Got Dirt?

THE SETTING

- **Multiple Almond Coal Seams**
- **300' Gross Interval**
- **Copper Ridge Field of SW Wyoming**
- **Water Zones above and below**
- **Staging Design Uncertain**

Pinnacle

THE BACKGROUND

Coal Bed Methane (CBM) is increasing in importance as a source of natural gas in North America. Today it comprises approximately 10% of the daily gas production in the U.S. Anadarko Petroleum Corporation evaluated the development potential of Almond Coals in the Copper Ridge Field of Southwest Wyoming with a 16 well pilot program. The coals in this field are present in two to twenty foot stringers spread over a 100' to 300' gross interval at depths ranging from 2600' to 3000'.

The most prolific seams are usually perforated in 20' intervals and fracture treated in one or two stages using crosslinked gel. Underlying the coals is the Ericsson sand, which is used for water disposal and overlying the coals are higher permeability water sands, both of which must be avoided during hydraulic fracturing.

Primary objectives of the project were to stay out of the prolific water sands located above and below the coal section, achieve complete payzone coverage using the minimum number of frac stages, and create long fractures with adequate conductivity. Fracture models are used in real-time today to estimate the fracture geometry based on net pressure behavior. Sometimes the use of fracture models as diagnostic tools can lead to non-unique solutions and inadequate results. However, fracture models, in conjunction with other direct diagnostic tools, can be effectively calibrated in an area so that they can be used to accurately predict fracture geometry and then be used as effective treatment design and optimization tools.

Data were integrated from the pilot wells to build a calibrated fracture model within FracproPT. Fracture mapping was performed on six wells and fracture engineering and modeling performed on all sixteen wells in this pilot program. Fracture growth was measured in real-time with Treatment Well Tiltmeters (TWTM) and the measured fracture growth integrated into FracproPT along with pressures, volumes and injection rates that allowed on-site adjustments in order to prevent fracturing into the water sands.

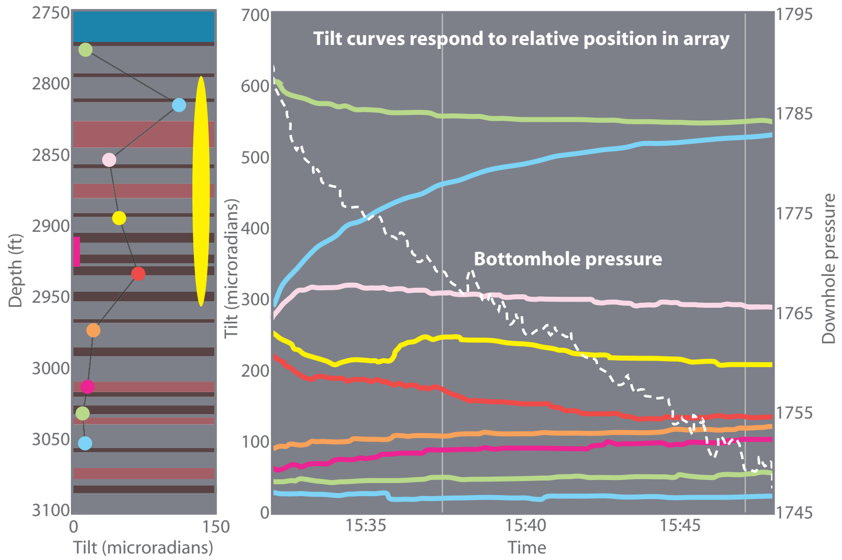
PINNACLE PERFORMS

Treatment well tiltmeters were used to directly measure fracture height growth in real-time. An array of slim-hole TWTM instruments is placed downhole in the frac well, straddling the perforated interval to be fractured. Direct measurements of wellbore deformation is telemetered back to the surface via electric wireline in real-time to allow direct viewing of the fracture top and bottom during pumping operations. Heretofore, this technology had only been applied on "clean" (proppant-free) treatments such as mini-fracs, acid fracs and water-only fracs. This project was the first in which "dirty" (propped) fracture treatments were pumped across a treatment well tiltmeter array. For most of these treatments at around 25 BPM and 5 ppg, the tools remained fairly well contacted with the casing. Occasionally, a few tools "lifted off" from the casing but the tools immediately reattached as soon as the pumps stopped at the end of the job, and fracture height measurements were obtained during closure.

