CREATION OF MINERAL LOG

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Objectives

Creation of mineral logs using traditional well logs, point-counting data, and radial-basis function network for:

1. Detailed stratigraphic correlation for reservoir simulation.
2. Calculation of mineral volumes for EOR design.
Well Logs Used to Create Lithology Logs

1. Density log: measure bulk density, since 1950s.

2. Sonic log: measure interval transit time, since 1950s.

3. Neutron log: measure porosity, after World War II.

4. Photoelectric absorption log (Pe): since late 1970s, measure matrix density.

Techniques Used to Estimate Lithologies

• **Graphical Methods:**
  - Overlay of porosity logs.
  - Porosity log crossplot.
  - M-N plot.

• **Numerical Methods:**
  - Matrix identification.

• **Computer software:**
  - Halliburton: GeoGraphix.

• **Important inputs:**
  - Pe values.
  - Elemental analysis.
Minnelusa Well Logs for Mineral Identification

• Sonic log available in most wells.

• Combination of Sonic, density, and neutron logs are available from late 1970s.

• Pe log in some wells after 1978.

• No pulsed neutron spectroscopy has been seen in Minnelusa wells.
Simple Mineral Composition
Quartz + Dolomite + Anhydrite
Working Procedures

• Point-count thin sections.

• Digitize density, neutron, sonic, and Pe logs at depths with point-counted thin sections.

• Log normalization.

• M-N plot (density, neutron, and sonic) to create inputs for network calculation.

• Using point-counting data in a hybrid learning of pattern recognition method based on radial-basis function network to calculate mineral composition.

• Generate precise mineral logs.

• Calculation of mineral volumes.
Log Normalization

- **Logging errors**
  - Environmental effects:
    - Borehole rugosity.
    - Mudcake thickness.
    - Formation invasion by mud filtrate.
  - Tool malfunctions.
  - Operation errors.

- **Normalization**
  - Use calibration units:
    - Anhydrite as reference.
    - Tight carbonates more consistent.
  - Crossplot for wells with simple mineralogies (clean sandstone, pure limestone, and dolomites), such as M-N plot.
  - Standardize porosity scale (limestone, sandstone, dolomite, or matrix density).
  - Comparison with core analysis.
M-N Lithology Plot for Log Normalization

M-N Lithology Plot

Single Well

Multi-wells

Single Well
Comparison of Point-counted Mineral Content with Estimated Based on M-N Plot

- Estimated Quartz in Matrix from MN Plot vs. Observed Quartz in Matrix
- Estimated Dolomite in Matrix from MN Plot vs. Observed Dolomite in Matrix
- Estimated Anhydrite in Matrix from MN Plot vs. Observed Anhydrite in Matrix

Comparisons show a close alignment between estimated and observed mineral contents, indicating the effectiveness of the M-N plot method.

EORI logo
Porosity Scale Standardization

### Dresser Atlas

<table>
<thead>
<tr>
<th>GAMMA RAY API UNITS</th>
<th>DEPTH</th>
<th>DENSITY – POROSITY %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>200</td>
<td>( \rho_{\text{ma}, 2.11} )</td>
</tr>
<tr>
<td>200</td>
<td>0</td>
<td>( \rho_{r, 1.0} )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CALIPER</th>
<th>NEUTRON POROSITY %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone, Matrix</td>
<td></td>
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### Schlumberger

#### Limestone Matrix

<table>
<thead>
<tr>
<th>CALIPER DIA. IN INCHES</th>
<th>4″</th>
<th>( 4^\prime )</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAMMA RAY API UNITS</td>
<td>0</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>400</td>
</tr>
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</table>

#### Porosity Index

\[ \text{Compacted Formation Density Porosity} \]

<table>
<thead>
<tr>
<th>JENTS(LB...)</th>
<th>20000</th>
<th>( 20^\prime )</th>
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<tbody>
<tr>
<td>DPHI</td>
<td>0.3000</td>
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#### Sandstone Matrix

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#### Grain Density

\[ \text{Grain Density} = 2.65 \text{ grams/cc} \]
Porosity Scale Standardization

Neutron Porosity

 Courtesy Halliburton Energy Services, ©1994 Halliburton Energy Services

Courtesy Schlumberger Wireline & Testing, ©1998 Schlumberger
Point-counting Data

Limitation:
1. Sample size.
2. Core availability.
3. Core-log depth-match.
Correlation of Quartz Content with Log Parameters

- **Density (G/C3)**
  - Formula: \( y = 415.79 - 141.35x \)  
  - Coefficient of Determination: \( R^2 = 0.72773 \)

- **Transit Time (us/f)**
  - Formula: \( y = -59.414 + 1.8478x \)  
  - Coefficient of Determination: \( R^2 = 0.57916 \)

- **Neutron Porosity (%)**
  - Formula: \( y = 43.222 + 1.1417x \)  
  - Coefficient of Determination: \( R^2 = 0.21542 \)
Correlation of Anhydrite Content with Log Parameters

- **Density (G/C3):**
  - Linear equation: $y = -67.902 + 29.658x$, $R = 0.27465$

- **Neutron Porosity (%):**
  - Linear equation: $y = 23.371 - 1.4261x$, $R = 0.42464$

- **Transit Time (us/f):**
  - Linear equation: $y = 23.4 - 0.23748x$, $R = 0.13581$
Creation of Network Inputs by M-N Lithology Plot
Work Plan

1. Point-counting representative Minnelusa samples with density, neutron, and sonic logs available, especially samples with different percentages of anhydrite.

2. Digitize density, neutron, sonic, and Pe logs.

3. Normalize well logs.

4. Calculate mineral compositions using point-counting data, traditional plot, and radial-basis function network.

5. Creation mineral logs using our new methodologies.

6. Calculate mineral volumes in interested stratigraphic intervals.

7. If successful, we can also work on Tensleep and other formations.