Multi-Scale and Multi-Disciplinary Approach to Unconventional Reservoir Characterization: Example of Hydraulic Fracturing Treatments in a Horizontal Barnett Shale Well

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Over the last few years the Barnett Shale formation has been the focus of tremendous attention. Large amount of data has been collected in this technology- and economics-driven play to develop local knowledge which to some degree is now being exported and adapted to its numerous cousins worldwide. We present the results of an on-going study associated to a multi-stage stimulation project in the Fort Worth Basin. A several thousand feet lateral was drilled along the direction of σ_h and had one offset well from which the fracture treatment was monitored using microseismic mapping. A sonic scanner log was run in the cased horizontal wellbore. The toe section of the lateral displays the highest stress normal to the borehole and therefore likely has the highest degree of stress anisotropy. Predicted planar narrow hydraulic fracture networks are confirmed by subsequent real-time microseismic data.

Conversely, the heel section of the lateral displays the lowest amount of stress in the σ_H direction and hence the lowest anticipated stress anisotropy. A fracture initiated in this section of the wellbore should create a wide complex hydraulic fracture network also confirmed by microseismic data. A variety of seismic attributes (e.g., effective curvature, anisotropy, etc.) has been used to predict pre-existing fracture probabilities and orientations. Striking correlations with microseismic response is observed and relates to pre-existing calcite filled fracture networks observed from cores. If the pre-existing fractures act as preferential planes of weakness (lower tensile strength than virgin shale) the expectation is to observe a long narrow fracture fairway to form parallel to the fractures and regional stress field as confirmed by microseismic data. Treatment pressure data shows a drop in pressure consistent with a simple hydraulically induced fracture fairway due to the alignment of pre-existing fractures. Converse consistent observations are made heel-ward. From a stimulation point of view, immediate implications are that more stages would have been required toe-ward to access the bypassed zones. For reservoir modeling purposes, we build an interpretation model based on a newly developed plane extraction method considering the uncertainty ellipsoid associated to hypocentral locations and prior knowledge of expected fracture orientations. In addition to plane interpretation, we consider each microseismic event‘s orientation relative to the interpretation, giving some insight into the fracturing mechanism using P/Sh values. The number and location of the major planes is determined quantitatively, but does not constitute an unambiguous deterministic result. We carry forward the complete probabilistic interpretation to the production prediction stage using the techniques of multiple realization simulation that are today commonplace in reservoir engineering.