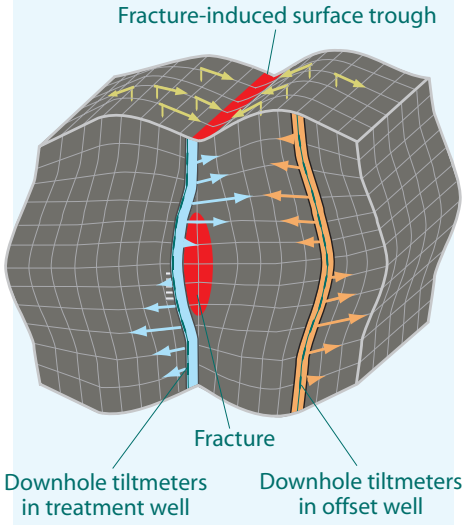
Offset Well Tilt Fracture Mapping

Pinnacle

GET RESULTS

- Hydraulic fracture dimensions: length, height, and width versus time
- Real-time direct measurement of out-of-zone growth or unstimulated pay
- Calibration of 3-D fracture models or economic optimization



Example deformation pattern surrounding a hydraulic fracture, measured using a downhole and surface tiltmeter array.

Pinnacle Technologies' tiltmeter fracture mapping technology is the first commercially available service that can directly measure fracture dimensions (length, height and width) in real-time. Available since June of 1997, Pinnacle's downhole tiltmeters were awarded Hart Publication's 1998 Meritorious Engineering Award.

HOW IT WORKS

Offset well tilt mapping involves running a multiple-instrument (typically 8 to 5 tiltmeters) wireline-conveyed array down a nearby well—in some cases two offset wells may be employed. This downhole array, spanning roughly the same depth interval as the hydraulic fracture treatment, records tilt continuously. The tiltmeters are coupled to the borehole with standard oil-field centralizer springs or with magnets. The wellbore must be coupled to the formation, but even poor cement jobs generally provide sufficient coupling.

Offset well tilt mapping measures the fracture-induced tilt and then solves the geophysical inverse problem to determine the fracture parameters that would produce the observed deformation field. The principle is similar to surface tiltmeter mapping, but the downhole array geometry is very sensitive to fracture dimensions and less sensitive to fracture orientation—just the reverse of surface tiltmeter mapping.

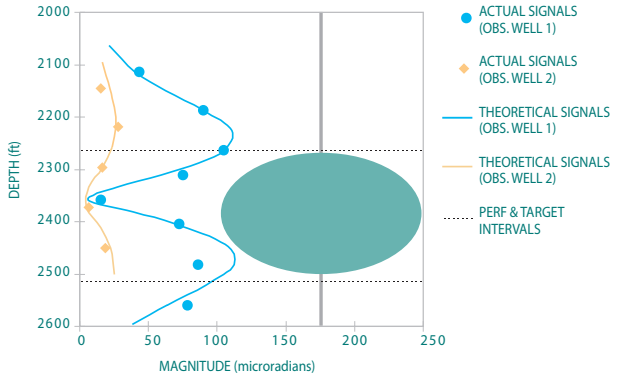
DATA ANALYSIS

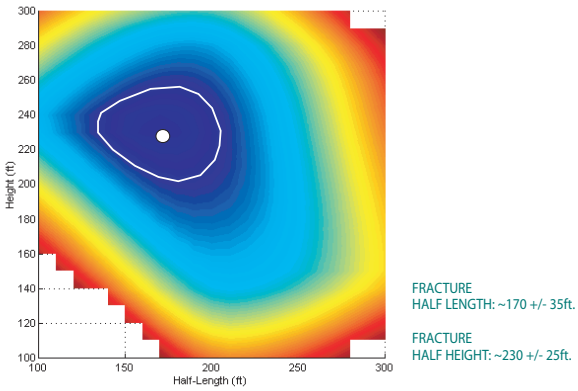
Inverting tilt data involves iterating for the fracture parameters that "best-fit" the measurements of many tiltmeters. Fortunately, the fracture-induced tilt is nearly insensitive to formation properties, which allows accurate measurements in virtually any reservoir environment and reduces the need for reservoir mechanical property data. The key factors are being close enough to resolve the fracture-induced tilt pattern and employing a sufficient number of tiltmeters. The observation well should be no more than three times the fracture length (or largest dimension) away from the fractured well.

The figure on the next page shows an actual example of downhole-tilt signals measured in two offset wells—one close to the fractured well and the other along the direction of fracture growth. The best-fit solution of the measured tilt in the two arrays indicates a fracture height of 230 ft and a half-length of 170 ft. The uncertainty of the mapped fracture dimensions is estimated by plotting the minimum fit-error for alternative solutions. The resulting error contour map shows a contour line representing the mapping uncertainty using a conservative 10% increase in error threshold. In this case, the fracture mapping uncertainty is +/- 25 ft for fracture height and +/- 35 ft for fracture length.

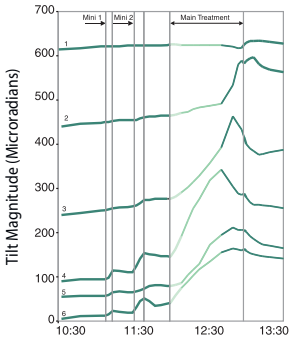
CONSIDERATIONS

The characteristic induced tilt pattern diffuses and attenuates with distance; therefore, mapping resolution declines with increasing offset well monitoring distance. Offset well tiltmeter fracture mapping can therefore not resolve fracture dimensions that are much smaller than offset well distance (resolution ~5-10% of offset well distance). Offset well tiltmeter fracture mapping provides "big picture" macroscopic fracture dimensions and does not provide "micro-details" of fracture growth.

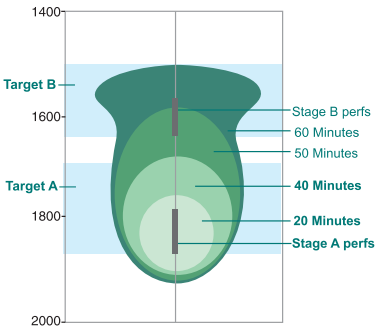




TILT RESPONSE VS. TIME



FRAC GEOMETRY VS. TIME



Tiltmeter signals and fracture growth versus time during a fracture treatment shows relatively confined height growth in the first 40 minutes of the treatment followed by extreme out-of-zone height growth during the last 20 minutes of the treatment. To prevent further out-of-zone growth, the treatment was cut short based on real-time offset well tiltmeter mapping information. Subsequent treatments were halted as soon as fractures grew out of the target interval, leading to considerable cost savings.

On the other hand, offset well tilt mapping technology can be utilized in numerous applications and environments, as the induced tilt pattern is relatively insensitive to formation type. Robustness across a wide range of formation types, ranging from soft, unconsolidated sands to coals and all types of hard rock, is a primary strength of this fracture diagnostic technique.

Pinnacle's downhole tiltmeter fracture mapping routinely improves production economics by increasing reservoir productivity and/or reducing completion costs. This can include optimizing individual fracture treatments, e.g., to optimize fracture length, to obtain effective payzone coverage, to avoid undesirable fluid (gas/water) contacts, or to optimize your entire field development in terms of well spacing and well layout. Pinnacle Technologies also calibrates fracture growth models with downhole tilt-measured fracture dimensions, allowing more reliable predictive fracture treatment optimization. Please contact us to learn how Pinnacle's award-winning diagnostics can help you.

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