Wilcox Rocks!

Fracture treatments in the Wilcox often encounter hot, highly pressured, hostile conditions, and that's just at the surface!

THE SETTING

- **Wilcox Sand in the Burgos Basin of Northern Mexico**
- **Tight Gas Sands**
- **6500' - 9800'**
- **Original Pore Pressure Gradient = .9 psi/ft**
- **Fault-bounded compartmentalized reservoir**

Pinnacle

THE BACKGROUND

Pemex is actively developing the Arcabuz-Culebra Field in the Burgos Basin and recognizes that continued economic development requires the efficient application of hydraulic fracturing, effective well spacing and optimum well placement. Long hydraulic fractures can significantly increase well productivity in these low permeability sands while the resulting drainage pattern is elliptical, requiring accurate knowledge of fracture direction in order to optimize well spacing. Well spacing and location are controlled by the in-situ stress-state, reservoir permeability, and the distribution and orientation of faults. Local variations in pore pressure due to compartmentalization or offsetting production can result in large variations in stress that can significantly impact reservoir production, fracture geometry and fracture direction.

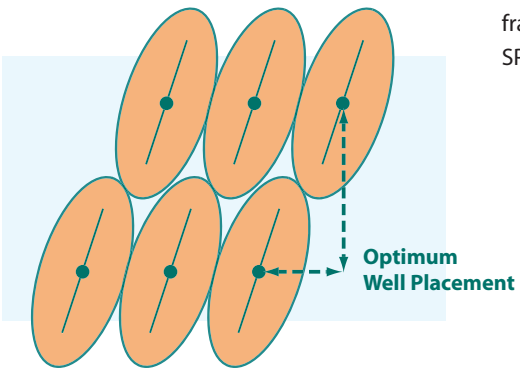
PINNACLE PERFORMS

Pemex believed that this field could be economically optimized through improved well positioning, more effective drainage patterns, better hydraulic fracture treatment designs and an optimized production strategy. Pinnacle Technologies was contracted to perform direct fracture diagnostic measurements on 4 fracture treatments in two wells and to perform fracture model calibration to develop a predictive tool for frac design. In addition, well spacing and placement were optimized using a reservoir model to predict well performance.

Fracture mapping results from Pinnacle's Surface and Downhole tiltmeters plus FracSeis[sm] Microseismic Fracture Imaging measured fracture orientation in a generally NNE-SSW in the Culebra Field, consistent with the regional stress trend, although fracture orientations on one well varied by 40 degrees between stages. These variations may result from pore-pressure depletion or proximity to faults.

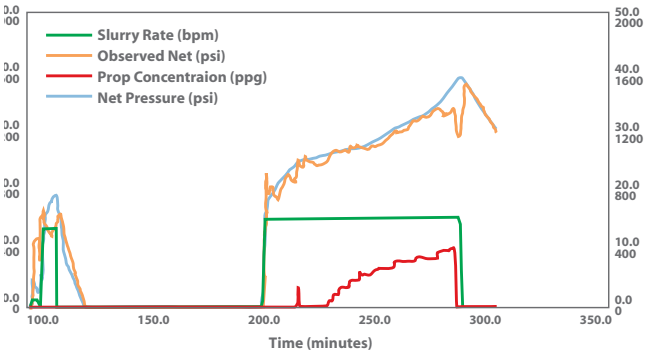
3-D Fracture Modeling with FracproPT indicated long fractures and confined fracture growth in the Wilcox 4 and shorter lengths in the Wilcox 2 and 3. The differences in geometry between these sand packets is due to lower pore pressure from offset well drainage in the Wilcox 4 that results in much larger stress differences between the sand and bounding shale, leading to good fracture confinement.

