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Microfracture Tests Directly Measure Geomechanical Properties in the Avalon Shale, Delaware Basin

Cross-calibration of microfracturing performed with the MDT tester, fracture injection tests, and sonic logs confirms minimum horizontal stress

CHALLENGE

Accurately and reliably measure the minimum in situ stress and determine fracture gradients in a low-permeability, organic-rich unconventional reservoir.

SOLUTION

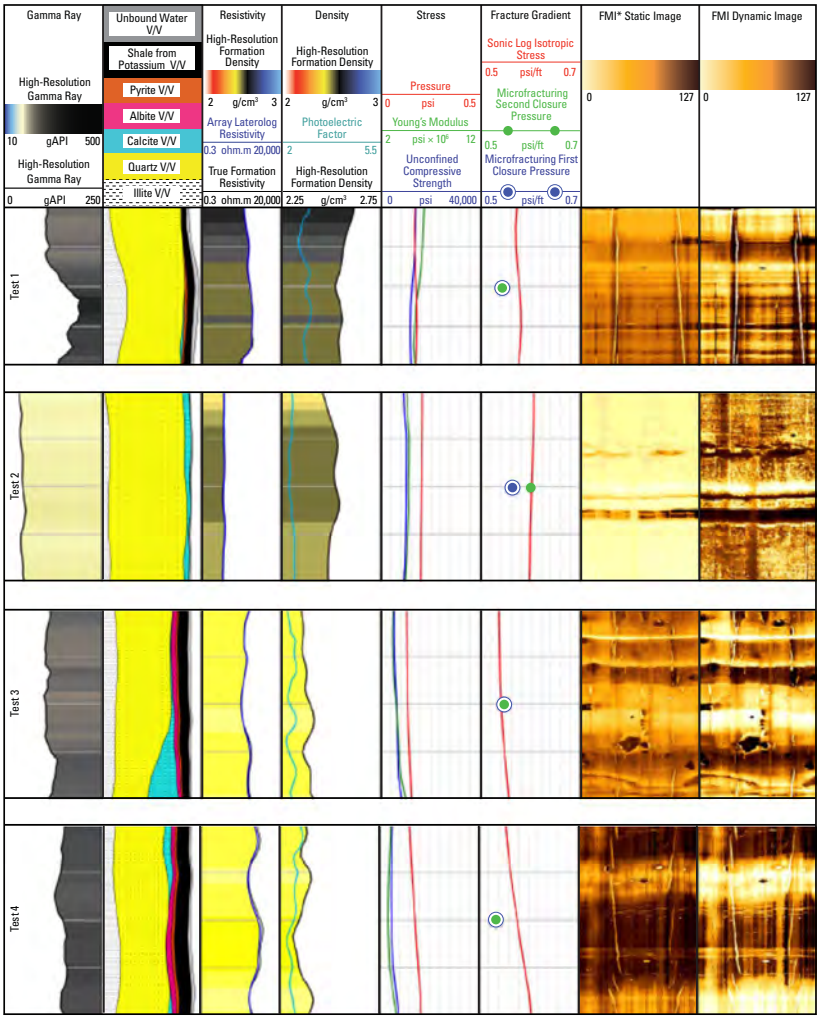
Conduct microfracture tests with the MDT* modular formation dynamics tester requiring only a few gallons of fluid to successfully induce fractures with the pressure response unaffected by frictional losses or a time lag.

RESULTS

Efficiently calculated stress gradients and calibrated the sonic-log-derived model and surface-based formation interval test to precisely design fracture placement.

Understanding stresses to improve completion

Because the in situ stress regime controls the orientation and propagation direction of hydraulic fractures, an operator wanted to better understand the stress gradient in the Avalon Shale and the bounding carbonate formations. The stress gradient across the Delaware basin varies widely with the lithofacies, and without a naturally occurring fracture network, the Avalon requires extensive fracture stimulation. However, conventional minifracturing by formation testing with straddle packers could not be used to successfully measure pressures or sample formation fluid in this low-permeability, organic-rich silty sandstone.



Microfracture tests efficiently provided stress gradients that match well with the results of a fracture injection test and stress gradients derived from sonic logging. The slightly lower stress gradients for microfracture tests 1 and 4 reflect the presence of drilling-induced fractures (imaged in Tracks 7 and 8) that extend beyond the straddled interval. The horizontal lines are at 1-ft spacing. Shading in Tracks 1, 3, and 4 is based on the high-resolution formation density measurement.

Microfacturing for efficiently measuring in situ stress

The MDT modular formation dynamics tester was configured to conduct microfracture tests across a 3.3-ft interval isolated by the high-performance inflatable elements of the Dual-Packer Module. Only a single Pumpout Module was needed to both inflate the packers and inject the formation to initiate and propagate fractures. This combination delivers injection rates ranging from 3 to 10 cm^3/s and a maximum differential pressure of 4,500 psi between the isolated interval and the hydrostatic pressure outside the interval.

Conducting microfacturing with the MDT tester provides significant advantages over conventional pipe-conveyed minifracture testing:

- Specific lithofacies identified from quad-combo and spectroscopy logs can be isolated for testing.
- Reduced injection volumes on the scale of gallons, as compared with barrels of fluid for minifracturing, greatly decrease shut-in and closure times for greater test efficiency.
- Smaller fracture growth makes it possible to readily approximate pore pressure from after-closure analysis and analyze pressure transients and flow regimes to determine permeability.

Microfracturing also improves on fracture injection testing, in which water is injected in a lateral and the pressure falloff response monitored using surface pressure gauges. The microfracture measurement of the formation's pressure response is not affected by the frictional loss and time lag resulting from wellbore storage and fluid compressibility.

Calibrating stress profiles to accurately design fracturing treatments

To avoid testing intervals with open natural or drilling-induced fractures, which compromise the test results because they limit the ability of the elements to seal against the borehole, the FMI fullbore formation microimager was first run to identify unaltered formation intervals. Caliper logs were also reviewed to also determine whether these candidate intervals were in gauge and relatively unaffected by rugosity or ovality.

Microfracture tests were conducted in multiple zones in a single run with high depth accuracy. Successive tests performed at each of the four stations validated the consistency and repeatability of microfracturing stress measurements as critical inputs in completion planning.

The direct in situ stress measurements derived from the microfracture tests were integrated with the dynamic Young's modulus and Poisson's ratio determined from cross-dipole sonic logs to calibrate the stress profile in the targeted pay zones and the overlying facies. With this knowledge of the geomechanical properties of the Avalon shale and bounding lithofacies, the operator was able to accurately predict fracture height and growth in designing fracturing treatments.

"MDT microfracture test results from four intervals were compared and verified with the results from the fracture injection test, and sonic-log-derived stress gradients. Such data integration improves the assessment of reservoir quality and, hence, enables targeting the best intervals for horizontal well development using multistage fracture stimulation."

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