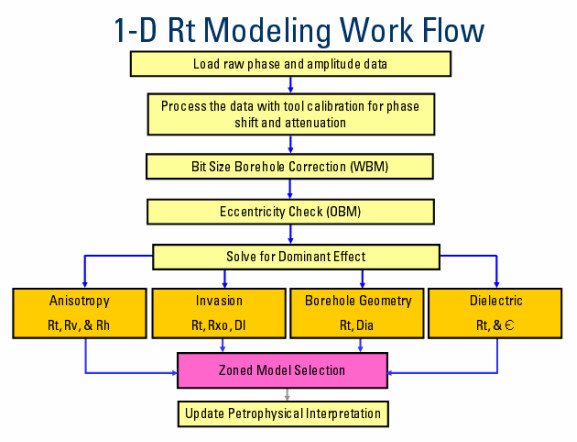

Figure 1: Flow chart for 1-D resistivity modeling

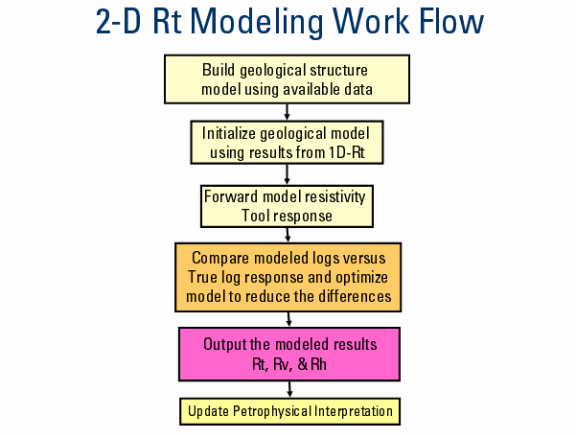

Figure 2: Flow chart for 2-D resistivity modeling

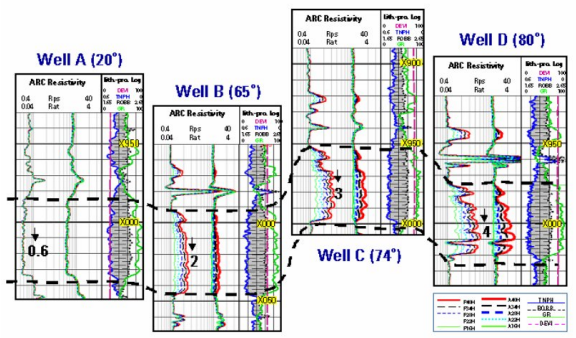

Figure 3: Same horizon drilled by different wells, what is the resistivity of the formation (Rt)? Which zone has pay?

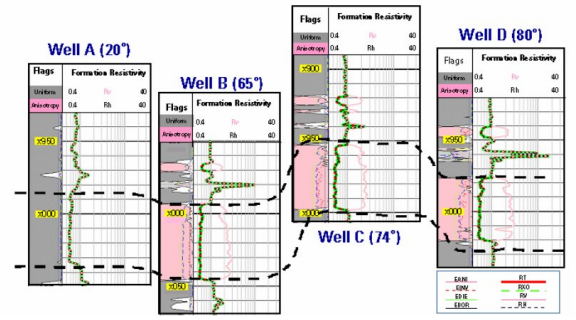

Figure 4: The dominant effect in wells B, C, & D is anisotropy. There is no pay in this zone in all the wells!!

Conclusions

Resistivity measured by wireline and LWD tools is affected by many factors and care should be taken when analyzing data for reservoir saturation. This is especially true when analyzing data from deviated wells.

Identifying the dominant effect is very crucial in solving for Rt. To identify dominant effect careful attention to history of the well, geological description, well deviation is essential.

Start with 1-D resistivity modeling approach and use 2-D resistivity approach for cases where you have shoulder bed effects.

1-D and 2D resistivity modeling are complementary and the results should be constrained using logs from near by vertical well provided the relative angle of the beds is not significant.

With modeled resistivity using 1-D Rt and 2-D Rt approaches, reservoir saturation can be characterized accurately and reduce uncertainties in the reserves analysis.

Table1: Tables should be properly annotated with each column head giving units of measurement.

References

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