Fracture engineering consisting of mini-fracs and stepdown tests was performed to determine closure pressure and lack of tortuosity. Net pressure history matching was then performed to model the created fracture geometry and determine optimum proppant and treatment size. Fracture and production modeling showed that 20-40 Ottawa Sand could be substituted for higher strength RCS. Also, a reduction in current job sizes of about 40% will obtain an optimal length of 500' for the Wilcox 4, sacrificing little productivity and optimizing the economic return from fracs on new wells. In the Wilcox 2 and 3, smaller job sizes result in less fluid and proppant being placed outside the pay zone, resulting in a more efficient frac. For more details on this project, see SPE 60314.

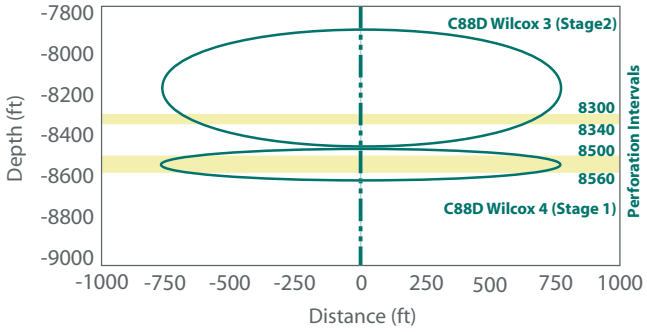


Optimum well placement in low-permeability Wilcox sands of Culebra portion of the Field. Illustration shows elliptical drainage pattern characteristic of low-perm hydraulically fractured reservoirs.

Wilcox 4 Stimulation



Net pressure history matching was performed and modeled fracture geometry was calibrated using fracture mapping measurements while honoring the pressure data. Economic analysis determined the optimal frac length for undepleted areas in the Wilcox 4 to be 500'.

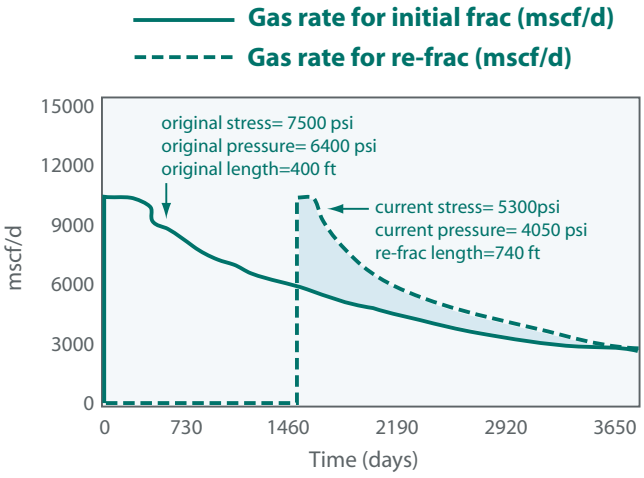


Downhole Tiltmeter measured frac height and length from two stages in the Wilcox 3 and 4 intervals. Current fracs are typically 650'-750' half length but economic optimum was determined to be 500'.

THE RESULTS

Well placement strategy in the Culebra portion of the field should be based on fracture drainage patterns consistent with regional stress orientation (NNE-SSW). From geomechanical modeling studies performed, fracture azimuths in the Arcabuz portion of the field are expected to propagate parallel to the nearest fault.

Integrating fracture mapping with a detailed fracture modeling study identified significant economic opportunities, including a new design to reduce treatment size and proppant costs with targeted savings of over $11 million. Additionally, re-fracture treatments were designed to take advantage of the intervals with higher stress contrasts, resulting in fractures longer than original, increasing recovery by an average of 3 BCF per well and increasing cash flow by over $6 million. The total economic benefit to Pemex of applying Pinnacle's fracture mapping and fracture engineering to optimize this field is more than $50 million dollars over the next 7 years.



Refracture treatments in older, more permeable Wilcox 4 wells can significantly increase production due to lower closure stress, hence better containment and the ability to achieve much longer lengths for the same size job compared to the original treatments. Forecasted here for this well is an incremental 3 BCF in less than 7 years.

Houston 281–876–2323
Denver 720–344–3464
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Reynosa 52–892–42191
Cairo 2025283356–8

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