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Seismic Monitoring of Mineral Precipitation within a Fracture

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For in-situ seismic monitoring of natural processes or reservoir engineering projects, it is important to understand how chemical alteration of a fracture or fractured media affects seismic wave propagation. Natural fractures and faults are subjected to chemical dissolution and/or chemical precipitation of minerals. Chemical interactions between the fluid within a fracture and the fracture walls affect the hydraulic and seismic properties of fractures. Mineral deposition can alter the fracture specific stiffness by changing the size and strength of the contact area and/or filling-in of the void space. We performed acoustic imaging experiments on single fractures in granite to determine the effect of mineral deposition on the seismic and hydraulic properties of single fractures.

Hydraulic and seismic measurements were made prior to and after the deposition of $CaCO_3$ in initially water-saturated fractures in granitic samples (110 mm x 104 mm x 70 mm). The transmitted compressional waves were recorded in 1 mm increments within a 64 mm by 64 mm region of the sample to determine the spatial variation in fracture properties. Plane wave 1 MHz transducers were used to send and receive the signals. Four pairs of ports were distributed around the perimeter of the fracture to measure the flow as a function of position. During mineral deposition, the flow rate at each port was monitored and the acoustic response was monitored at the center of the sample. Over a period of a month after mineral deposition, acoustic measurements were recorded over the two-dimensional region. Fluid flow measurements were repeated one month after chemical invasion.

We observed that the largest and fastest increases in seismic amplitudes (Figure 1) after initiation of precipitation occurred for fractures that were initially more compliant because transport and mixing of the two chemical species is faster (slower) for larger (smaller) aperture fractures. The flow rate through the sample decreased by an order of magnitude, and certain ports no longer supported flow, i.e., the flow paths to certain ports were blocked by mineral deposition. The most reliable seismic indicator that the fracture had been altered is the shift in the most probable frequency in the received signal (Figure 2). The most probable frequency shifted to higher frequency after chemical invasion indicating a stiffening of the contact regions of the fracture and possibly a reduction in fracture aperture through mineral deposition. The frequency shift may provide a seismic diagnostic method for remote assessment of alteration of a fracture by mineral deposition.

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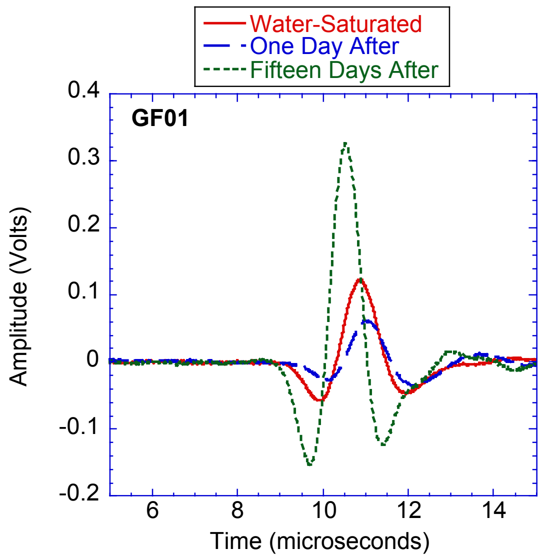

Figure 1. Received compressional-waves for a fracture in the water-saturated condition, one day after chemical invasion and fifteen days after chemical invasion. Mineral precipitation results in an increase in amplitude of the signal.

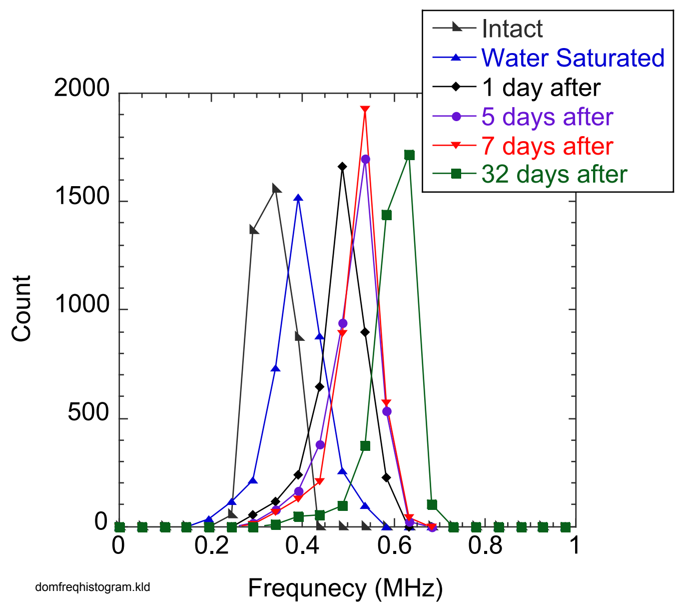

Figure 2. Histogram of the most probable frequency determined from 3844 compressional-wave signals (representing a 62 mm x 62 mm region of the fracture) for an intact sample, the intact sample after inducing a fracture and saturating the fracture with water, and for 1, 5, 7 and 32 days after chemical invasion in the induced fracture.