Consider a velocity data set in sandstone with varying volumetric content of clay in rock. The dry-rock P-wave velocity measured at 40 MPa differential pressure is plotted versus porosity below. Velocity, in general, decreases with increasing porosity but it is hard to identify a clear trend. The scatter is due to variations in clay content. Indeed, if the samples are grouped by clay content clear trends appear.

One way of handling the situation will be to run a multivariate regression where velocity is related to porosity and clay content (e.g., \( V = V_o - A\phi - BC \)). Such approach is valid but does not guarantee generality. It is more rewarding to rationally analyze the situation. We observe that the increasing volume of clay acts to reduce velocity at the same porosity. We also know that clay is softer than quartz and tends to fill the pore space between quartz grains not adding much stiffness to the load-bearing frame of the rock.

We speculate that this pore-filling clay does not affect the stiffness of the rock and thus does not affect the velocity. Then the only factor affecting the velocity is the porosity of the load-bearing frame made of the quartz grains. This porosity (\( \phi_F \)) can be calculated from the total (measured) porosity of a sample (\( \phi_t \)), internal porosity of clay (\( \phi_c \)), and the volume of clay in rock (\( C \)): \( \phi_F = \phi_t + C(1 - \phi_c) \). Then by assuming that clay porosity is 40%, we can calculate the load-bearing frame porosity and plot velocity versus this porosity (below). A single universal trend appears. Now a simple linear regression can be used to find an expression for this trend or a more sophisticated model describing this trend can be derived (see below).
Goal: Porosity from Seismic

\[ P_{\text{Differential}} = P_{\text{Overburden}} - P_{\text{Pore}} = gh \cdot (\rho_b - \rho_f) \]
Consolidated Uplifted Sands -- Effect of Reduced Overburden

\[ P_{\text{Differential}} = P_{\text{Overburden}} - P_{\text{Pore}} = gh \cdot (\rho_b - \rho_f) \]

Consolidated Uplifted Sands -- Effect of Non-Load-Bearing Clay
### Apiay Case Study 1

#### Table: Fluid Properties

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Density (g/cc)</th>
<th>Bulk Modulus (GPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td>0.846</td>
<td>1.13</td>
</tr>
<tr>
<td>Water</td>
<td>0.96</td>
<td>2.42</td>
</tr>
</tbody>
</table>

#### Diagrams and Charts:

- Depth (kft) vs. GR
- Neutron vs. Density
- Resistivity vs. Caliper
- Fluid Density vs. Bulk Modulus

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**GP170/2001 #11**
Apiay Case Study.2
Apiay Case Study.3

Porosity Disparity between Log and Core
Apiay Case Study

Diagnostic: Elastically Analogous Dataset -- Han’s Data at 40 MPa

\[ \text{PHI}_{\text{MODIFIED}} = \text{PHI}_{\text{TOTAL}} + 0.45 \times \text{CLAY} \]

\[ = 0.60 - 0.0590 \times \rho_p \]

\[ = 0.60 - 0.0587 \times \rho_p \]
Apiay Case Study 5

Porosity Prediction in Wells

\[ \text{Porosity} = 0.69 - 0.0456 \text{ Ip} \]

Fluid Detection? -- Above and Below Water Table

Below OWC
Above OWC
A systematic disparity between the log-derived porosity values and core porosity values has been observed in Apiay wells. The core porosity is systematically smaller than the log-derived porosity.

One possible explanation for this disparity is that the core plugs had residual oil that has not been cleaned out during the cleaning process prior to porosity measurement.

With this hypothesis in mind, we have sent 12 Apiay plugs to Core Laboratories at Bakersfield (CA) for additional cleaning and porosity measurement. The samples were cleaned in Toluene vapor for several days prior to porosity and permeability measurement.