In this chapter we will show the methodology of identifying the zone of LRLC in two wells in the study area.

4.1 Application:

4.1.1 Program work flow:

After the well log done the composite well log data was saved as (Las file form)

Fig. (4.1) work flow using IP
4.1.2 Step One:

Loading data:

![Data Loading Image]

Fig. (4.2) showing data load

4.1.3 Step Two:

Calculate the clay volume by using:

- **Gamma Ray**:

The Gamma Ray clay indicator ($V_{cl_{GR}}$) can be calculated using the following methods:

- **Linear**:

$$I_{sh} = \frac{GR - GR_{cl}}{GR_{sh} - GR_{cl}} \quad (4.1)$$

GR= log response in the zone of interest, API units.

GRcl= log response in clean beds, API units.

GRsh= log response in shale beds, API units.
The following plot shows the different gamma ray V clay relationships

![Gr Method Relationships](image)

Fig. (4.3) Gr method relationship

The best way to calculate the clay volume by using gamma ray in IP is to make reasonable zonation in all well as what we doing in Fig (4.4). The greater the number of shale base line, the greater the intensity and by this method we can do that.
Fig. (4.4) reasonable zonation in all well

- **Curved:**

  
  \[ Z = V_{cl \text{GR}} \text{ as above} \]

  \[ V_{cl \text{GR}} = 0.0006078(100 \times z)^{1.58527} \tag{4.2} \]

  For \( Z \) less than 0.55

  For \( Z \) greater than 0.55 and less than 0.73

  \[ V_{cl \text{GR}} = 2.1212 \times Z - 0.81667 \tag{4.3} \]

  For \( Z \) greater than 0.73 and less than 1.0 \( V_{cl \text{GR}} = Z \)

- **Clavier:**

  \[ V_{cl \text{Gr}} = \sqrt{3.38 - (Z + 0.7)^2} \tag{4.4} \]
• Stieber (South Louisiana Miocene and Pliocene):

\[ V_{cl_{GR}} = \frac{0.5 \cdot Z}{1.5 - Z} \]  

(4.5)

• Larionov older rocks (Mesozoic):

\[ V_{cl_{Gr}} = 0.333(2^{2 \cdot Z} - 1) \]  

(4.6)

• Larionov younger rocks (Tertiary clastics):

\[ V_{cl_{GR}} = 0.08336(2^{3.7 \cdot Z} - 1) \]  

(4.7)

• Self-potential (SP):

\[ V_{cl_{SP}} = \frac{SP - SP_{Clean}}{SP_{Clay} - SP_{Clean}} \]  

(4.8)

• Neutron:

\[ V_{cl_{Neu}} = \sqrt{\frac{\phi_{neu} \cdot (\phi_{neu} - \phi_{neuclean})}{\phi_{neuclay} \cdot (\phi_{neuclay} - \phi_{neuclean})}} \]  

(4.9)

• Resistivity:

\[ Z = \frac{R_{clay}}{R_{t}} \cdot \frac{(R_{clean} - R_{t})}{(R_{clean} - R)} \]  

(4.10)

For \( Rt \) greater than 2 x \( R_{clay} \) then

\[ V_{cl_{Res}} = 0.5 \cdot (2 \cdot Z)^{0.67\cdot(Z+1)} \]  

(4.11)

Otherwise \( V_{cl_{Res}} = Z \)

4.1.4 Step three:

Calculate Porosity and water Saturation:

Archie’s equation, rewritten for saturation of the flushed zone, to determine moveable oil

\[ S_{xo} = \frac{a \cdot R_{xo}}{\sqrt{\phi_{m} \cdot R_{mf}}} \]  

(4.12)
And Indonesian (Poupon-Leveaux) equation for calculating:

\[
\frac{1}{\sqrt{R_t}} = \sqrt{\frac{\phi^m}{aR_w}} + \frac{V_{cl}}{2 \sqrt{R_{cl}}} \cdot S_{w}^{2} \tag{4.13}
\]

4.1.5 Step Four:

Cutoff and Summation:

Each depth in the data is considered a discrete interval, with the recorded depth being the centre of the interval. Therefore, when making averages over an interval, only half of the top and bottom depth increments are counted. The following diagram provides an example explaining how 'net reservoir' would be calculated:

