DEFORMATION AND PERMEABILITY IN TIGHT ROCK FORMATIONS BY MEANS OF X-RAY TOMOGRAPHY AND TRI-AXIAL TESTING

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ABSTRACT

Understanding the mechanical behavior of rocks and their saturating fluid is critical to many geological and engineering fields. It is crucial to optimizing hydrocarbon exploration and development operations, CO_2 storage and sequestration, improving geothermal energy yields, and understanding natural and human-made phenomena such as the increased seismic activity in Oklahoma in recent years. Of particular importance is understanding the behavior of fractured geological materials, and the effect of stress on their hydraulic permeability.

A standard approach to study geological materials involves replicating their in-situ stress and temperature conditions before testing. Reproducing these conditions is done utilizing tri-axial testing apparatuses on cylindrical rock samples. Due to the high pressures associated with tri-axial testing, the testing devices are entirely sealed, leaving a great deal of uncertainty regarding the mechanical behavior of the testing samples during the experiments. With the advent of micro-CT imaging, geologists and engineers can 'visually' inspect the samples during tri-axial testing. Also, advanced micro-CT data analysis allows for the extraction of quantitative information about the rock sample during deformation.

Here, we propose an experimental investigation that combines tri-axial testing, micro-CT imaging, P- and S-wave velocities, acoustic emissions, and hydraulic permeability. I will use this combination of data to investigate the dependence of hydraulic permeability on varying the stress, strain, and strain-rate on low-permeability sedimentary rocks such as shales and tight carbonates. This proposal is unique because studies that combine micro-CT imaging with the stated array of data types are few, and no study known to the author has integrated all of these data types to study the dependence of hydraulic permeability on the previously stated variables.

Successful work will yield at least four complete experiments and a model explaining the relationship between permeability and strain-rate for the tested samples. Such a model will improve the understanding of fluid flow in naturally and artificially fractured rocks.

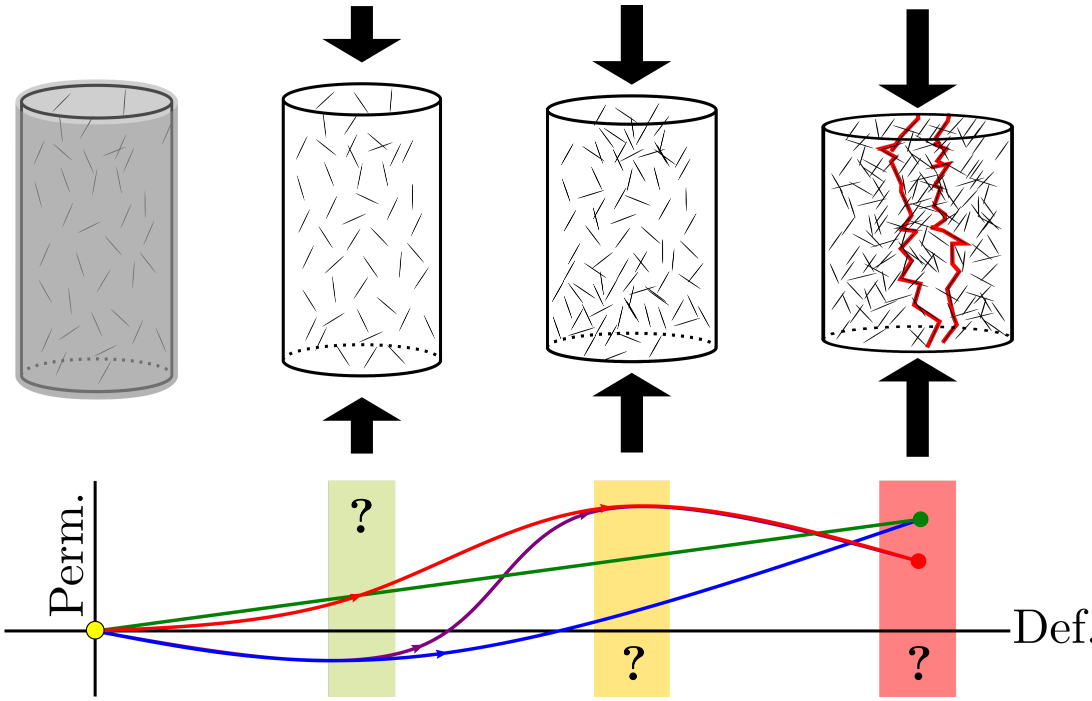

Figure 6. Schematic of the deformation progression (horizontal axis) and micro-fracture development through a single experiment. Vertical axis represents possible relative permeability values. Colored curves represent possible permeability paths compared to the initial yellow reference state. From left-to-right: intact shrink-wrapped sample; sample brought to in-situ conditions; increasing axial stress and observing significant micro-cracking activity using (AE); sample in the post-failure state where the red color highlights possible fluid flow pathways. The horizontal axis is analogous to time where. The colored boxes indicate the approximate regions where imaging and measuring will take place.