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THE SAND-SILT-CLAY (SSC) MODEL: AN ADVANCED PETROPHYSICAL ANALYSIS AND ITS ESSENTIAL APPLICATIONS TO LITHOLOGY COMPUTATION, PERMEABILITY ESTIMATION AND SATURATION MODELLING

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OUTLINES

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❖ Determination of Lithology Fractions
❖ Saturation, Permeability, and Saturation Modelling
❖ A Holistic SSC Petrophysical Interpretation
❖ Summary and Conclusions
Objectives

❖ To make industry aware on Sand-Silt-Clay Petrophysical Model

❖ To provide detail regarding the input for Choo approaches on permeability prediction and saturation modelling.

❖ To demonstrate the accurate quantification of Choo permeability equation and saturation modelling as they are affected by SSC lithology derivation.
Universal Permeability Equation (Choo)

\[ k = 0.125 \frac{r g^2 \phi^m c^{(\frac{c}{c}+1)+2}}{10^{(6V_{cl} + 3V_{silt})}} \]

Global Saturation Modelling (Choo)

\[ S_{w.cap} = \frac{10^{[2b_o - 1)\log(1 + S_{wb}^{-1}) + \log(1 + S_{wb})]}}{0.2166 \frac{P_c}{\sigma \cos(\theta) \sqrt{\phi_l}} \left[ k \frac{b_o}{3} \log(1 + S_{wb}^{-1}) \right]} \]
Why do we need to perform saturation modelling?
1. Saturation prediction
2. Volumetrics
3. FWL Predictions

Who defines these parameters?

$\text{HC volume} = h \times A \times \phi \times S_{hc}$

Saturations Prediction:
1. Averaged SW from Analogue Wells.
2. Modelled SW
How we do estimate the volumetrics?

<table>
<thead>
<tr>
<th></th>
<th>GDT (mTVDSS)</th>
<th>FWL (mTVDSS)</th>
<th>GRAD (psi/ft)</th>
<th>SWT (v/v)</th>
<th>SHC (v/v)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A Upper</td>
<td>1,915.00</td>
<td>1,965.00</td>
<td>0.07</td>
<td>0.65</td>
<td>0.35</td>
</tr>
<tr>
<td>1A Lower</td>
<td>1,938.00</td>
<td>1,965.00</td>
<td>0.07</td>
<td>0.57</td>
<td>0.43</td>
</tr>
<tr>
<td>1B</td>
<td>1,974.00</td>
<td>2,015.00</td>
<td>0.14</td>
<td>0.90</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Are we confident to use this saturation value?
Saturation Modelling Weighted by Area-Depth

Sand | SHC Ressum (v/v) | SHC SHF-AD (v/v)
--- | --- | ---
1A Upper | 0.35 | 0.49
1A Lower | 0.43 | 0.54
1B | 0.10 | 0.50

(Kyi, 2008)
Model Overview

- SSC model is developed to solve the problems encountered in analyzing most of reservoirs in Malay Basin. This type of reservoir generally consists of fine to very fine grained sediments (silt) with low formation water salinity.

- The Model defines the lithological components using three main groups of particle sizes which are so called Sand, Silt, and Clay sized particles.

- The density-neutron cross-plot is used to determine the lithology fractions and the porosity of the rocks.

- This method has been applied since 2010, such as Malaysia, Venezuela, Turkmenistan, Myanmar, Mauritania, Indonesia, and else.

The Concept of SSC Fraction Volume
(After Anwar, 2011)

Lithology from Neutron-Density Crossplots
(Kyi, 2008)
Sand-Silt-Clay Model Ternary Diagram

**SSC’s Parameters:**

1. Fluid point
2. DrySand point
3. DrySilt point
4. WetClay point
5. DryClay point

- Any calculation of lithology and porosity in SSC model will be based on these 5 points.
**Determination of Lithology Fractions**

- Project the data point to DryRock Line.
- Find the position of projected point on that line (green circle).
- This point is called the **Dry-Data Point** (rhob_proj, nphi_proj).
- Rhob_proj or nphi_proj then is used calculated sndsfltfrac and clysfltfrac.
- From the example; sndsfltfrac=0.4 and clysfltfrac < 0.

Projecting those points to x-axis of D-N crossplot will also give:

\[
\text{sndsfltfrac} = \frac{nphi\_proj - NPHI\_DRYSL}{NPHI\_DRYSD - NPHI\_DRYSL}
\]

\[
\text{clysfltfrac} = \frac{nphi\_proj - NPHI\_DRYSL}{NPHI\_DRYCL - NPHI\_DRYSL}
\]

Where:

- NPHI\_DRYSD = Dry-Sand Neutron
- NPHI\_DRYCL = Dry-Clay Neutron
- NPHI\_DRYSL = Dry-Silt Neutron
- sndsfltfrac = Sand-Silt fraction
- clysfltfrac = Clay-Silt fraction
Example of Lithology Volume Determination

- Dry Sand Point: (2.65, -0.02)
- Dry Silt Point: (2.68, nphidrys)
- Dry Clay Point
- Wet Clay Point

### Example 1

- $V_{sn} = 0.85$
- $V_{si} = 0.13$
- $V_{dc} = 0.02$

### Example 2

- $V_{sn} = 0.27$
- $V_{si} = 0.53$
- $V_{dc} = 0.20$

### Example 3

- $V_{sn} = 0.0$
- $V_{si} = 0.09$
- $V_{dc} = 0.91$
A Holistic SSC Petrophysical Interpretation
Predicted Permeability and Modelled Water Saturation
Summary and Conclusions

✓ The lithological components derived using the SSC model were compared and validated with XRD and sieve analysis results.

✓ Porosity computed from logs, based on the lithological composition from the SSC model, matches very well with the porosity from core analysis.

✓ The Sand Silt Clay (SSC) model was successfully tested by evaluating well log data from a number of wells from Malaysian gas and oil fields.

✓ The advantage of Choo permeability and saturation modelling is a fast, robust and inexpensive method to predict permeability, universal equation (not case by case study as with the current curve fittings practice), no need for Swirr input, able to predict with low uncertainty with limited amount of core data which leads to cost saving.

✓ The Choo permeability and saturation height function equations have yielded very consistent results where the log prediction matches with the core data.
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End of Presentation

Terima kasih

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