Laboratory Scale Hydraulic Fracture and Proppant Injection

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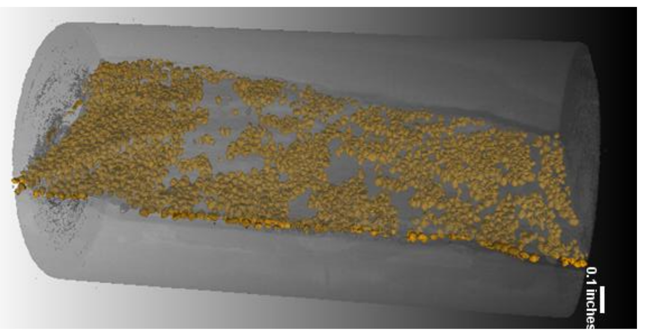
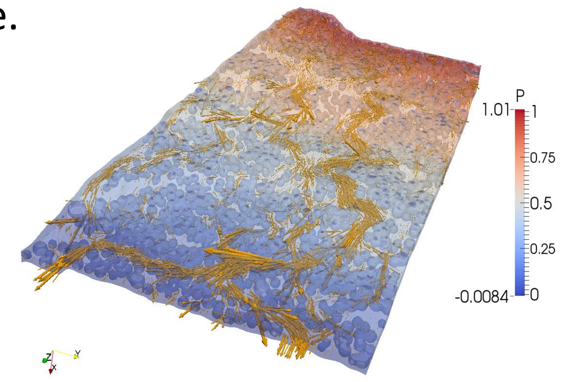
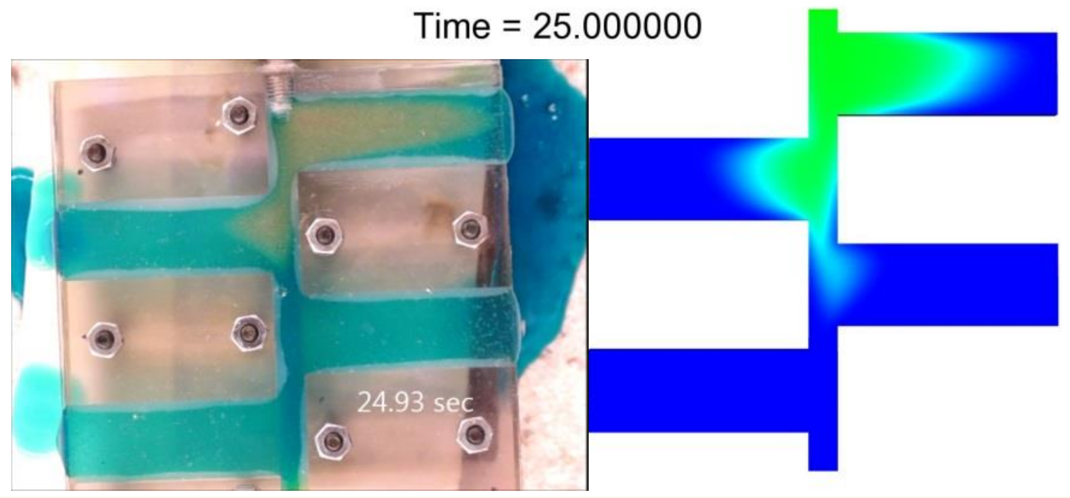
Testing and modeling was performed on manually fractured and propped shale. The specimens were fractured sub-parallel to bedding and manually propped with a monolayer of quartz sand (30/50 sieve). Computed Tomography (CT) was used to image the specimens periodically through testing to evaluate the evolution of the void space in the crack. The resulting image stacks were processed using a combination of thresholding, edge detection and watershed algorithms to identify crack volume and individual particles. This allowed meshes to be generated from the CT data.

