Fracture Systems and Development in an Active Fault Zone

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1. Abstract

The Little Grand Wash (LGW) fault, located in Emery County, Utah, is an east-west trending south-dipping anastomosing normal fault system. The area is known for its association with Crystal Geyser, a cold-water CO_2 charged geyser emanating from an abandoned borehole drilled within the fault damage zone in 1935. The LGW fault zone provides a natural laboratory to study rock fractures in various lithologies to better understand the controls on rock failure within a fault zone. The fault system contains multiple splays and interaction zones and records a complex history of faulting, fracture creation and reactivation, and multiple fluid flow events. In this project, outcrop exposures are being tied to core recovered in 2019 from the fault zone. The core samples were collected across the Jurassic Brushy Basin Member (JMb) of the Morrison Formation in the hanging wall and the Jurassic Summerville Formation (JS) in the footwall. These core samples and outcrops allow us to compare deformation within the hanging wall sandstones of the JMb and the footwall siltstones of the JS. Here we combine core observations, including structural descriptions, and petrography, to understand the mechanical and facture distribution data that can be tied to the outcrop expression, away from surface weathering processes. These data are supported by computer tomography (CT), where multiple generations of deformation events are identified. We use this data to interpret the controls on fracture development and reactivation including uplift history, early soft sediment deformation, fluid-rock interactions, and mechanical rock strength changes associated with structural diagenesis and overpressure in the active CO_2 fluid system.

2. Methods & Data

Core recovery at the Little Grand Wash fault zone crossed the main fault strand of this anastomosing fault zone recovering 16.5 meters of core sampling both the hanging wall and footwall damage zones. We present results from the cores LGW 1A and LGW1B, which provide a composite length of core from the hanging wall to footwall and juxtaposes the Jurassic Brushy Basin against the Jurassic Summerville Formation. Structural descriptions and petrographic observations from the core samples are combine with mechanical data from both core and outcrop to characterize facture distribution and reactivation processes. Air permeability measurements were made using NRS TinyPerm instruments on core (TinyPerm2) and outcrop (TinyPerm3) samples, in outcrop an N-type Schmidt Hammer was used to estimate unconfined compressive strengths (UCS). Optical petrography of core samples were compared with stratigraphically equivalent samples away from the fault and influence of CO_2. Core measurements include a systematic permeability assessment of fractured versus unfractured core sections supported by CT images and are used to identify trends in permeability, rock strength, structural and early soft-sediment deformation.

3. Observations

During drilling CO_2, water, and oil reached the surface and core samples were bleeding oil from fractures. Optical petrography provides evidence of multiple fluid flow events occurring within the fault zone. These fluid rock interactions are preserved in the vein minerals and cements of the fault rocks (Figure 1).