![Diagram showing the calculation of net reservoir](image)

Fig. (4.5) an example explaining how the net reservoir would be

It is worth pointing out that the above equation misses out the zero points as in total there are nine intervals and so the equation should really be written like this:

\[
Net = \left[ ((1 \times 6) + (1 \times 0)) + ((0.5 \times 0) + (0.5 \times 1)) \right] \times 0.5 = 3.25 \tag{4.14}
\]

Average porosity:

\[
\phi_{av} = \frac{\sum_{i=1}^{n} \phi_i \cdot h_i}{\sum_{i=1}^{n} h_i} \tag{4.15}
\]
Average water saturation:

\[
S_{av} = 1 - \frac{\sum_{i=1}^{i=n} \phi_i \cdot h(1 - SW)}{\sum_{i=1}^{i=n} \phi_i \cdot h} 
\]  
(4.16)

Average Clay volume:

\[
V_{clav} = \frac{\sum_{i=1}^{i=n} V_{cli} \cdot h_i}{\sum_{i=1}^{i=n} h_i} 
\]  
(4.17)

Where

- \(i\) = i'th input value
- \(h_i\) = i'th input interval
- \(n\) = number of samples

### 4.2 Hadida low resistivity pay zone:

After well study in master log and comparison it with the well that result from software, we can tag out low resistivity pay zone.

#### 4.2.1 Low resistivity pay zone in Hadida N-8:

- Interval of LRLC in Hadida N-8: 1849.65 - 1856.51
- Resistivity RD= 22.08
Fig. (4.6) Hadida N-8 master log Bentiu Formation (Aptian-Cenomanian).
Fig. (4.7) Hadida N-8 well log
Interval 3094.47-3119.7

RD = 15-16 ohm.m

Fig. (4.8) Hadida well log Interval 3094.47-3119.7
Fig. (4.9) Hadida N-8 well log Abu Gabra Formation (Neocomian)
### 4.2.2 Cutoff Summary

<table>
<thead>
<tr>
<th>No.</th>
<th>Interval</th>
<th>Thick</th>
<th>AVG PORE</th>
<th>AVG VSH</th>
<th>Interval</th>
<th>Thick</th>
<th>AVG PORE</th>
<th>Perm*h</th>
<th>AVG PERM</th>
<th>SW*h</th>
<th>AVG SW</th>
<th>AVG VSH</th>
<th>RESULT</th>
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<tbody>
<tr>
<td>6</td>
<td>1835.01</td>
<td>12.1</td>
<td>253.01</td>
<td>20.91</td>
<td>1835.02</td>
<td>12.08</td>
<td>252.71</td>
<td>20.92</td>
<td>1214.54</td>
<td>100.54</td>
<td>594.34</td>
<td>49.2</td>
<td>22.02</td>
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<td>7</td>
<td>1849.49</td>
<td>7.02</td>
<td>119.62</td>
<td>17.04</td>
<td>1849.65</td>
<td>6.85</td>
<td>116.72</td>
<td>17.04</td>
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<td>342.64</td>
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<td>11.63</td>
<td>260.63</td>
<td>22.41</td>
<td>1857.58</td>
<td>11.61</td>
<td>260.30</td>
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<td>162.57</td>
<td>515.83</td>
<td>44.43</td>
<td>16.87</td>
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<td>16</td>
<td>1958.69</td>
<td>6.85</td>
<td>133.301</td>
<td>19.46</td>
<td>1958.70</td>
<td>6.84</td>
<td>133.11</td>
<td>19.46</td>
<td>308.95</td>
<td>45.17</td>
<td>340.97</td>
<td>49.85</td>
<td>31.02</td>
</tr>
</tbody>
</table>

**Total/Average Oil (Bentiu Formation)**

<table>
<thead>
<tr>
<th>No.</th>
<th>Interval</th>
<th>Thick</th>
<th>AVG PORE</th>
<th>AVG VSH</th>
<th>Interval</th>
<th>Thick</th>
<th>AVG PORE</th>
<th>Perm*h</th>
<th>AVG PERM</th>
<th>SW*h</th>
<th>AVG SW</th>
<th>AVG VSH</th>
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</tr>
</tbody>
</table>

| Total/Average Oil (Bentiu Formation) | 37.38 | 762.84 | 20.41 | 3592.29 | 96.10 | 1793.78 | 47.99 | 24.73 |