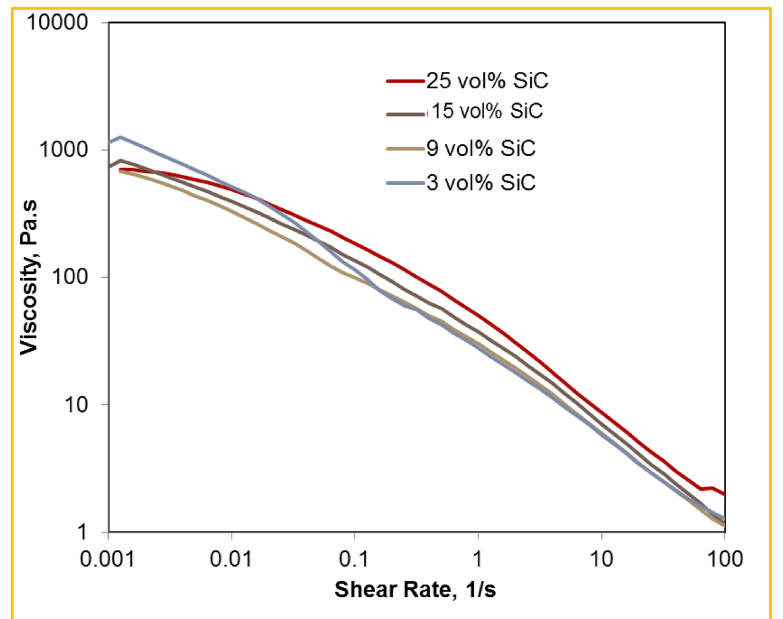
Meshing the proppant particles directly proved to be overly cumbersome, so the location of the center of each proppant particle was determined, and proppant particles were replaced with spheres of corresponding volume. The resulting mesh was used for simulations of flow through the propped fracture geometry. The images to the left show a false color image of the proppant in the crack and the flow through the crack space.

