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Influence of pressure on permeability and elastic wave velocities in macro- and micro-fractured rock

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Long-term integrity is required for many sub-surface structures excavated in the rock mass; such as repositories for radioactive wastes and caverns for the storage of liquid petroleum gas and natural gas. An essential requirement for long-term integrity is to retard the migration of fluids into and through these structures. In crustal rocks, fracture and pore networks provide the principal pathways for fluid flow. However, if fractures and pores are closed or sealed, the migration of fluids can be retarded. Thus it is important to study the process of fracture and pore closure. Here, we report changes in the fluid permeability and P- and S-wave velocities of intact, macro-fractured, and micro-fractured rock sample subjected to elevated effective pressures.

In order to investigate the influence of pressure on the closure of macro-fractures and micro-fractures, we used a rock sample with no visible pre-existing cracks and very low initial permeability. For this reason, Seljadur basalt (SB) from Iceland was chosen as the sample material. SB is a fresh, columnar-jointed, intrusive basalt with a porosity of 4 % and no visible microcracks.

Permeability was measured in a servo-controlled permeameter using the steady-state flow method. The permeameter is equipped with transducers that allow the simultaneous measurement of P- and S-wave velocities. The wave velocities were measured by the ultrasonic transmission method.

Measurements of permeability and elastic wave velocities were first made on intact samples. The Brazil test technique was then used to split the samples in half to provide macro-fractured sample for further testing. Measurments of permeability and elastic wave velocities were then made on the macro-fractured sample in order to investigate the effect of fracture closure. Then, we heated the macro-fractured sample at 800 degree Celsius in order to produce micro-fractures in the sample and conducted further measurements of permeability and wave velocities.

It was shown that the permeability of intact SB was low and remains essentially constant over the whole effective pressure range. By contrast, the permeability of the macro-fractured SB was initially much higher, but decreased clearly as effective pressure was increased and the fracture became closed. The permeability of the macro- and micro-fractured SB also decreased with increasing the pressure. The permeability of the macro- and micro-fractured SB was similar to that of the macro-fractured SB under low pressure. This result indicates that the open macro-fractures dominate the permeability under low pressure. On the other hand, the permeability of the macro-and micro-fractured SB was higher than that of the macro-fractured SB under high pressure. This indicates that the macro-fractures with low aspect ratio close easily and open micro-fractures with high aspect ratio become dominant to the permeability with increasing the pressure.

The difference in the wave velocities between intact, macro-fractured, and macro- and micro-fractured samples decreased with increasing effective pressure, tracking the closure of the fractures. Specifically, the increase of S-wave velocity vibrating nornal to the macro-fractures was clear with increasing the pressure, which

indicates the closure of fracture.

Overall, results in this study demonstrate the importance of the closure of fractures to increase the shielding ability of rock and to retard the migration of fluids into and through structres in a rock mass.