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# Resolving stratigraphic variations in natural fracturing using core data

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## Summary

The manner in which a rock unit fractures and heals is dependent on the mechanical and diagenetic properties of the unit. This study aims to better assess fracture stratigraphy at the formation scale by comparing data from four different units in a single conventional core. In ascending stratigraphic order, these units are limestone, calcareous shale, sandstone, and argillaceous shale. We apply fracture analysis, sedimentology, rock mechanics, and Helical CT scanning to compare fracturing of mechanically different lithostratigraphic units with the same complex structural history.

## Introduction

Because natural fractures can profoundly influence the performance of an unconventional reservoir, an understanding of fracture properties is essential for reservoir optimization. Fracture analysis in conventional core is used to constrain fracture properties and to ground-truth image-log interpretations. Since natural fracture characteristics are directly related to rock properties, assessing fracture attributes in a stratigraphic/sedimentologic context can improve the accuracy of fracture models.

This study compares natural fracture characteristics of four mechanically different lithostratigraphic units from a structurally complex region. Core and fracture descriptions are related to X-ray diffraction (XRD) mineralogy, thin-section descriptions, rock mechanics data, and Helical CT (HCT) scan data to relate fracture attributes to rock properties. This data set allowed for comparison of two brittle units (limestone and sandstone), and two shale units (calcareous shale and argillaceous shale).

## Methods

The vertical conventional core analyzed in this study comprises four formations: limestone, calcareous shale with interbedded siliceous limestone, very fine to fine-grained sandstone, and argillaceous shale (ascending stratigraphic order). We completed a detailed core description and fracture description on the entire core length. Lithology and texture were documented, as well as natural fracture properties such as fracture length, orientation, aperture, and mineralization composition and percentage. Lithology was further constrained using XRD mineralogy and thin-section analysis.

Helical CT (HCT) image slices give a three-dimensional view of core through a fractured interval, and HCT datasets were used to quantify fracture characteristics, including relative orientation and mineral fill percentage. Fractures in the two shale intervals were viewed in hand sample and then related to HCT data to determine if mineralized fractures were open or fully healed, and the degree to which open fractures are dilated.

Geomechanical analyses, involving multi-stage triaxial compressive strength (M-STCS) and unconfined compressive strength (UCS), were conducted on samples collected from the limestone and sandstone units, allowing us to compare natural fracturing to the mechanical properties within the two more brittle units.

## Examples

Analysis of 381 natural fractures, fracture zones and swarms, and bed-bound fracture sets documented, revealed distinct differences in fracturing between the four formations. Natural fracture density for open and healed fractures is significantly higher in the limestone and sandstone formations, whereas bed-parallel shear density is highest (by an order of magnitude) in the argillaceous shale unit. Joints and other long, high-aperture, high-angle fractures are more concentrated in the limestone and sandstone formations, whereas lower-angle shear fractures are more concentrated in the shale units. Of the four units, the limestone has the longest fractures and the largest average fracture aperture.

In comparing the two shale units, the argillaceous shale is dominated by low- to intermediate-angle shear fractures, bed-parallel shears, and some high-angle sheared joints, whereas the calcareous shale contains mostly long, high-angle joints and short, high-angle, bed-bound fractures confined to thin, silicified limestone beds.

In general, fracture properties are similar in the sandstone and the limestone. However, fracture properties in the sandstone are variable, seemingly related to facies variations within the formation. Although average aperture in the limestone is more than four times greater than the average aperture in the sandstone, the most conductive fractures occur in the sandstone, specifically within more massive beds.

## Conclusions

While comparing fracture properties of the four formations, some of the results are surprising. The two more brittle units (sandstone and limestone formations) bear the greatest similarity. Despite likenesses between the sandstone and limestone units, production from fractures within these units would likely be significantly different. However, the two shales do not share the same degree of similarity as the sandstone and limestone. The calcareous shale actually bears more in common with the sandstone than with the argillaceous shale. Despite these formations possessing a singular tectonic history, lithostratigraphy was clearly a major control of mechanical response to deformation at this locality. Perhaps most importantly, compositional and sedimentological differences in shale formations resulted in significantly different fracture attributes in these fine-grained units. Results suggest that all shales are not created equal and that fracture models need to consider multiple variables related to stratigraphy to accurately represent fracture properties.

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