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# Assessing elastic properties of cracks in rock samples subjected to thermo-hydro-chemo-mechanical damage

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An understanding of micro- and macrofracture behavior in low porosity rocks is pertinent to several areas of energy and environmental science such as petroleum production, carbon sequestration, and enhancement of technologies based on geothermal energy, etc. For example, the carbonate reservoirs in dolomitic or micritic formations with matrix porosities below 6% suggest the importance of fracture-augmented permeability in production. Similarly, hydrocarbons have been found on nearly every continent in tight basement rocks, all of which have little matrix porosity and their permeability therefore rely solely on hydraulic connectivity from fractures. For geothermal energy, various igneous and sedimentary rocks (granites, basalts, and limestones) are being exploited across the globe, with some of the lowest porosity and permeability. In all these cases, fractures are necessary to improve rock permeability and thermal exchange between the rock and working fluid, which can be enabled by hydraulic stimulation, as well as by secondary cracking due to extreme temperature gradients from the injection of cold water. The fracture geometry, density, and distribution all together control not only fluid and thermal transport in the rocks, but also their seismic attributes that can be used to extract information about the fractures.
In order to accurately interpret the seismo-acoustic data (usually, the velocities of compression and shear waves) reliable rock physics models are required. Here, we report the results of interpretation of such experimental data for both as-cored rock samples and those subjected to thermo-hydro-chemo-mechanical damage (THCMD) in the laboratory. For interpretation, we use a convenient model of fractured rock in which fractures are represented as planar defects with decoupled shear and normal compliances. The application of such an approach makes it possible to assess and compare the elastic properties of fractures in the rocks before and after application of THCMD procedures. For the analyzed samples of granites, basalts, and limestones it has been found that for a significant portion of rocks, the ratio of normal-to-shear compliances of cracks significantly differ from the value typical of conventionally assumed penny-shape cracks. Furthermore, for some samples, this ratio appears to be noticeably different for fractures existing in the as-cored rock and arising in the same rock after THCMD procedures. These results indicate that damage to a rock typically changes its compliance ratio since the old and new cracks are likely to have different elastic properties. Our results are also consistent with the notion that a specific damage process occurring for a given microstructure will consistently create cracks with a particular set of elastic properties. The proposed methodology for assessment of elastic

properties of cracks in rock samples subjected to thermo-hydro-chemo-mechanical damage has given previously inaccessible useful information about the elastic properties of fractures and can be extended to interpretation of seismic attributes of rocks for a broad range of other applications.