**Net Pay**

<table>
<thead>
<tr>
<th>No.</th>
<th>Interval</th>
<th>Thick</th>
<th>AVG PORE</th>
<th>AVG VSH</th>
<th>Interval</th>
<th>Thick</th>
<th>AVG PORE</th>
<th>Perm*h</th>
<th>AVG PERM</th>
<th>SW*h</th>
<th>AVG SW</th>
<th>AVG VSH</th>
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</tr>
</tbody>
</table>

| Total/Average Oil (Abu Gabra Formation) | 32.47 | 460.06 | 14.17 | 666.57 | 20.53 | 1600.61 | 49.30 | 22.12 |
4.3 Low resistivity pay zone in Hadida N-2:

- Interval of LRLC in Hadida N-2 (1948.5-1952.6)
- RD = 11-15 ohm.m

Fig. (4.10) interval of LRLC in Hadida N-2 (1948.5-1952.6).
Fig. (4.11) Master log for Hadida N-2 for the interval of LRLC (1948.5-1952.6).
4.3.1 Cutoff summary

<table>
<thead>
<tr>
<th>No.</th>
<th>Interval (m)</th>
<th>Thick (m)</th>
<th>Pore*h (%)</th>
<th>AVG PORE (%)</th>
<th>AVG VSH (%)</th>
<th>Interval (m)</th>
<th>Thick (m)</th>
<th>Pore*h (%)</th>
<th>AVG PORE (%)</th>
<th>Perm*h (%)</th>
<th>AVG PERM (mD)</th>
<th>SW*h (%)</th>
<th>AVG SW (%)</th>
<th>AVG VSH (%)</th>
<th>RESULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1791.0 - 1795.4</td>
<td>4.4</td>
<td>93.3</td>
<td>21.2</td>
<td>21.0</td>
<td>1791.0 - 1795.4</td>
<td>4.4</td>
<td>93.3</td>
<td>21.2</td>
<td>673.1</td>
<td>153.0</td>
<td>40.1</td>
<td>21.0</td>
<td></td>
<td>oil</td>
</tr>
<tr>
<td>2</td>
<td>1805.3 - 1807.9</td>
<td>2.6</td>
<td>45.8</td>
<td>17.8</td>
<td>23.7</td>
<td>1805.3 - 1807.9</td>
<td>2.6</td>
<td>45.8</td>
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<td>176.7</td>
<td>68.5</td>
<td>43.0</td>
<td>23.7</td>
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<td>oil</td>
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<tr>
<td>3</td>
<td>1808.8 - 1822.9</td>
<td>14.1</td>
<td>307.7</td>
<td>21.8</td>
<td>15.7</td>
<td>1808.8 - 1822.9</td>
<td>14.1</td>
<td>307.7</td>
<td>21.8</td>
<td>4656.8</td>
<td>329.3</td>
<td>436.1</td>
<td>30.8</td>
<td>15.7</td>
<td>oil</td>
</tr>
</tbody>
</table>

Total/Average Oil (Bentiu Formation)

| Net Pay | 21.1 | 446.1 | 21.2 | 550.6 | 260.7 | 723.1 | 34.2 | 17.8 |

Total/Average Possible Oil (Bentiu Formation)

| Net Pay | 23.1 | 517.2 | 22.2 | 592.8 | 256.4 | 1285.7 | 55.6 | 19.8 |

Total/Average Oil (Abu Gabra Formation)

| Net Pay | 3.9  | 74.1  | 18.8 | 275.4 | 70.1  | 176.9  | 45.0 | 21.9 |

Total/Average Possible Oil (Abu Gabra Formation)

| Net Pay | 12.4 | 196.3 | 15.8 | 344.2 | 27.7  | 666.9  | 53.7 | 25.7 |

- **Table (4.2)** Hadida N-2 (525.5-3250.0m) Net Pay Cutoffs

- **Cutoff summary**

- **Hadida N-2 (525.5-3250.0m) Net Pay Cutoffs: (MIN Pore: 17%, MAX Vsh: 50%, MIN SW: 50% for Bentiu, MIN Pore: 12% for Abu Gabra)**