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Effect of fluids on the failure mechanism in crystalline rocks

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We have conducted true triaxial tests in two crystalline rocks, an amphibolite (from the KTB ultra-deep borehole) and a rhyolite (from a deep boring in Korea). Rectangular prismatic specimens were subjected to three independent principal stresses to better replicate in situ stress conditions. Two sets of experiments were conducted for each rock. In one, specimens were jacketed and tested dry; in the other, the pair of faces subjected to confining fluid (through which the least principal stress was applied) were kept unjacketed. This latter set was meant to simulate stress conditions at a borehole wall in which the least principal stress (σ_3) is typically the radial component provided by the borehole fluid in direct contact with the exposed rock surface. During a test we maintained σ_3 and σ_2 constant and increased the major principal stress (σ_1) until brittle failure occurred.

In jacketed specimens of both rocks tested failure occurred in the form of a fracture steeply dipping in the σ_3 direction. SEM studies reveal that the main fracture (or fault) forms from the coalescence of a multitude of stress-induced microcracks subparallel to $\sigma_1 - \sigma_2$ plane, which start developing upon dilatancy onset and localize as σ_1 increases. The steeply dipping fault exhibits shear displacement inferred from the visible gouge within its opening and the offset noted in some grains. This type of failure under compressive stresses is commonly expected for crystalline rocks.

The second set of experiments, in which one pair of the prismatic specimen faces was left unjacketed and in direct contact with the confining fluid, brought about a fundamentally different failure mechanism from that in dry specimens. In unjacketed specimens brittle fracture occurred at or soon after dilatancy onset, and resulted from the development of densely spaced extensile fractures subparallel and adjacent to one

of the unjacketed faces. We infer that upon dilatancy onset the confining fluid intrudes through the exposed faces and into newly opened microcracks, and promotes their elongation into through-going fractures. For any given least and intermediate principal stresses, the compressive strength of unjacketed rock is dramatically reduced from that under dry conditions. The true triaxial strength criterion of the two rocks can be expressed as a linear relationship between the octahedral shear stress and the octahedral normal stress at failure. The mechanism of failure of unjacketed rock simulates failure conditions at the borehole wall in which breakouts are the result of the development of a swarm of subparallel tensile cracks creating rock flakes that buckle sequentially and fall into the borehole.