Numerical Examples of Double-Porosity Reflectivity Effects and Proposed Physical Modeling
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ATTENUATION

\[ \alpha^2 = 0.5 \left( 1 - \frac{\rho_f}{\rho_r} \right)^2 \left( \frac{\rho_r}{\rho_f} + \frac{\rho_f}{\rho_r} \right) \]

\[ \gamma = \frac{1}{\sqrt{1 + \frac{\rho_r}{\rho_f}}} \left( \frac{\rho_f}{\rho_r} + \frac{\rho_r}{\rho_f} \right) \]

\[ \beta = \text{rock compressibility} \]
\[ \beta_r = \text{fluid compressibility} \]
\[ \beta_f = \text{porosity} \]
\[ \rho_f = \text{fluid density} \]
\[ \rho_r = \text{bulk density of the fluid-saturated rock} \]
\[ \kappa = \text{permeability} \]
\[ \eta = \text{fluid viscosity} \]
\[ \nu = 2\pi f = \text{frequency} \]

REFLECTION FROM TOP OF RESERVOIR

\[ R^f = \frac{z - z_2}{z + z_2} \left( 1 - \frac{1}{\beta_f} \right) \frac{2z_2z_1^2}{\eta} \sqrt{\frac{\kappa}{\rho_f}} \]

Asymptotic equations of the P-wave attenuation and reflection coefficients are expressed through the mechanical properties of the fluid-saturated reservoir rock (Silin et al., 2005; Goloshubin et al., 2005). The equations are based on a combination of Biot’s approach to the poroelasticity model with Barenblatt’s model of flow in fractured rocks (i.e., Biot-Barenblatt model). We computed attenuation and reflection coefficient as functions of frequency, permeability, dry-rock modulus and viscosity.

The dual-porosity physical model consists of horizontally-stacked sheets of fritted glass beads. Fritted glass are easily manufactured from particles of glass which are fused, or sintered into a solid, but porous material (see picture left). We plan to create thin sheets of sintered or fritted glass beads then lay them side-by-side (below) to simulate porous but fractured rock formations.

The frequency-dependent part of reflection coefficient is primarily influenced by rock compressibility as well as permeability.

ATTENUATION

Attenuation depends on various parameters and it shows a strong linear proportionality to rock permeability.

Reflected Coefficient

The frequency-dependent part of reflection coefficient is primarily influenced by rock compressibility as well as permeability.

PROPOSED WORK

We will conduct seismic experiments to determine the connection between permeability and low-frequency attenuation. The properties of the porous media as well as fluid saturation strongly influences attenuation. The porosity of our model is the sum of the void spaces in the rock matrix and the space between fractures. In their Dual Porosity model, Silin et al. (2005) proposed that the void space associated with fractures acts as a conduit for fluid movement and this is related to the permeability. The proposal leads to an intriguing implication - fractured rocks yield different frequency-dependent attenuation and reflection response from non-fractured rocks that have the same poro-elastic properties. Our plan is to create a physical model consisting of horizontally-stacked thin sheets made of fused glass beads to simulate rock formations with porosity rising from both matrix and fractures. Identical reflection seismic experiments will be carried out over the dual-porosity model and over a simpler physical model of (fused) glass beads of exactly the same porosity. The results of the study will test the validity of the Dual Porosity model (Silin et al., 2005) and advance our understanding of how permeability and frictional-fluid flow influences seismic wave attenuation.

References


G. Goloshubin and D. Silin, 2005. Using frequency-dependent seismic attributes in imaging of a fractured reservoir zone. 75th Annual SEG Meeting, Houston, TX