Treatment volumes changed substantially from the original designs and were further modified on-the-fly based on direct TWTM measurements integrated into the calibrated fracture model. Modified proppant volumes varied from 32,000 lbs up to 154,000 lbs and only one early screenout was encountered. After that screenout, treatments were altered to use smaller proppants (20/40) with a less aggressive proppant ramp, finishing at the designed sand concentrations.

Figure 1 shows Treatment Well Tiltmeter data from one of the wells. The fracture top and bottom can easily be seen in the tilt data. In general, large amounts of tilt at left indicate the presence of a fracture. The top and bottom of this frac can easily be seen in the left panel, showing some propensity to upward growth towards the overlying water sands. The proppant ramp was immediately adjusted to be more aggressive early to ensure adequate conductivity in the event the treatment needed to be halted early due to the fracture top getting too near the

Figure 1. Real-time output of Treatment Well Tiltdata showing location of fracture top and bottom during specific time-window of treatment. Fracture top is approaching water sands above Almond interval at this point in time.



water sands. The propped treatment was pumped to completion and the fracture stayed below the water sands.

Once the model was successfully calibrated, it was used to develop correlations between frac treatment size and rate vs. height and length growth. Initial treatment designs had called for 150,000 to 350,000 lbs of proppant at rates of about 40 bpm. Tilt measurements showed that undesirable height growth was occurring with the larger volumes and higher rates, so the calibrated model was built predicting that treatments would remain fairly well contained at around 75,000 lbs of proppant and 25 BPM. This was then confirmed with direct TWTM measurements. Figure 2 shows the uncalibrated frac geometry compared with the calibrated geometry for one of the treatments. A conventional tip-dominated model would have incorrectly predicted a fairly tall and short fracture, while the direct measurements and calibrated model show the frac to be reasonably well contained and long.

THE RESULTS

Based on project results, Anadarko can now treat these Almond Coals and stay out of the nearby water bearing intervals while effectively stimulating all of the productive coal seams. Early use of these fracture diagnostics produced a calibrated model and resulted in the quick optimization of fracture treatments in this field at significant cost savings. Anadarko estimates that they will save about $1.3 million for just the first year on these pilot wells alone! Current water production (and disposal cost) is about 1/3 of the expected water production if the fracture treatments had breached the adjacent water sands. Additional savings came from treatment size optimization. More details can be found in SPE 84490. Sometimes, you just need to get down and dirty with your frac!

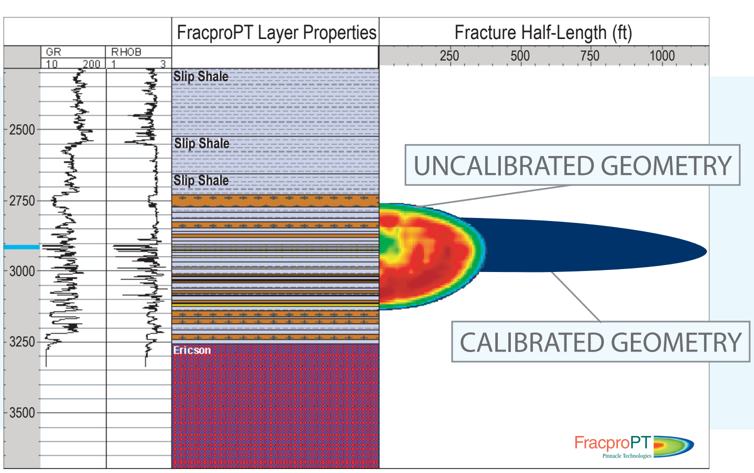


Figure 2.

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