Role of Faults and Natural Fractures to Hydraulic Fracturing and Production from Wolfcamp Horizontal Shale Wells

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Our study focuses on characterization of tectonics and natural fractures, occurring in the Wolfcamp shales located in the Midland Basin, to understand the role of natural fractures on hydraulic fracturing and hydrocarbon production from horizontal wells penetrating the Wolfcamp A and B intervals. We integrate recent 3D seismic acquisition, microseismic, and image log data.

We observe high angle E-W reverse faults, with a left lateral slip component, throughout the Sub-Leonardian formations. Fault displacement along these fault planes results in fault propagation folds through overlying strata as the dominant structural style in the basin center; transcurrent faults have secondary occurrence. These structures accommodate regional shortening related to far-field plate convergence. Fault patterns within the Midland basin imply a NE-SW compression, fitting the tectonic grain of the SW United States, which consists of NW-trending yoked basins and uplifts. NE-trending tectonic fractures are dominant, implying that regional paleo-stress was oriented NE-SW.

Two sets of natural fractures are observed in horizontal wells of the Wolfcamp formation. A set of NE-trending (30-60°) tectonic fractures are dominant, with subjugate NW-trending (310-330°) fractures occurring orthogonal. Image log interpretation shows these fractures to be both partially conductive and resistive, implying both open and cemented fracture types. Drilling induced fractures are consistently E-W in a direction consistent with the present day S_{Hmax}. These fracture sets do not vary with local structure orientation. The majority of fractures occurs in organic rich beds, as indicated by a high gamma ray response (80+gAPI), and are bed-bounded.

We have discovered previously unknown north -south trending transcurrent faults with right lateral offset in the southern part of the Midland basin. 3D seismic data mapping reveals numerous N-S faults with dimensions of less than one to more than 10 miles of length. These accommodate strain from shortening and tend to terminate as a series of broadening horsetail fault splays with dip slip accommodation. Vertical displacement of up to 200 feet can be seen in Paleozoic formations below the Wolfcamp while evidence of offset within the section of typical landing zones for the horizontal wells is beyond seismic resolution.

A critical finding to well performance is that fault displacement on transcurrent faults is transmitted into Wolfcamp strata. Fracture density approaching 2 fractures/foot measured from image logs along the length of the lateral wellbore correlates with a reduction in well performance versus that of relatively undeformed strata having 0.1 to 0.2 fractures/foot. This manifests in oil production impairment and higher than anticipated water cut for extended time periods when placing horizontal wells into strata with increased fracture density.

Microseismic surveys have extended our ability to map faults and fractures. In the seismic domain, we observe microseismic events to align with fracture swarms associated with mappable faults at deeper stratigraphic levels. Fracture sets that are not visible at the target level appear as linear trends of microseismic events. Observations of lower background gas on mudlogs in these regions may be related to loss of pressure in reservoir targets.

Geophysical mapping using 3D seismic attributes such as curvature in conjunction with ground truth image log observations show potential as tools to predict damaged zones of fracture swarms related to fault structures. These attributes at present serve as a guideline, however multivariate analysis of seismic, microseismic, and petrophysical logs shows promise in delineating highly fractured zones and allows planning teams to better react to future well targets.