

# Tilt Fracture Mapping



GET RESULTS

- Real-time mapping of hydraulic fracturing
- Calibration of fracture growth models for economic optimization
- Fracture complexity (multi-planar growth, fracture twisting, etc.)

Pinnacle Technologies' tiltmeter fracture mapping provides a unique and robust fracture diagnostic technique to determine fracture orientation (surface tiltmeters) and fracture dimensions (downhole tiltmeters).

Surface tiltmeter mapping is currently utilized on more than 2,000 fracture treatments per year to measure fracture orientation, volume, complexity and approximate location. Surface tiltmeter mapping has been performed to depths greater than 6,000'. Pinnacle's award-winning downhole tiltmeter mapping was developed in 1997 and has been used to map fracture dimensions on more than 500 fracture treatments. A new generation of downhole tilt tool has been developed to map fracs from the active treatment well.

Hydraulic fractures are not always as well-behaved as we would like. Several phenomena can arise during frac growth (see picture below), such as:

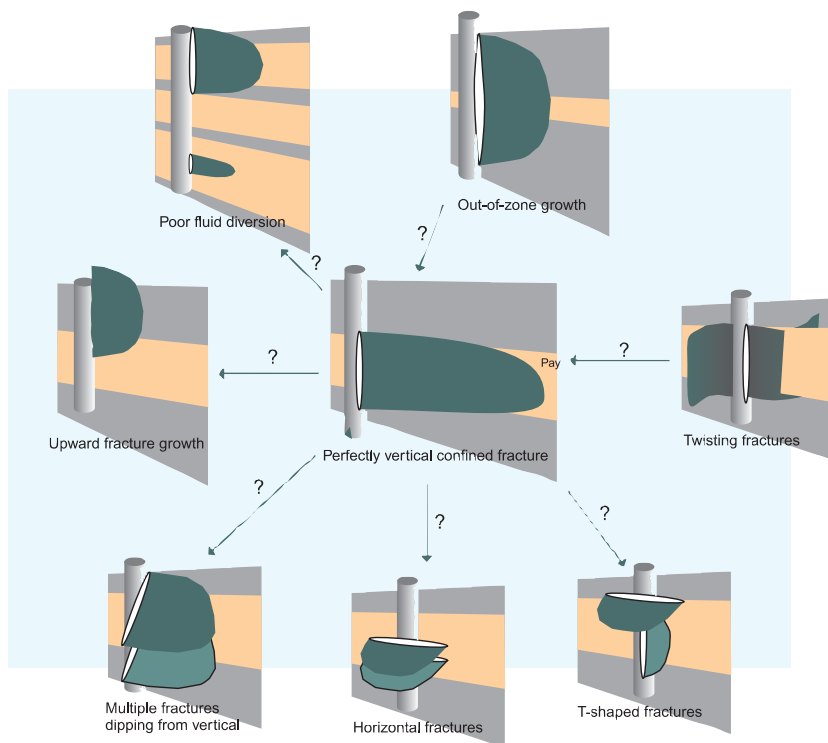
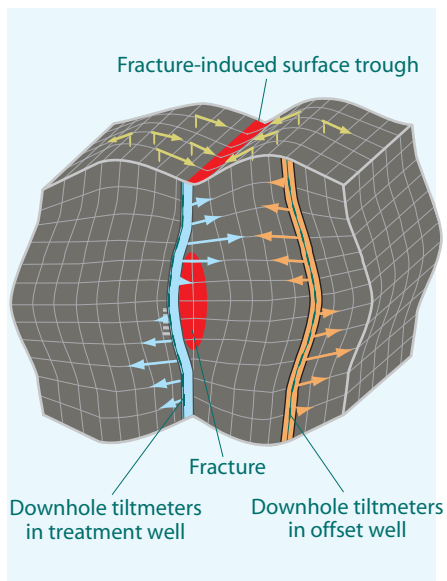
- Extreme out-of-zone fracture height growth and/or incomplete pay coverage;
- Poor coverage from "distributed limited entry" perforations;
- Steeply dipping or horizontal fractures;
- Fracture growth in multiple planes.