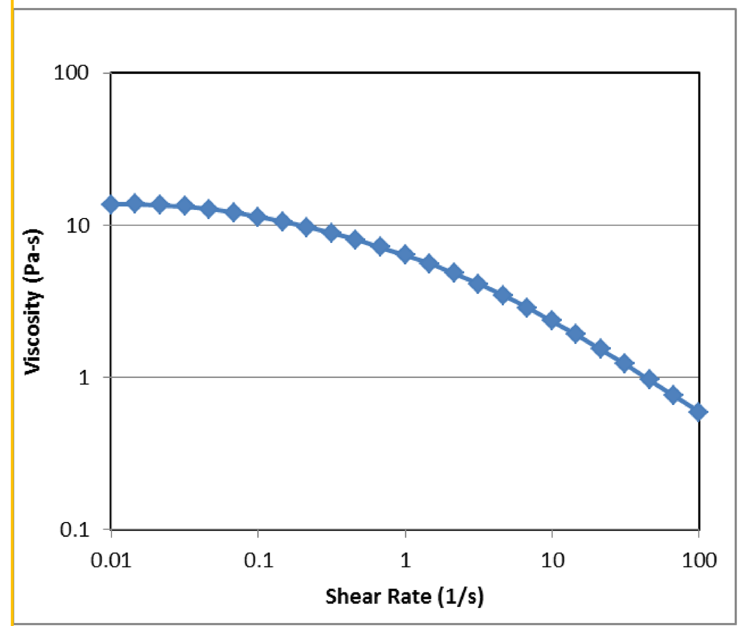


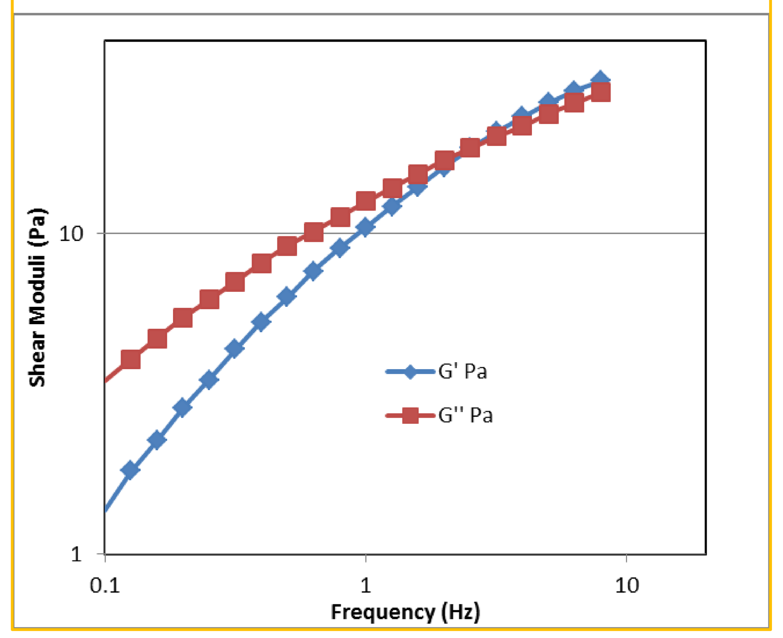


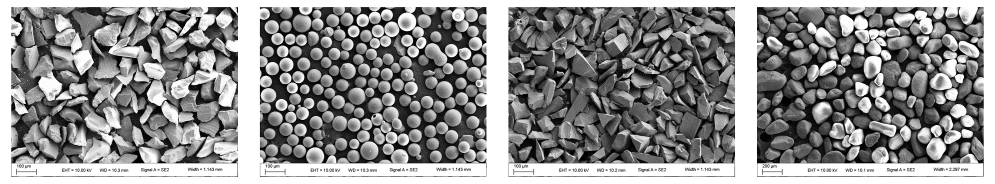
Initial tests were performed with water as the fluid in the fracture. As testing progressed in order to prop fractures under in situ conditions, after fractures were formed, a thicker fluid was needed. A guar/boric acid based fracturing fluid was used, in conjunction with a number of proppant types. Proppants other than sand were used in order to allow for more particle visibility in the CT scanner. Therefore Aluminum Oxide and Silicon Carbide were used. The Aluminum Oxide was discarded as it reacts with the carrying fluid forming particle chains, and complicating the already complicated rheology of a viscoelastic particle laden fluid. To the right are plots of the rheology of the fluid, and images of flow cells and the corresponding models which are being used to validate the flow codes with the complex rheology fluids are shown below.











Proppant particles had to be scaled down in order to have them able to be injected in the smaller fracture openings generated in the lab. The particles shown are approximately 100 microns in size. From left to right they are, Aluminum Oxide, Glass Bead, Silicon Carbide, Quartz Beads

This work was undertaken to develop a better understanding of proppant flow into fractured rock and how that proppant is distributed. In order to achieve this a process for fracturing rock in the proper orientation with respect to bedding and stress state was required.

