PRF grant #58572
Project Title: Making Laboratory Deformation Bands in Sandstones for Comparison with Natural Field Data from the San Andreas Fault System
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2018-2019 Summary

The goal of this project is to use deformation bands, which are developed within the Etchegoin Formation across much of central California, to interpret stress directions and their relationship to the San Andreas fault system. These Plio-Pleistocene-age rocks are exposed northeast of the San Andreas fault where other indicators of stresses show S_{Hmax} directions that are at a high-angle (80°-90°) to the San Andreas fault. Our preliminary field observations, however, suggest much lower values of S_{Hmax} (60°). The project has two avenues of exploration: a laboratory component trying to create deformation bands in a controlled setting and a field component to better characterize deformation bands across the region.

Laboratory experiments

The laboratory experiments are performed in collaboration with Dr. Melodie French at Rice University. Three Carleton College undergraduates have been involved in this work as summer researchers: Peter Lindquist (prior to the grant in 2017), Kate Nootenboom (2018), and Lena Nyblade (2019). Together they have conducted 12 deformation experiments under varying conditions. We do not believe that these experiments have created any deformation bands yet, but they have yielded useful insights about the mechanical behavior of a fine-grained sandstone from the Etchegoin Formation (Fig. 1).

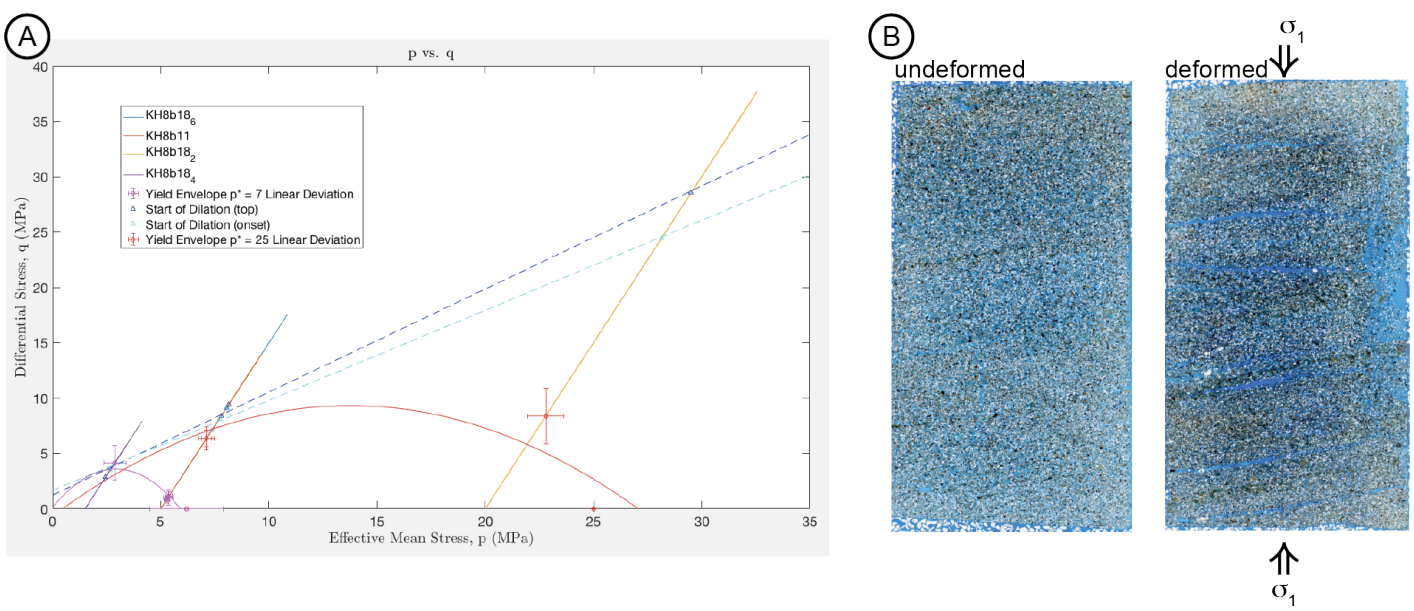

Figure 1: Panel (A) shows a preliminary construction of the yield cap for the Etchegoin sandstone using results from four different experiments. Panel (B) shows and undeformed (left) and deformed (right) thin section of the Etchegoin Formation. The blue color is epoxy. Although there is compaction in the deformed sample, we have not been able to detect deformation bands–they would be expected to form at $\sim 60°$ angle from the horizontal. Note, the horizontal features in the deformed sample are probably due to the unloading process.

Field observations

The field component is focusing on understanding larger-scale structures that are themselves composed of deformation bands. There were two short field seasons in December and in March, whose timing is dictated both by the Carleton College academic calendar and the weather in central California. Four students participated in these field seasons—Nora Mertz, Nootenboom, Lindquist, and Emily Houlihan—as well as one post-doc (and Carleton alum), Dr. Chelsea Scott from Arizona State University. Dr. Scott's involvement included flying a drone over two critical outcrops near the San Andreas fault to create high-resolution maps. This coming year, Mertz and Nootenboom are analyzing data from the field studies as part of their senior theses. Our work over the past year suggests that Riedel structures are be observed at varying scales and may be important for analyzing regional data (Fig. 2).

Figure 2: Three scales of observation of deformation bands from the field. At left, two students collect data from a Riedel ladder structure. In center, a drone photo captures the larger-scale parts of a similar ladder-style geometry; there is a person for scale in the lower-left. At right, an image of one of the field site constructed using photogrammetry by Chelsea Scott.

Impacts

Impact for the PI

This project has expanded the scope of my research within structural geology in two new directions. The laboratory experiments with Dr. French are well outside the standard tools that I use for my work, allowing me to connect field observations to the micromechanical behavior of the Etchegoin sandstone. The high resolution addition of drone imagery with Dr. Scott allowed unprecedented mapping abilities at several newly identified and spectacular outcrops (e.g., Fig. 2).

Impact for the students

The students involved in the laboratory experiments gained hands-on experience with geologic research equipment, data analysis, and ideas well outside the scope of their coursework at Carleton College. They also expanded their professional network, with mentoring from Dr. French and her graduate students. Nyblade will be presenting combined results of summer experiments at the upcoming AGU Fall meeting. The students who came in the field gained valuable experience on how to conduct field work, seek permissions, and had access to cutting-edge field tools (drones, photogrammetry, etc.) via their interactions with Dr. Scott.