PETRONAS CARIGALI

Sand Silt Clay Petrophysical Model

for Evaluating Shaly Sand Reservoirs in The Malay Basin
Model Overview

- Traditionally petrophysicists use a Sand-Shale lithological model to evaluate shaly sands reservoirs
  - Adequate enough to derive reliable shale volume, porosity, water saturation
- Routine use of geocellular models resulted in the need to better characterize the formations
  - Three component lithological model consisting of Sand, Silt and Clay introduced.
- Sand, Silt and Clay software available in the market does not fully meet the requirements to characterize the formations encountered in the Malay Basin.
  - An in-house Sand, Silt and Clay Model developed.
Model Principles

Data from Core Analysis

Bulk Density vs. Neutron Porosity Crossplot
Sand, Silt & Clay Volume Derivation

Bulk Density vs. Neutron Porosity

Lithology Fraction Plot

Points' relative location in crossplot to Clean Sand line
Sand, Silt and Clay petrophysical model automatically corrects the hydrocarbon effects on Bulk density & Neutron porosity logs. For clean sand, a standard hydrocarbon correction equation is used. However in shaly sand reservoir, the hydrocarbon corrections were iteratively done by using Gamma Ray log as shaliness reference.
Total Porosity Calculation

A well example above shows the calculated porosity matches with core porosity. The volume fraction of Sand, Silt and Clay derived from the Lithology Fraction plot were used to calculate the total matrix density. The porosity is then calculated based on the equation stated below:

\[
\rho_{\text{matrix}} = (V_{\text{sandfrac}} \times \rho_{\text{sand}}) + (V_{\text{siltfrac}} \times \rho_{\text{silt}}) + (V_{\text{clayfrac}} \times \rho_{\text{clay}})
\]

\[
\Phi_T = \frac{\rho_{\text{matrix}} - \rho_{\text{logcorrected}}}{\rho_{\text{matrix}} - \rho_{\text{fluid}}}
\]
Unique Features

Incomplete Data & Badhole Correction Processing

Unlimited & independent number of zones parameters
Unique Features

Unlimited Gamma Ray Zonation

Unlimited Bulk Density and Neutron Porosity Zonation
Field Example Results
Discussion

The Sand Silt Clay (SSC) model has been tested successfully by evaluating well log data from a number of wells from Malaysian gas and oil fields. The lithological components derived using the SSC model have been compared and validated with XRD and sieve analysis results. Light hydrocarbon correction has been implemented and optimized by comparing clay volume from neutron/density logs with that from gamma ray log, to avoid over-correction. Porosity computed from logs, based on the lithological composition from the SSC model, matches very well the porosity from core analysis. Additional features of the SSC model, such as Badhole Correction, Incomplete Data Restoration and Unlimited Zonation, are very useful functionalities for petrophysical evaluation. The SSC model has been successfully used to evaluate well data as input for geocellular modeling.
Conclusion

Since the SSC model is robust and stable, it has been adopted as the standard model in PETRONAS Carigali for performing petrophysical evaluations.

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Thank You

Sand, Silt and Clay (SSC)
Petrophysical Model