geoconvention
Calgary • Canada • May 7-11 2018

Geometry and failure mechanisms from microseismic in the Duvernay Shale (Canada) to explain changes in well performance with drilling azimuth

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Non-contiguous acreage positions commonly lead to drilling azimuths parallel to section boundaries. Analysis of well-performance with drilling azimuth across plays in North America reveals that on-azimuth wells (parallel to $sigma_{Hmin}$) are typically better than off-azimuth wells. A simple, but elegant microseismic trial by Athabasca Oil Corporation has two wells on the same pad thus minimizing geological variability; one on-azimuth and one ~45 degrees off-azimuth, from which rock failure and connectivity can be assessed.

Microseismic from the hybrid fracture treatments in the two wells shows a large contrast in event density, with the on azimuth well showing far fewer events, but double the productivity. There is also a difference in treatment fluid, with the on-azimuth well having 1/3 more gel and 1/3 less slick-water, although total injected volumes are equivalent. Events were filtered in multiple ways: by stage; every 5 minutes within a stage; by fluid type, and by magnitude to understand the azimuthal, stress and completions controls on the mechanics and the productivity.

The treatments of the two wells have very different spatial patterns as detected by both surface and downhole arrays. The off-azimuth well has a well-developed 'longitudinal frac' which is interpreted to facilitate re-stimulation of previous stages. In-situ stress calculations show that both shear failure and bedding parallel stimulation are more likely with this drilling azimuth. Furthermore, the off-azimuth well has two distinct domains during gel treatment; near-wellbore and far-field. The intensity of structural lineaments is similar between the two wells, so the contrast in events results from enhanced reactivation. Filtering by event magnitude shows that the off-azimuth well also has more larger events in the far field, presumably enabled by the greater proportion of slick-water. Several hypotheses exist to explain the poorer off-azimuth well performance: 1) near wellbore frac complexity introducing tortuosity, measured by an increase in ISIP; 2) out-of-stage stimulation causing over-flushing and loss in near well-bore conductivity; 3) planes of shear failure pinching out, resulting in areas of stranded connectivity. A conceptual model is developed that shows how shear and tensile failure may be preferentially developed in the off- and on-azimuth wells respectively, with an analysis of the S/P ratios from both wells.

Other authors (e.g. Cipolla et al., 2014) recognized that the size of the event cloud is not proportional to productivity, but in this trial the inconsistency is striking. The interpretation herein, supports the assertion that tensile failure in the hydraulic fracturing process is largely aseismic (e.g. Maxwell, 2011; Warpinski et al., 2013) and that off-azimuth drilling has a higher risk for delivering lower quality fracture treatments, the impact of which decreases with higher matrix permeability.