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A seismic-reflection-based approach for determining the hydraulic permeability of rocks in a subsurface region

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Abstract. The hydraulic permeability of rocks characterizes fluid mobility in the pores of underground reservoirs. Accurate information on this quantity is important for various geotechnology applications with urgent social, environmental and political significance (e.g., the exploration, optimization and monitoring of underground disposals of gases, fluids and radioactive wastes; safe underground engineering operations; and the exploration and development of geothermal and hydrocarbon energy). Because of the high resolution and large penetration range of seismic waves as well as the ability of seismic exploration to operate from the Earth's surface, a seismic-reflection-based method for characterizing underground permeability is very important.

The elastic properties of rocks of a given lithology are strongly influenced by the compliant pore space. However, the hydraulic permeability of such rocks can be controlled by compliant pores, stiff pores or both types of pores. Using stress-dependent rock-physics experiments, we derive models of elastic properties (e.g., seismic velocities) as functions of compliant and stiff pore-space geometries. Simultaneously analyzing the stress-dependent behavior of the porosity and of the permeability, we identify which part of the pore space controls the permeability – compliant and/or stiff pore space – and derive a corresponding model. These models are used to directly characterize stiff and compliant pore spaces from seismic velocities and to calculate the underground permeability.

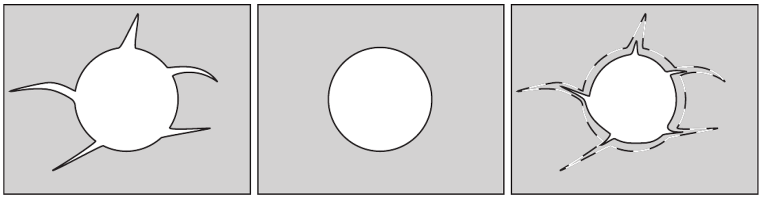

Figure 1. Idealized sketch of the pore space. In the unloaded state, the pore space consists of stiff pores and compliant pores (left panel); this is in contrast to the reference state (middle panel) where the pore space consists only of stiff pores. In the loaded case (right panel), both stiff and compliant pores are deformed due to an applied load (after Shapiro and Kaselow, 2005).

References

Shapiro, S. A. and Kaselow, A.: Porosity and elastic anisotropy of rocks under tectonic stress and pore-pressure changes, Geophysics, 70, N27–N38, 2005.

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