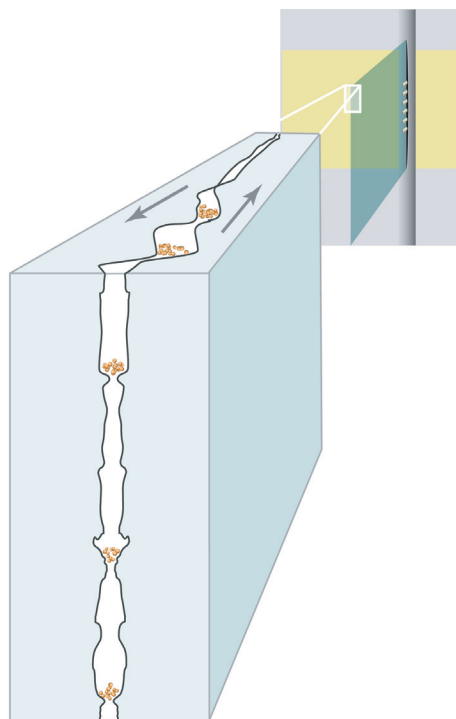


Waterfrac Engineering



GET RESULTS

- Select Candidates
- Optimize Designs
- On-site Engineering
- Model Calibration



Pinnacle Technologies engineers are at the forefront in using waterfracs as a viable stimulation technique for many reservoirs. Since 1996, with our re-introduction of waterfracs to the Cotton Valley in East Texas, Pinnacle engineers have been involved onsite and as technical authors on virtually every major project around the world where waterfracs were performed. We've designed, pumped and evaluated more of these treatments than any other engineering company in some of the world's most geologically diverse environments.

Some reservoirs are unsuitable for waterfrac technology. Rigorous engineering is necessary to determine if a particular formation is a good candidate for a waterfrac. This integrated approach to the application of waterfrac technology is a capability unique to Pinnacle Technologies, as we have extensive experience in the five technologies essential to successful waterfracs:

Fracture Engineering. Pinnacle performs the design, on-site direction, QC and evaluation of waterfracs.

Reservoir Engineering. Our engineers routinely evaluate petrophysical, production, and pressure transient data to characterize and compare waterfrac performance.

Fracture Diagnostics. We directly measure waterfrac geometry using microseismic and tiltmeter fracture mapping.

Fracture Modeling. FracproPT is calibrated for waterfrac treatments in numerous reservoirs.

Rock Mechanics. Pinnacle scientists have led studies on waterfrac rock mechanics and conducted the first rock mechanical study to evaluate potential mechanisms and rock properties that lead to successful waterfracs.

Mechanisms that we have identified as being critically important for the success of waterfracs are:

- Residual fracture opening due to rough fracture surface and shear displacements.
- Areas where clean-up problems are associated with conventional cross-linked fracturing fluids.
- Proppant settling in vertical fracture offsets. The accumulated proppant forms bridges acting as wedges, which keep the fracture open.
- Rock debris may act as a self-propping agent.
- Low fluid viscosity creates longer fractures.

Based on our experience we have developed general guidelines for the application of waterfracs. The general guidelines are as follows:

- Apply waterfracs in the most marginal, lowest permeability areas first. Then proceed to better, higher permeability areas. Some plays may only be economical if developed with waterfracs.
- Environments with high Young's Modulus (very hard rock), normal stress and very low permeability appear to be the best candidates. However, waterfracs have been successful even at higher stresses, replacing expensive Bauxite fracture treatments. High deviatoric stresses may also contribute to fracture roughness and shear displacements.
- Low reservoir pressure and increased depletion may prohibit proper cleanup of conventional gel fracs. Waterfracs avoid gel damage and clean up faster.

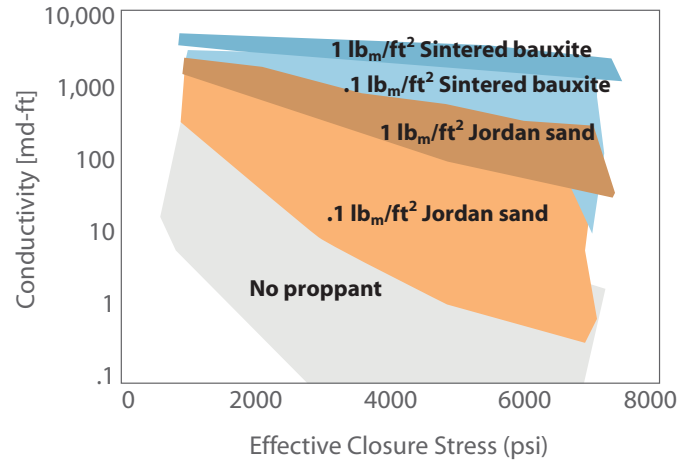
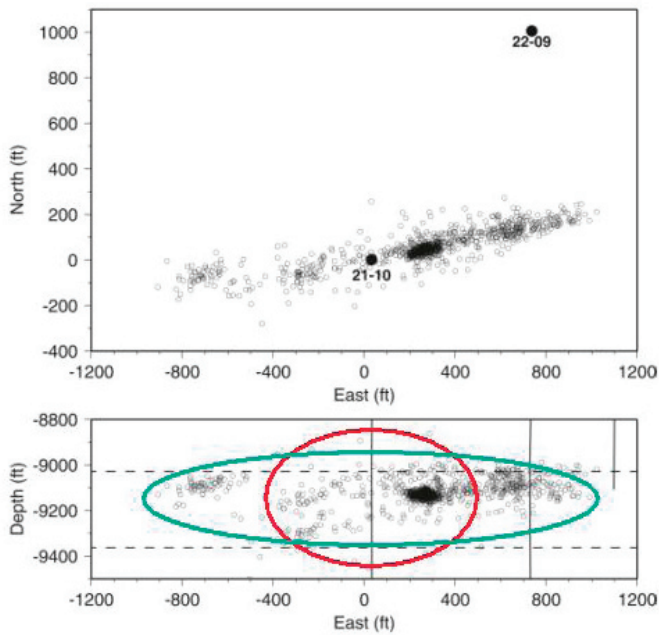


Figure taken from SPE 74138

- Naturally fractured formations may be good candidates, especially where proppant placement is difficult.
- Optimization of fluid volume, injection rate, perforated intervals, pad size, proppant concentration, "sweeps", and proppant size should be treatment-specific.
- Higher injection rates and larger volumes are likely to achieve better fracture stimulation, but cost/benefit must be considered.
- It is desirable to have small increases in net pressure throughout the job and avoid "proppant banking".

- Fracture diagnostic techniques that measure fracture geometry and evaluate fracture quality (e.g. pressure transient well tests and pressure transient analysis of injection falloff tests), proper production analysis and fracture modeling are instrumental in evaluating waterfracs.

Our innovative waterfrac team has the capability and experience to ensure the success of your waterfrac project. Pinnacle provides our clients with waterfrac knowledge and technology that is unparalleled in the industry. Please contact us to learn how Pinnacle's award-winning team can help you.

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Houston 281-876-2323	Bakersfield 661-335-7711	Delft 31-15-219-0062	Oklahoma City 405-604-5634
Denver 720-344-3464	San Francisco 415-861-1097	Moscow 7-495-781-4820	Midland 432-386-6791
Calgary 403-516-2260	Dallas 972-401-0090	Beijing 86-13838562150	Reynosa 52-892-42191
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