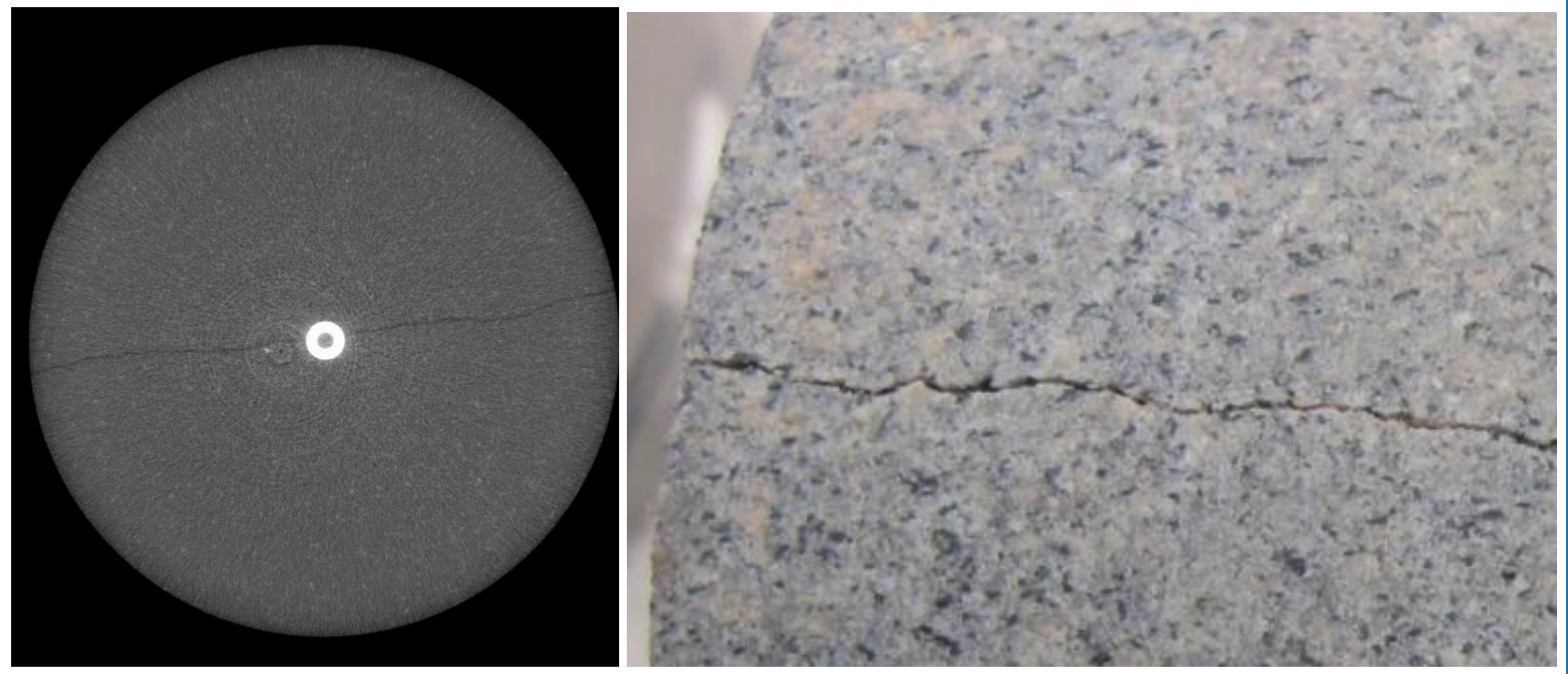
Coupled with this a modeling investigation has been undertaken to look at proppant transport and flow within a fractured rock at small scales to inform upscaled models, and better understand proppant distribution in situ.

