Determination of Hydraulic Fracture Orientation in the Kuparuk River Field, Alaska

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The Kuparuk River field on the North Slope of Alaska (Figure 1) is the second largest producing oil field in North America. Currently the production from the Lower Cretaceous Kuparuk formation exceeds 300,000 barrels of oil per day under waterflooding. This reservoir is overlain by the Colville, West Sak, and Ugnu reservoirs which contain an estimated 20 billion barrels of oil in place. These formations are unconsolidated, have widely varying fluid and rock properties, and will require waterflooding and enhanced oil recovery processes. Development options for all of these reservoirs include hydraulic fracturing of the injection and production wells; hence, characterization of the in-situ stress field is critical for optimizing field performance and recovery.

The regional crustal stress field on the North Slope is extensional with maximum principal horizontal stress oriented northwest-southeast. Previous work on fracture direction in Kuparuk, however, indicated that the in-situ stress field was more complex in its orientation. The Kuparuk reservoir occurs within a broad northwest to southeast-trending anticline which plunges to the southeast. Normal fault patterns within the Kuparuk River field show two dominant strike trends: (1) northwest-southeast and (2) north-south.

In this study the hydraulic fracture direction, at both shallow and deep horizons, was determined by integrating geologic, engineering, petrophysical and geophysical data. Dipmeter logs were processed and interpreted to determine wellbore breakout directions for both shallow and deep horizons. Formation microscanner (FMS) images were used to discriminate between incipient wellbore breakout zones and mechanical fracturing from drilling. Hydraulic fracture screenout data were correlated with wellbore azimuth, and a tiltmeter survey was conducted in the northern sector of the field to further refine predictions of hydraulic fracture direction.

The results of all these analyses indicated a variation in fracture direction across the Kuparuk River field. In the northeast sector of the field a northwest-southeast (NW-SE) fracture direction (Figure 2) was determined from dipmeter data in ten wells and confirmed with fracture screen-out data (Figure 3). This direction, which is N39°W with a standard deviation of 26° azimuth, is consistent with the regional orientation of maximum principal stress across the North Slope of Alaska. In the northern sector of the field, a NNW-SSE fracture direction was determined based on dipmeter data from 2 wells, FMS log images (Figure 4), a tiltmeter survey and fracture screen-out data. This direction, which is N10°W ± 10°, is aligned subparallel to the strike orientation of the major faults in that area. In the southwest sector of the field, the fracture direction was determined to be northeast-southwest (NE-SW). The N46°E ± 21° fracture direction is interpreted to result from the influence of a paleostress regime linked to early deposition of the Kuparuk formation in a broad, northeasterly-trending structural trough that existed prior to structural inversion.

The results of this study have indicated three distinct fracture directions for the Kuparuk River field. This variation is interpreted to result from the influence of faults and reservoir structure on a near isotropic horizontal stress field. Recognition of the change in orientation of hydraulic fractures across the anticlinal crest of the Kuparuk structure was accomplished by integrating reservoir engineering data, geophysics, geology, petrophysics and rock mechanics. This paper has shown how interdisciplinary work can lead to improved reservoir description and modelling which will ultimately improve resource exploitation.