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Topical Report

Results of the Multi-Site Project Experimentation in the B-Sand Interval: Fracture Diagnostics and Hydraulic Fracture Intersection

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1.0 EXECUTIVE SUMMARY

This report documents the results of fracture diagnostics research conducted in the informally designated B-Sand interval of the upper Mesa Verde Group as a part of the GRI/DOE Multi-Site Project. The field site for the project includes wellbores and surface infrastructure from the former DOE Multi-Well (MWX) Experiment located in the Piceance Basin, Northwest Colorado.

The information documented in this report is divided into two main sections: 1) results of fracture diagnostics experimentation and fracture modeling in the B Sand; and 2) results of an intersection well designed to remotely intercept the B-Sand hydraulic fractures and provide information to verify the microseismic mapping technique and provide far-field information on hydraulic fracture character.

The focus of the M-Site fracture diagnostic experimentation has been the application of subsurface, remote-well accelerometer arrays to map microseismic events occurring in association with hydraulic fractures. The fracture mapping in the B Sand utilized the 30-accelerometer array cemented in place in the Monitor Well and a wireline-retrievable 5-level array wall-locked in the MWX-3 casing. The microseismic event maps from these two arrays provided a time-dependent view of hydraulic fracture growth and geometry in the B Sand.

Simultaneous to microseismic data acquisition, data acquisition supporting other independent fracture diagnostics techniques occurred. These techniques included fracture geometry based on treatment pressure modeling, near-wellbore fracture height estimation based on radioactive (RA) tracers in injected fluids, and fracture dimensions based on modeling of inclinometer data provided by six instruments cemented in combination with the accelerometers in the Monitor Well. The inclinometers provide a measurement of the mechanical deformation of the earth associated with hydraulic fracture inflation and deflation.

Seven injections were performed in the B Sand and the various fracture diagnostics techniques provided information on fracture growth and total extent. The microseismic and inclinometer data indicated that the fracture(s) propagated in Injections 2-B through 6-B which used relatively simple fluids (i.e., KC1 water and linear gel) in volumes ranging from 27 to 400 bbl, attained a maximum half-wing length of approximately 400 ft and had only limited out-of-zone height growth (total height approximately 65 ft). Inclinometer data modeling independently confirmed the limited fracture height growth in these same injections.

Fracture diagnostics measurements acquired during the fluid-only injections resulted in several interesting observations:

- Rapid lateral growth was observed for all treatments using thin fluids (KC1 water or linear gel).
- Time-dependent microseismic fracture imaging usmg the Seismic Visualization Program provides a unique view of the timing of height growth, fracture extension after shut-in, staccato fracture growth behavior, and the redirection of fracture growth after shut-in.
- Inclinometer data further suggested that the unpropped fractures retained a residual fracture width of approximately 20% of the maximum frac width.

The fracture(s) propagated in Injection 7-B, which included 77-klb proppant and 601-bbl fluid (linear and crosslinked gel), initially were contained in the B-Sand interval but ultimately had significant upward, out-of-zone height growth. The lack of downward growth in all injections, but primarily in the propped treatment, suggests that the process of height growth in hydraulic fracturing is more complicated than currently envisioned.

Fracture modeling results, which included comprehensively acquired stress test data, approximated the microseismically measured fracture lengths, but model-predicted fracture heights were greater than those mapped microseismically.

Intersection Well No. 1B (IW-1B) was subsequently drilled and 11 hydraulic fractures in the B Sand were recovered in core at a point 126 ft from the MWX-2 treatment well. The fractures occurred over a 2.6-ft horizontal interval. Several independent techniques (including observations of pressure transients down the fracture(s) , RA anomaly in the IW-1B, and recovery of colored proppant included in Injection 7-B) confirmed that the fractures recovered were hydraulically induced through B-Sand injections. Wellbore survey data was used to determine that hydraulic fracture azimuth was N71.6°W which verified the N72°W average determined through microseismic fracture mapping.

Well-to-well fracture conductivity was measured along the 126-ft section of intersected hydraulic fracture system at a depth of 4730 ft. This is a complex fracture system that includes a total of 11 hydraulic fractures of which 1 or 2 are propped. The analytic solution that assumes linear fluid flow yielded a fracture conductivity, $k_f w_f$, of 675 md-ft. Reservoir simulation yielded a value of 650 md-ft.