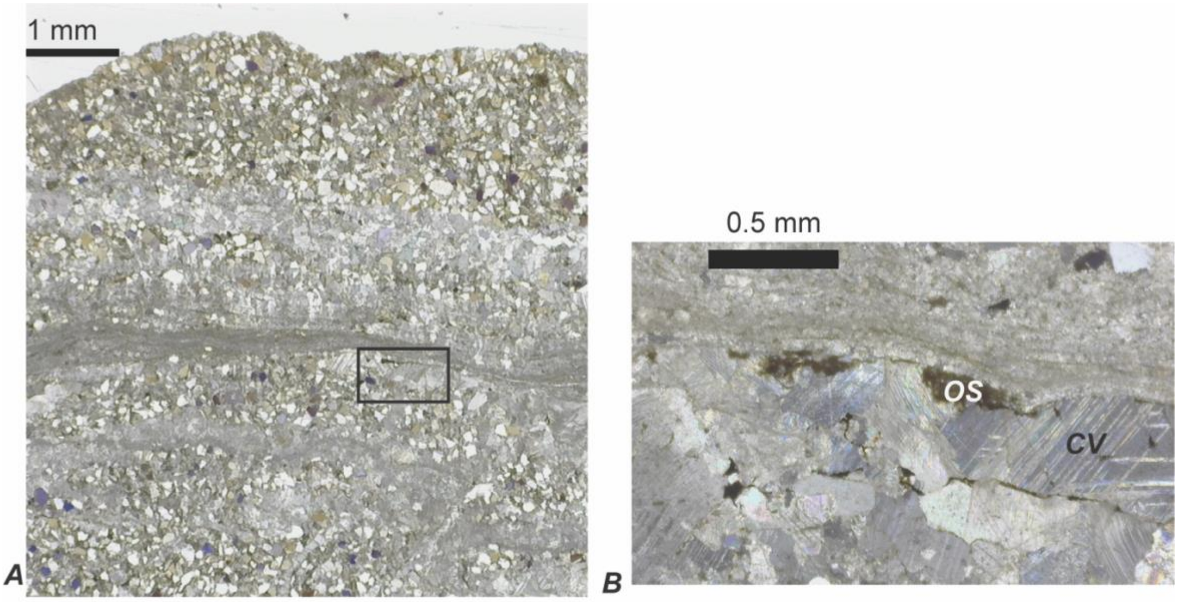

Figure 1. Photomicrographs, PPL showing calcite cements and veins observed in the JMb hanging wall damage zone. Inset B (black outline in A), shows oil stain (OS) associated with the calcite veins (CV).

We compare the fault zone sandstones to their stratigraphic equivalent sandstones outside the influence of the fault and away from known subsurface accumulations of CO_2. Off-fault sandstones within the same stratigraphic interval contain sparse calcite and hematite cements. We note that the sandstones samples from the core are recemented and contain abundant calcite cement (Figure 2). The cement and vein mineralization provides evidence of rock-fluid interactions and likely impact both permeability and UCS in sandstones within the fault zone. Preliminary data from outcrop indicates an inverse relationship between air permeability and UCS, in most samples the higher the permeability the lower the UCS.

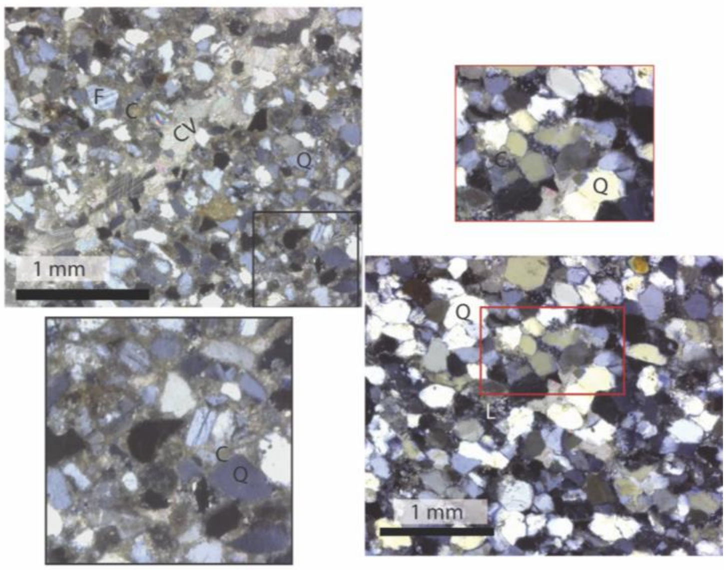

Figure 2. Comparison of cements observed in core sample (left) and outcrop samples collected away from the fault (right). C- calcite, F – feldspar, CV- calcite vein, Q – quartz, L-lithic.

In the core samples recovered from the footwall Js, we observe open fractures that were open in the subsurface. These joints are associated with bleached margins suggesting that fluid was able to flow through these permeability pathways removing iron and leaving a bleached margin (Skurtveit et al 2020). These bleached fractures have a higher range in permeability values than the unbleached fractures and both the hematite cemented, and calcite cemented fault rock (Figure 3).

