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Reservoir Characterization for Energy Security

How right do we have to be? Refinement of Saturation Modelling in Unconventional Reservoirs

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ABSTRACT

Saturation modeling has traditionally been done using block or zonal methods with individual Archie parameter inputs for each zone. This method holds well for conventional plays, where the change in any one input parameter has very low effect on the overall saturation model due to the higher resistivity readings and higher porosity. However, in tighter low resistivity rocks it can be shown that a small change in the Archie exponents, Water Resistance or porosity has a large and potentially compounding effect on the resulting saturation model. With analytical evidence showing that tight unconventional reservoirs of today are increasing in complexity and heterogeneity, adjustments to the zonal approach become necessary.

The proposed workflow begins by assessing indicators of changing clay speciation and/or clay distribution. For example, evaluation of spectral wireline data (monitoring variations in thorium and potassium ratios), multifrequency dielectric measurements (where shifts in the lower frequency measurements suggest potential changes in clay type), and gamma ray intensity in conjunction with triple combo measurement changes. These relative indicators are validated against XRD data obtained from core samples.

Once clay speciation is defined by zone, a determination of effective water resistivity by integrating RwCore™ measurements with total clay volume, parsed by variations in clay speciation, can be determined. This allows the modeled equivalent water resistivity (Rwe) to replace Rw in the Archie Saturation Equation. As a result, the modified equation accounts for the clay effect on resistivity measurements, effectively functioning as a Modified Simandoux Saturation Model without having to assume clay resistivity.

The remaining as-received electrical properties can be integrated in a variety of ways. A commonly used technique is Pickett analysis by zone, with results compared to core measurements. However, this method struggles with the increased heterogeneity observed in tight unconventional reservoirs. To overcome this, two distinct approaches are proposed for calculating the cementation exponent "m." The first approach is that of a multivariant method that takes the delta of micro-resistivity measurements and clay volume as the order pairs and the measured as-received "m" parameter as the dependent variable. The secondary model is to solve for "m" by rearranging the apparent water resistance calculation. This requires the previously developed Rwe model as an input along with total porosity. By comparing the calculated "m" versus that of the measured, confidence in the modeled output and input variables is achieved when strong agreement exists. When available it is recommended to run both methods for validation purposes.

For the saturation exponent "n", success has been found in modeling it directly from the high frequency dielectric measurement. This method primarily works for tight reservoirs due to the shallow depth of investigation. The

$$R_{wa} = \frac{R_t \times \phi^m}{a} \implies \frac{\log_{(10)}\left(\frac{R_{we} \times a}{R_t}\right)}{\log_{(10)}(\phi - \phi_{CBw})} = m$$

dielectric measurement is dominated by the tortuosity of the water phase in the near wellbore environment, the effects of "m" and "n" are combined and related to the recorded permittivity. That said one could use the core

CEGA

calibrated continuous and variable modeled "m" as an input into a multivariant model along with the permittivity to solve for "n." The resulting outputs from the various methods outlined above allow for continuous archie parameters that vary over sections based on changes in clay speciation, clay distribution, lithology, tortuosity, and fluid.

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