Exercise #5 -- Effect of Pore Pressure in Gas Sand

Uncemented Troll Sand: Pressure Behavior

\[ P_{\text{Differential}} = P_{\text{Confining}} - P_{\text{Pore}} \]
### Two-Layer Model

\[ P_{\text{Differential}} = P_{\text{Confining}} - P_{\text{Pore}} \]

#### Material Properties

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Bulk (GPa)</th>
<th>Shear (GPa)</th>
<th>Density (g/cc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>36.6</td>
<td>45</td>
<td>2.65</td>
</tr>
<tr>
<td>Clay</td>
<td>21</td>
<td>7</td>
<td>2.34</td>
</tr>
<tr>
<td>Water</td>
<td>2.5</td>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>Gas</td>
<td>0.02</td>
<td>0</td>
<td>0.1</td>
</tr>
</tbody>
</table>

#### Model Parameters (Uncemented Sand Model)

<table>
<thead>
<tr>
<th>Layer</th>
<th>PhiC</th>
<th>Coordination#</th>
<th>Diff. Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shale (Top)</td>
<td>0.4</td>
<td>8</td>
<td>15 MPa</td>
</tr>
<tr>
<td>Sand (Normal)</td>
<td>0.4</td>
<td>8</td>
<td>15 MPa</td>
</tr>
<tr>
<td>Sand (Pressed)</td>
<td>0.4</td>
<td>5</td>
<td>5 MPa</td>
</tr>
</tbody>
</table>

#### Model Results

**SHALE**
- \( I_p = 4.42 \)
- \( R_P = 0.4 \)

**SAND NORMAL**
- \( I_p = 3.37 \)
- \( R_P = 0.15 \)

**SAND OVERPRESSURED**
- \( I_p = 2.42 \)
- \( R_P = 0.08 \)

\[
R(0) = \frac{I_{p2} - I_{p1}}{I_{p2} + I_{p1}}; \quad R(\Theta) = R(0) \cos^2 \Theta_1 + \left( \frac{1}{1 - V_2} - \frac{1}{1 - V_1} \right) \sin^2 \Theta_1.
\]

\[ R_{\text{Normal}} = 0.7 \]

\[ R_{\text{Overpressure Normal} + \text{Normal PR}} = 0.65 \]

\[ R_{\text{Overpressure Overpressure}} = 0.55 \]
This velocity dispersion mechanism is related to the heterogeneity of natural rocks and reservoirs. The high-frequency wave travels faster than the low-frequency wave.

Consider a layered 1D medium made out of two types of materials: one material is soft and has density \( \rho_1 \) and the elastic modulus \( M_1 \); the other has density \( \rho_2 \) and the elastic modulus \( M_2 \). If the wavelength is short, the wave sees every layer as an infinite space. Then the travel time through two layers made of different materials but having the same thickness (one length unit) is (Wyllie's time average):

\[
\tau_{\text{Short}} = \frac{1}{V_1} + \frac{1}{V_2} = \frac{1}{\sqrt{M_1 / \rho_1}} + \frac{1}{\sqrt{M_2 / \rho_2}} = \tau_1 + \tau_2.
\]

Let now the wavelength be much larger than the individual layers. Then the wave sees the layers as a single elastic body. The effective elastic modulus of this body is given by the iso-stress (Reuss) average:

\[
1 / M_{\text{Eff}} = (1 / M_1 + 1 / M_2) / 2.
\]

The effective density of the new elastic body is \( \rho_{\text{Eff}} = (\rho_1 + \rho_2) / 2 \); the resulting effective velocity is \( V_{\text{Eff}} = \sqrt{M_{\text{Eff}} / \rho_{\text{Eff}}} \), and the travel time through two layers is \( \tau_{\text{Long}} = 2 / V_{\text{Eff}} \).

For \( N \) layers:

\[
\tau_{\text{Backus}} = \frac{\sum_{i=1}^{N} h_i}{V_{\text{Backus}}} = \frac{\sum_{i=1}^{N} h_i}{\sqrt{M_{\text{Eff}} / \rho_{\text{Eff}}}}, \quad \frac{1}{M_{\text{Eff}}} = \frac{1}{\sum_{i=1}^{N} h_i M_i}; \quad \rho_{\text{Eff}} = \frac{1}{\sum_{i=1}^{N} h_i \rho_i}.
\]
Assignment #5

1. Input file for this assignment is Twolayer.dat and is placed in GP170 directory on Clay. The columns are:
   Depth    Clay_Content_in_Solid    Porosity    Sw

2. Use material properties from page 2 to calculate RHOB, Kf, RHOf

3. Assume that the top shale and gas sand are both described by the same "Uncemented" model. See suggested model parameters on page 2.

4. Run the “Uncemented” applet for these parameters once for shale and twice for sand (normally pressured with 15 MPa differential pressure and overpressured with 5 MPa differential pressure).

5. Poisson’s ratio in sand at 15 MPa is underpredicted by the model. Correct by adding 0.1 to the model-calculated value.

6. Take average Ip and PR in the top and bottom layer of the 2-layer model. For sand do it twice (normal and overpressured).

7. Produce Rpp versus angle curves.

8. Calculate the apparent P-wave velocity through 2 equal-thickness layers one of which is shale and the other is OVERPRESSURED SAND using (a) Wyllie’s time average; and (b) Backus average (see example on page 3).