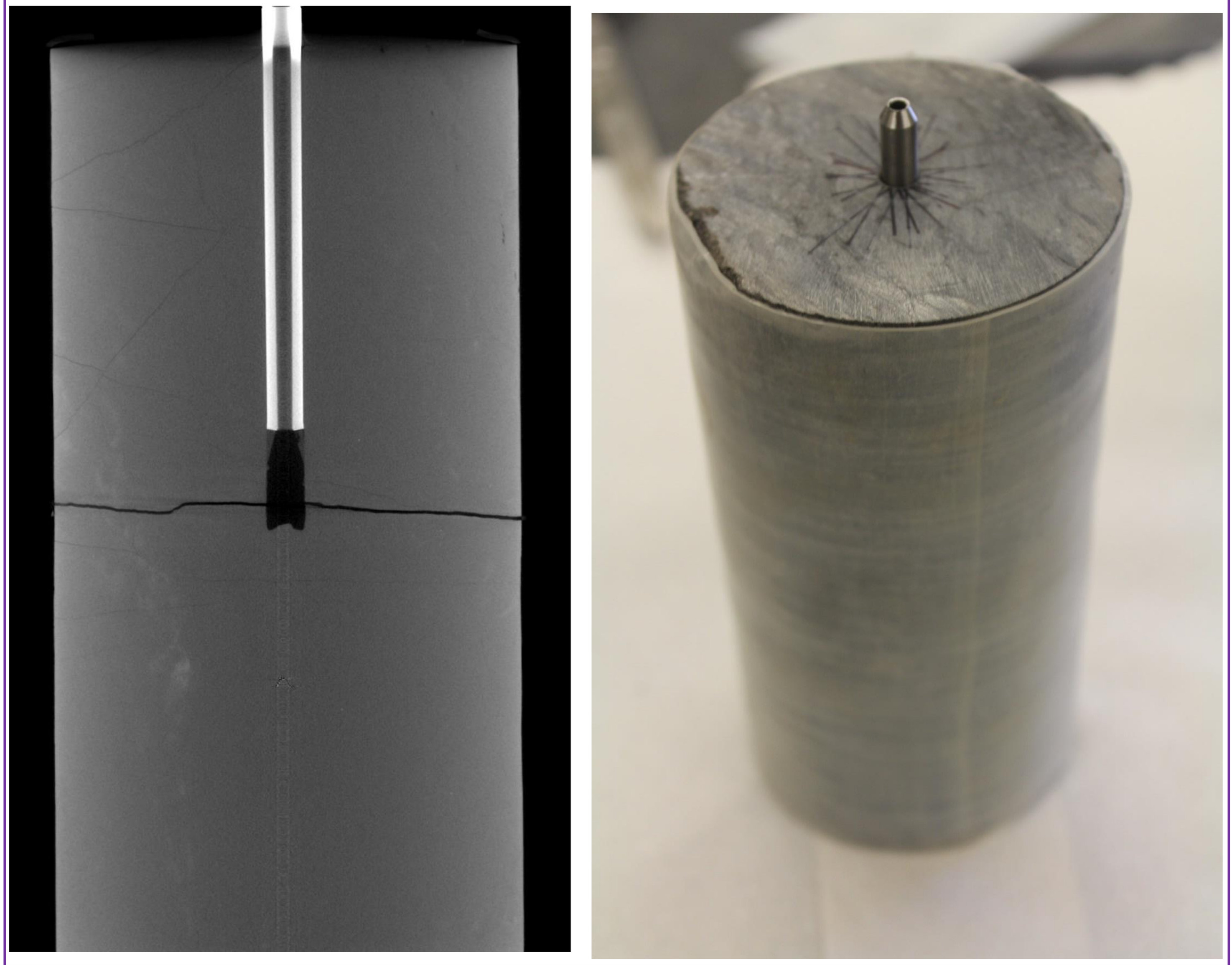
To date models have been successful in matching behavior in flow cell tests. Laboratory tests have been successful in generating representative fractures and injecting proppant into the fracture.

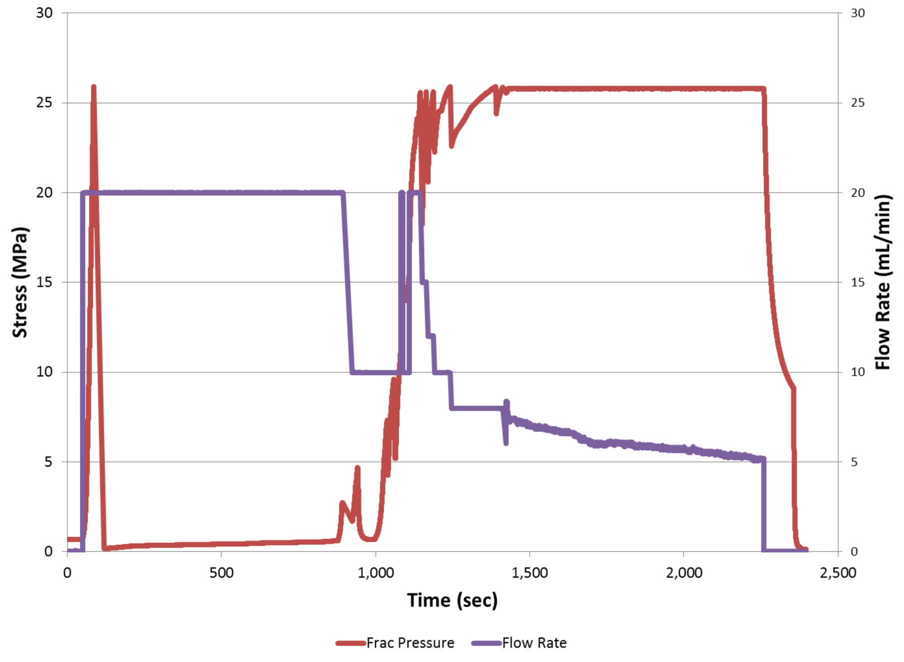
Tests were performed on shale specimens 3 inches in diameter and 6 inches long under extensile conditions in order to generate fractures which are normal to the coring direction or "disks on a string." Cores were taken from the parent rock parallel to bedding in order to best represent orientation of bedding, and coring direction in a field scenario. Specimens are drained to atmosphere after fracture through a filter media in order to allow for injection of large quantities of proppant into the fracture to simulate a longer fracture in a larger body of rock. The specimen shown has not been propped, but shows proper fracture orientation.

