



Borehole Microseismic Monitoring to Optimize Hydraulic Fracturing and Re-Fracturing Treatments

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Summary

Significant volumes of gas are being produced from unconventional shale reservoirs such as the Barnett, Fayetteville, Whirlpool and Woodford Shales in the US. These plays are partly technology driven and partly economics-driven. Modern well log evaluation techniques and completion methods are required to yield economic wells. Understanding the created fracture geometry is critical to the effectiveness of any stimulation program. However, almost all predictive models used by reservoir and production engineers to estimate recovery in stimulated wells are based on assumptions that naturally lead to oversimplified fracture geometry.

Firstly, we discuss the basics of microseismic monitoring, which is one of the latest and most accepted technologies allowing reservoir engineers and geoscientists to understand hydraulically induced fractures as well as naturally pre-existing fracture networks in three dimensions. In the cases highlighted, we use one or several arrays of sensitive and high-vector fidelity geophones in one or several observation wells at a monitoring distance from the wells to be treated. These geophones record the microseismic events generated while the formation fails in relation to the hydraulic treatment. These recordings being performed along a continuous time-line, microseismic hypocentral locations and associated source parameters can be determined and mapped in real time to document how the hydraulically induced fracture system propagates in regards to the zone of interest.

Secondly, we present the results of several microseismic monitoring campaigns performed in these various shale environments to highlight the variability of the induced fracture systems to be expected during an initial stimulation program. We document how local stress fields can sometimes vary along a lateral and how perforation strategies can be developed to ultimately maximize production. We illustrate that it is critical to integrate surface seismic data with real-time microseismic monitoring of hydraulic fracture

treatments to detect potential geo-hazards unresolved by surface seismic data, verify interpreted fault geometries and allow on-the-fly changes in fracture stimulation design to maximize the reservoir volume effectively contacted by the stimulation treatment.

Thirdly, following initial completion, oil and gas wells experience a production decline that results from depletion, water influx, lost conductivity, drainage interaction, equipment failure, etc. Some of the causes for lost productivity can be remedied, while others cannot. A well might also contain potentially productive zones that were bypassed either intentionally or inadvertently during the original completion. In an attempt to increase productivity, operators sometimes initiate re-fracturing programs designed to identify and re-complete underperforming wells. We show re-fracture stimulation case studies where a novel diversion technique is successfully applied to Barnett horizontal wells. We emphasize real-time monitoring and control decisions to produce diversion, increase lateral coverage, influence fracture geometry and improve gas recovery.