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# Shearing vs Shear-tensile Failures in Unconventional Plays and Their Potential Impact on Stimulation Effectiveness

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Microseismic monitoring has been a well-established practice in the hydraulic fracturing industry for over a decade now, allowing operators to determine event (fracture) locations, magnitudes and to estimate the relative geometry of the fractured zone. The increase in multi-well pads has increased the information that can be obtained from microseismic monitoring by providing the opportunity for multi-array monitoring. With multiple monitoring arrays, the coverage of the events' radiation patterns is robust enough to enable the calculation of failure characteristics, such as fracture orientation and principal strain/stress axes, through moment tensor inversion of microseimic signals.

The moment tensor of an event is a representation of the mechanism responsible for the observed radiation of seismic energy; in other words, it defines the mode of failure that caused the microseismic event. Seismic moment tensor inversion (SMTI) is the process by which these mechanisms are determined and can be obtained for an event that has a high signal to noise ratio observed on multiple arrays and with sufficient volumetric coverage around the source to allow for a unique solution to be determined. By inverting for the failure mechanisms of these events, we can distinguish between tensile crack opening (increase of volume), tensile crack closing (loss of volume) or shear (pure slip on a plane) fractures as well as previously mentioned, the orientation of these fracture planes. The orientation of the fracture planes can be used to assess the fracture network and to distinguish between activation of natural fractures and new fractures being created.

In our study we compare microseismic results from various hydraulic fracture stimulations, including examples from the Permian, where the array configuration allowed for SMTI to be performed on the events. Through these examples, we will show how differing geological settings combined with differing completion programs resulted in very different fracture behaviour. In most cases, injection results in the activation of pre-existing fractures, however, the modes of failure appear to be site/geologically different. In some sites, failures are dominated by sub-vertical shear-tensile failures, exhibiting both opening and closing during different injection intervals, whereas as other sites exhibit vertical shearing with little to no tensile behaviour. These differences are reflected in the calculated enhanced fluid flow rates (or relative permeability values) and thereby may be an indication of the stimulation effectiveness or in-effectiveness.