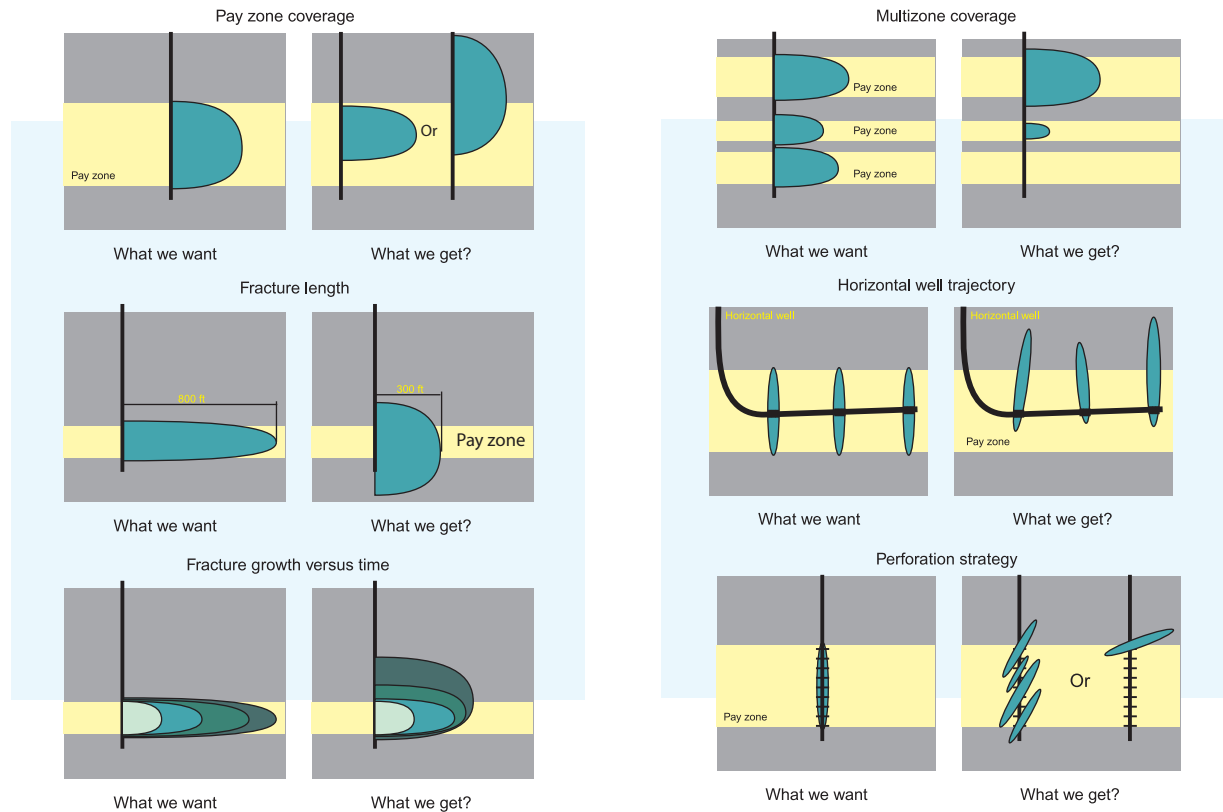
Pinnacle Technologies' tiltmeter fracture mapping allows resolution of these fracture growth complexities. This knowledge can be used to aid economic optimization of fracture treatments, completion strategies, well placement, etc.

Creation of a hydraulic fracture, by definition, involves parting of the rock and displacing the fracture faces to create fracture width (see picture above). The principle of tiltmeter fracture mapping is simply to infer hydraulic fracture geometry by measuring this fracture-induced rock deformation using extremely accurate "carpenter's levels". The induced deformation field radiates in all directions and can be measured either downhole with wireline-conveyed tiltmeter arrays or with a surface array of tiltmeters.

For surface tilt fracture mapping, the simplicity of the concept allows robust and unambiguous determination of a few primary fracture parameters like fracture azimuth and dip and, with somewhat less precision, created fracture volume, depth-to-fracture-center and fracture offset due to asymmetric growth. The characteristic shape and orientation of the tilt field is not altered with increasing fracture depth. Although the magnitude of the tilt is attenuated with increasing fracture depth, fractures greater than 10,000' depth can now be successfully mapped using surface tilt mapping.

Offset well tiltmeter mapping was developed to solve the fracture dimension resolution limitation of surface tiltmeter mapping





by bringing the measurement distance down to the same order of magnitude as the created fracture dimensions. Downhole tilt fracture mapping can provide resolution of fracture height and length within 5-10% of the offset well distance.

Surface and downhole tiltmeter fracture mapping can be used separately and in combination, and can provide answers to several fracture-related questions, including:

- How does the fracture length, height, and width grow with time?
- How much more length/height is obtained with an increase in treatment size?
- Are fracture wing-lengths asymmetrical?
- Do fractures effectively cover the pay zone?
- Are fractures confined to the pay zone?
- In the case of multi-zone completions, can the number of fracture treatment stages

be reduced and unnecessary overlap of fractures be minimized or is an increase in treatment size or number of stages required to achieve complete coverage of all prospective zones?

- Are fractures aligned with the direction of natural fractures?
- In what direction should a new horizontal well be drilled to complete it with transverse (or longitudinal) multi-stage fractures? Is the selected horizontal well path appropriate?
- Is the well pattern appropriate for effective sweeping in steam/waterflood areas? Should the fracture treatment be shut-down before excessive height growth is observed, to ensure steam is injected in the correct zone?
- Does the injected waste and/or drill cuttings remain within the selected zone, or

does it penetrate or threaten protected water sources?

Pinnacle's surface and downhole tiltmeter mapping are unique in the hydraulic fracturing industry, and the insights that they provide have benefited our clients considerably in their efforts to optimize field development and increase fracture treatment effectiveness. Please contact us to learn how Pinnacle's award-winning diagnostics can help you.

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