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TIME DEPENDENCE AND WIDTH CONSTRICTION IN ROCK FRACTURE - EXPERIMENTAL EVIDENCE AND MODELING RESPONSES

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ABSTRACT

Rock fracture is a fundamental building block for modeling of a wide range of geophysical processes, natural hazards, and engineering applications. For decades, the starting point of such modeling is Linear Elastic Fracture Mechanics (LEFM). In this regard, and to the extent these models are successful for their intended purposes, LEFM has an extensive history of impact on the field of rock mechanics. However, another important, but perhaps less acclaimed role of LEFM in rock mechanics has not to do with pragmatic success. Rather, LEFM-based models provide a baseline that calls into sharp relief the ways in which rock fracture fails to conform to this classical theory. As a path to scientific discovery, this is the more profound of the two roles LEFM has played and, for the purposes of this presentation, provides a backdrop for two examples of such experimental deviation from classical LEFM and subsequent modeling responses in the field of rock fracture.

The first example focuses on time-dependence of rock fracture, beginning with a striking observation of time-dependent acoustic emission (AE) from the vicinity of a macroscopic tensile crack in a rock sample that persist for hours to days after crack propagation [1]. These comprise the first of a series of experiments resulting in a modeling response bringing time-dependence into simulation of rock fracture in order to explain phenomena ranging from AE aftershocks to delayed initiation of multiple hydraulic fractures within each stage of multistage hydraulic fracturing of oil, gas, and geothermal wells [2].

The second example begins with field data for a fluid-driven crack created at around 300 m depth in a very low permeability formation in the Western Canadian Sedimentary Basin. Combining pressure records with novel caliper measurements of crack width and advanced interpretation of tiltmeter data to constrain crack volume, orientation, and geometry made it clear the crack compliance was far below what could be explained by an LEFM-based model. Additionally, with multiple re-injections of fluid at ever-increasing volumes, the compliance increased in a history-dependent manner exceeding the change LEFM would predict based only on the growing crack size [3]. The modeling response considers rock fracture to leave intact bridges that constrict the crack opening and which eventually can be broken if the crack aperture is sufficient to stress the bridges past their breaking points. The resulting models of width constriction [3, 4] provide a new paradigm to interpret the frequent observation of unexpectedly-large fluid pressures and constricted widths observed for fluid-driven cracks such as energy storage lenses, hydraulic fractures, and magma-driven dykes.

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