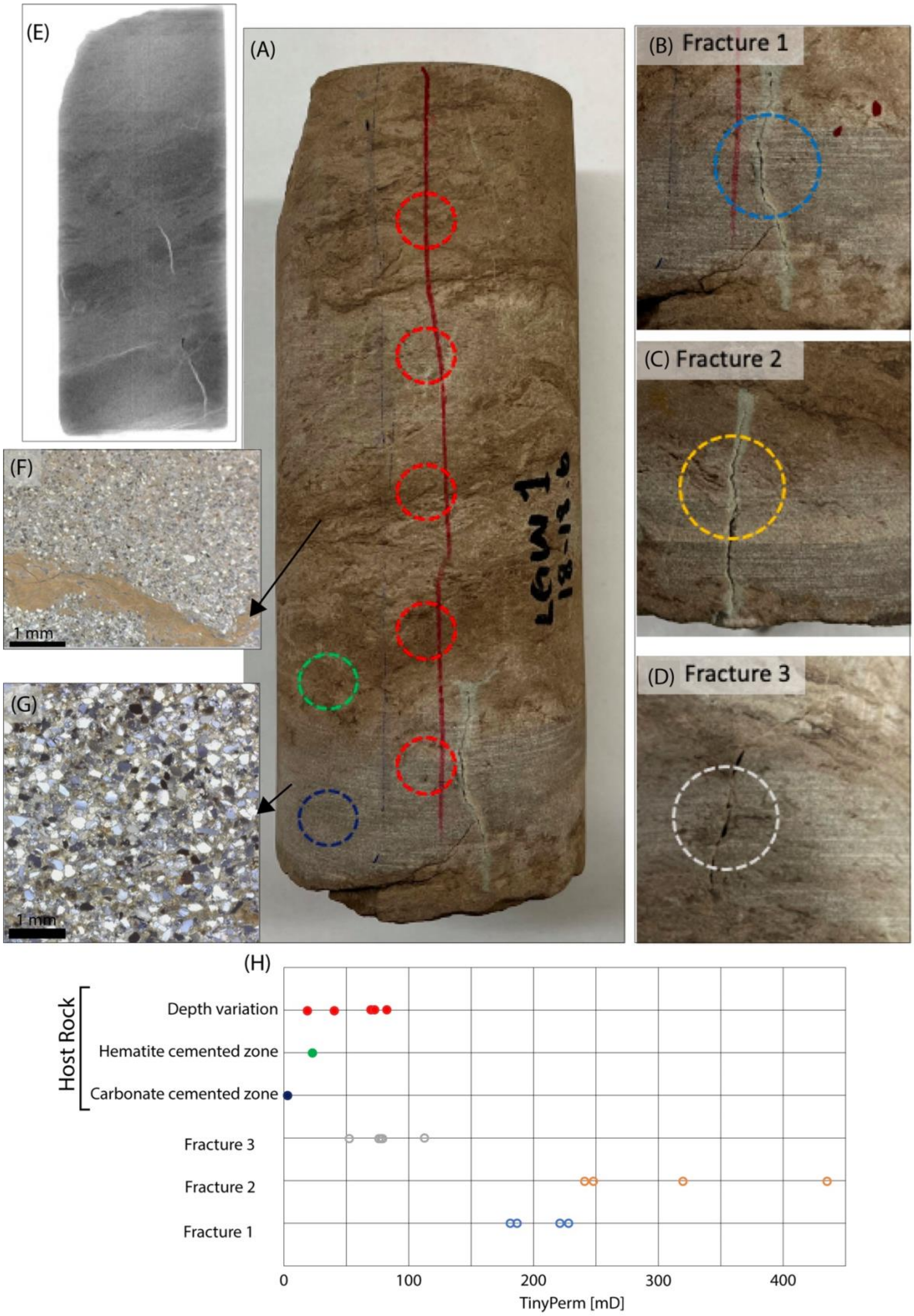

Figure 3. Core analysis of Jurassic Summerville Formation. (A) Core photo illustrating the permeability measurements positions. (B & C) Example of fracture with bleached margin. (D) Example of fracture without bleaching. (E) Computer tomography image showing density variation and open fractures (light color = low density). (F) Photomicrographs of hematite cemented core (G) Photomicrographs of calcite cemented core. (H) Measured permeability for fractures and fault rock.

4. Conclusions

This new dataset with core samples from within a fault core provides a unique opportunity for detailed analysis of fault rock properties within a fault zone with long history of fluid expulsion events. Comparison with same formation away from the fault show extensive cementation within the faults zone varying from hematite to calcite cement. Open fractures with bleached margins provide evidence of fractures as important structures for fluid transport within cemented fault rocks. Detailed studies on deformation processes and timing of fluid-rock interaction events is part of the ongoing interpretation work.

5. Acknowledgments

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6. References

Skurtveit, E, Sundal, A, Bjørnarå, TI, Soldal, M, Sauvin, G, Zuchuat, V, Midtkandal, I, Braathen, A. 2020. Experimental investigation of natural fracture stiffness and flow properties in a faulted CO2 bypass system (Utah, USA). Journal of Geophysical Research (JGR): Solid Earth 2020. Volume 125.(7)