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

Julius Doruelo, Gennady Goloshubin and Fred Hilterman

ATTENUATION

$$\alpha^P = 0.5\frac{1-\delta^2}{1+\gamma_\beta}\left(\frac{\gamma_\rho}{1+\gamma_\beta}\right)^{\frac{3}{2}}\sqrt{\rho_f\phi\beta_f}\,\frac{\kappa}{\eta}\rho_f\,|i\omega|^2$$

$$\delta = \frac{1+\gamma_\beta}{\gamma_\rho} \qquad \gamma_\beta = \frac{\phi\beta_f}{\beta} \qquad \gamma_\rho = \frac{\rho_\beta}{\rho_f}$$

REFLECTION FROM TOP OF RESERVOIR

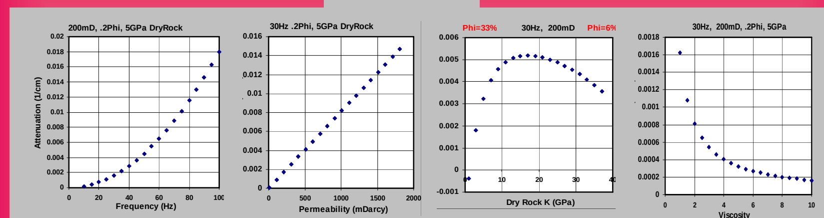
$$R^1 = \frac{z_1 - z_2}{z_1 + z_2} + \left(1-\frac{1}{\delta}\right)\frac{1}{\gamma_\beta}\frac{2z_1 z_2^2}{(z_1+z_2)^2}\sqrt{i\omega\frac{\kappa\rho_f}{\eta}}$$

$$z_1 = \rho_1 V_1\ ;\ \ z_2 = \rho_2 V_2;\ \ z_3 = \rho_3 V_3;\ \ z_2^s = \frac{1-\phi}{\beta}\sqrt{\phi\beta_f\rho_f}$$

β = rock compressibility
β_f = fluid compressibility
ϕ = porosity
ρ_f = fluid density
$\rho_b = \phi\rho_f + (1-\phi)\rho_s$
= bulk density of the fluid-saturated rock
κ = permeability
η = fluid viscosity
$\omega = 2\pi f$ = frequency

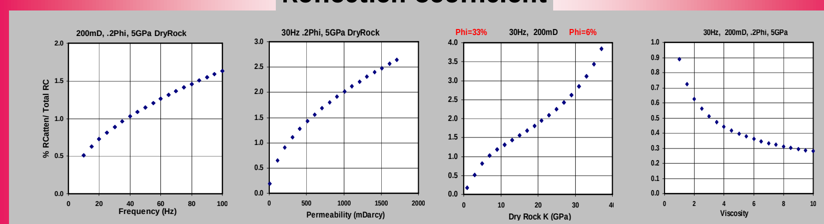
Asymptotic equations of the P-wave attenuation and reflection coefficients are expressed through the mechanical properties of the fluid-saturated reservoir rock (Silin *et al.*, 2005; Goloshubin *et al.*, 2005). The equations are based on a combination of Biot's approach to the poroelastic model with 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.

Attenuation

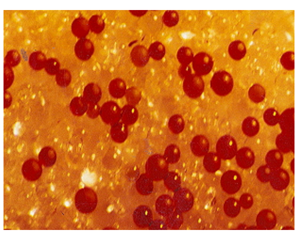


Attenuation depends on various parameters and it shows a strong linear proportionality to rock permeability.

Reflection Coefficient

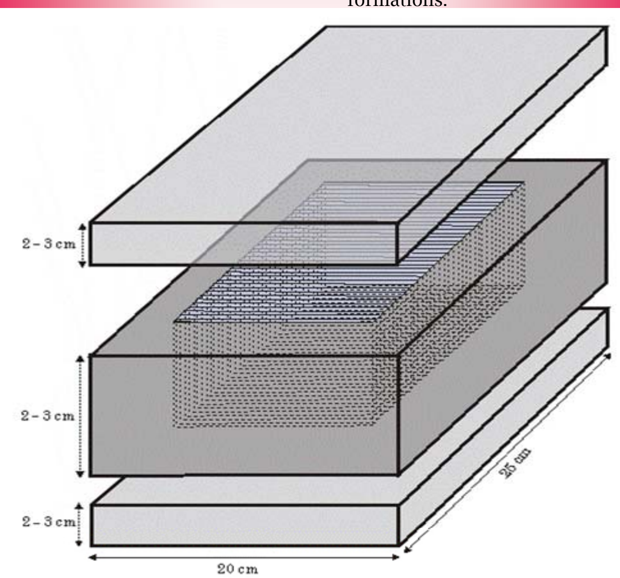


The frequency-dependent part of reflection coefficient is primarily influenced by rock compressibility as well as permeability. .



Picture modified from http://www.adamschittenden.com/technical/500Frits/504Mesh_and...

The dual-porosity physical model consists of horizontally-stacked sheets of fused 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.



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 will 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

Silin, D., Goloshubin, G., Kornev, V. and T. Patzek, 2005. Low-frequency asymptotic analysis of reflection coefficient from a hydrocarbon reservoir. 2nd International Workshop, Lawrence-Livermore Berkeley National Laboratory, Berkeley, California

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