Mechanical Characterization and Failure Development within Jurassic Sandstones in Proximity to Salt Structures, Paradox Basin, Southern Utah

Lauren Reeher, Amanda Hughes, George Davis, David Streeter, Chad Julius
University of Arizona

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Abstract

Numerous and well-exposed systems of faults and fractures throughout the Paradox basin have motivated mechanical investigations into the structural development and stress conditions required to produce the observed failure. This research has been encouraged by the presence and abundance of high angle conjugate shear fractures and faults within sandstones near salt structures throughout the basin. High angle fractures can develop due to nonlinear failure criterion at low differential stress, either under the Hoek and Brown model with mode II shear failure or under the Griffith model with bimodal (trans-tensile) failure. Both types of failure indicate distinct paleostress conditions that require low differential stress, presumably caused by circumstances related to the adjacent Pennsylvanian salt. The specific stress conditions required to produce the observed failures can be determined by a precise analysis of the mechanical properties of fractured Jurassic Sandstones. In order to quantify this, we carried out a mechanical characterization of reservoir quality sandstones that dominate the Jurassic section, including the Curtis, Wingate, Navajo, and Entrada formations. This characterization has involved a series of geomechanical analyses including Brazilian, seismic velocity, uniaxial and triaxial testing to determine the elastic constants and the complete failure envelope. Our results indicate that the tensile strength of the sandstones is too low to reasonably produce widespread bimodal failure. Our samples exhibit distinct nonlinear failure envelopes under low confining stress and the

observed parabolic geometry can be used to explain the steep failure angles seen near the salt structures. We hypothesize that because the salt has essentially no strength and deforms readily, its presence will decrease differential stress in nearby sandstones, producing the required stress conditions for high angle failure. With detailed field mapping, we have demonstrated that further from the salt sediment interface, shear fractures are less steeply dipping, conforming to the Coulomb criteria with higher differential stress. We have combined the observed failure angle with the established failure envelopes to determine the extent of the impact of salt on differential stress in the adjacent sandstones and the encompassing area of stress field influence. This integrated study provides field-based evidence for the applicability of a parabolic, rather than linear, failure criteria to describe deformation in natural geologic settings, as has been successfully utilized in many borehole and mining engineering applications.

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