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Laboratory studies on seismoelectric effects

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Seismoelectric describes the physical phenomena of sound waves inducing electromagnetic signals in porous, fluid-filled media. The coupling is due to a layer of excess charges adsorbed to the surfaces of the solid grains that is balanced by mobile ions in the fluid electrolyte; the coupling is of electrokinetic nature. A sound wave propagating through such material induces a small amount of relative motion between the fluid and the solid phase. This relative flow will carry along the excess ions in the electric double layers near the grain surfaces. Thus, a sound wave can act as a current source for macroscopic-electromagnetic disturbances. The acoustic source signal and the secondary electromagnetic signal can then be correlated.

The seismoelectric effects vary strongly on the petrophysical properties of the rock, its type, as well as pore-fluid type. The wide range of phenomena is still poorly understood. However, well-designed laboratory studies with well-controlled rock-sample geometries permit to systematically quantify the electroseismic signals as function of acoustic-signal strength and frequency content, as well as the geometric configuration and relative position of acoustic source, electromagnetic sensors and the rock samples.

Several sandstone and limestone samples are characterized with respect to their petrophysical properties, such as elastic and electric properties, porosity and permeability. Then these identically shaped, cylindrical samples are saturated with water of known salinity and coaxially installed in a cylindrical water tank. An acoustic monopole source in the water, on the cylinder axis above the sample generates compressional waves that are reflected and transmitted by the upper sample face. These echoes are acoustically detected and thus serve as time references. Single-electrode monopole or dual-electrode dipole detectors serve to monitor the induced electroseismic signals. These signals are compared to the acoustic reference echoes and are characterized in amplitude and frequency content as function of rock properties.

The simple and highly symmetric laboratory setup permits direct comparison of the experimental observation with numerical simulations based on Pride's theory (1994). Although the seismoelectric physical phenomena depends on many parameters such as the elastic properties and electrical properties of the porous media, the observations are accurately reproduced for rock samples that are quite homogeneous and isotropic-within the few percent of uncertainty of the laboratory data; and fairly for rocks samples of more complex nature such as limestones. The modeled reproduction of the experiments serves to determine a small number of parameters that completely describe the electrokinetic phenomenology of the present laboratory experiments.