Preliminary tests were performed on Granite due to its low permeability, low cost, and ease of specimen manufacture. Granite tests were performed under axisymmetric compression and fractures were formed parallel to the coring direction, as shown below. Fractures were typically initiated with the injection pump running in a constant flow mode, then after the fracture formed the pump was switched to a constant pressure mode for injection of proppant.

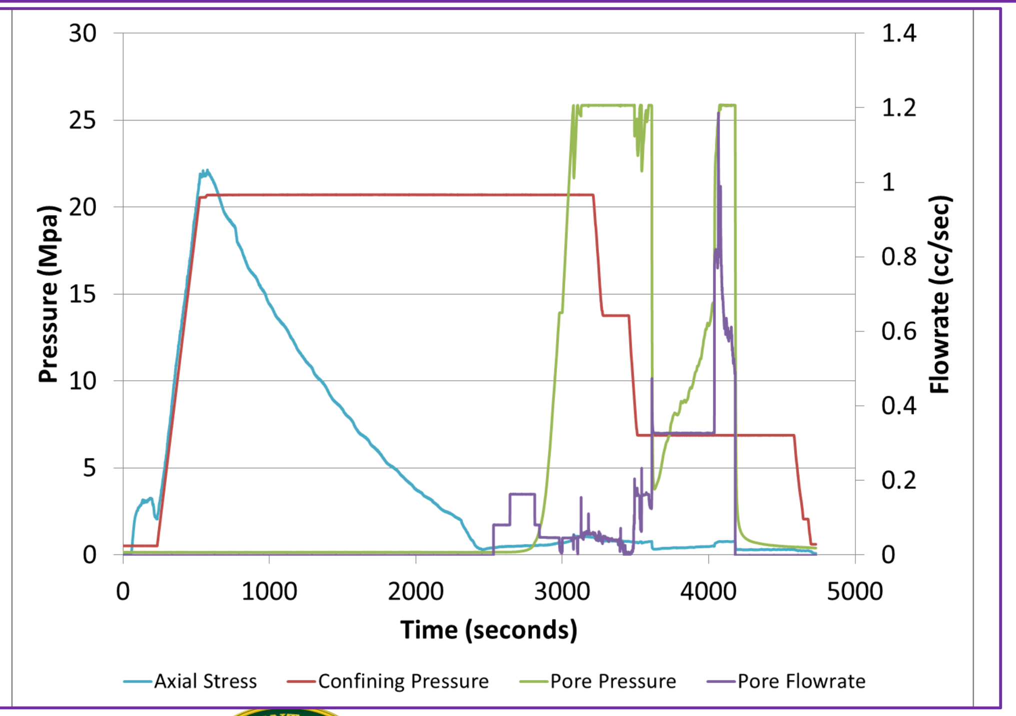
Due to the density of the granite and the size of the specimens (4 in diameter, 8 in long). Visualization of the proppant is difficult in the CT images.







Extensile fractures were performed by first hydrostatically confining the specimen to 3000 psi (plot to the right) confining pressure, then decreasing the axial load (the specimen is sealed to the piston to prevent confining pressure from being applied to the end of the specimen). Because of the limitations on the injection pump for this test it was necessary to reduce the confining pressure in order to generate the fracture, but future testing will be performed with a higher pressure injection pump which will allow the stress conditions to be closer to field conditions when the fracture is formed.



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