Deep Horizontal Experiment Taps Tight Gas

It's a 'Frontier Play' In Green River

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For more than 20 years the Greater Green River Basin in southwestern Wyoming has been known to hold large gas resources, with estimates ranging from 200 TCF to as much as 5,000 TCF, trapped in unconventional, tight, basin-centered or "continuous" accumulations.

During this time more than 30 wells have been drilled through Cretaceous sediment in the basin's deepest parts, all with overpressured gas shows but none economically productive.

But this story starts about five years ago, when Fort Worth-based Union Pacific Resources, a leader in horizontal drilling, teamed with the U.S. Department of Energy's Energy and Technology Center and GRI in a $10 million research project.

Their goal: Evaluate the technological and economic feasibility of drilling horizontal wells in fractured, but very-low permeability sandstone three miles below the sage brush flats of southwestern Wyoming.

Today, after more than five years of geological and geophysical evaluation and approximately six miles of drilling, the team can now point to an unqualified success with the UPR Rock Island 4-H horizontal well, completed flowing gas from the Cretaceous Frontier Formation with an IP of 14 MMCFG/D.

Photo courtesy of Lee Krystinik

This blaze is just the top of a gas flare at the UPR Rock Island 4-H in Wyoming's Greater Green River Basin. The hole that held this inferno was 15 feet deep.

After producing over 3 BCF, the well continues to produce at approximately 10 MMCFG/D, with an estimated ultimate recovery in the range of 15-20 BCF.

The project's success came as the result of improving downhole technology and developing a keen understanding of the region's depositional and structural history.

"We believe UPR Rock Island 4-H to be the world's deepest economic

horizontal tight-gas sandstone well," said Lee Krystinik, UPR's manager of geology and principal investigator for the research partnership with DOE.

"But much more importantly," he added, "it opens the possibility of exploiting a resource that could have strategic importance for the United States."

Good Drill Hunting

Krystinik presented a paper on the project, "Hunting Fractures Three Miles Down," at the recent AAPG Hedberg Conference in Houston on horizontal drilling.

In his presentation, Krystinik noted that the success of the UPR Rock Island 4-H well has spurred industry activity. Three additional wells targeting the Frontier Formation at 14,000 to 16,000 feet presently are drilling in the area in the attempt to delineate the magnitude of the discovery.

One of those wells is presently drilling horizontally with good gas shows and indications of fracturing. The other wells should be completed late this year or early next year - and more drilling is planned.

"The results of these new exploration wells will determine what we do in the future," Krystinik said. "The play could be very large, but we have only proven a 50 BCF or so resource at this point.

"Now it will be up to the drill bit to determine whether we have a nice little resource add, or several TCF to exploit."

The integration of a wide range of technical analyses and efficient drilling technologies was key to the project, he said.

In determining proposed drill sites the UPR/DOE/GRI team integrated outcrop sedimentology, stratigraphy and fracture data from the basin's margins, with subsurface core data, well logs, production test data and over 1,400 square miles of 3-D seismic data.

These data were then tied with structural and predictive fracture models to aid in prediction of optimal fracturing for drill-site selection.

On the drilling side, expertise from previous experimental wells across the country was provided by DOE and GRI, and UPR pulled heavily on drilling engineers working successful programs in deep vertical well programs in the Rockies, as well as their drillers working the deep portion of the horizontal Austin Chalk play in Texas.

Good fortune smiled on the team when a vertical well drilled by Texaco and UPR for a deeper objective produced naturally from the Frontier Formation near one of the potential UPR/DOE horizontal sites. The well was cored and numerous open fractures were observed.

The orientation scribe on the core failed, but UPR, working with AAPG member John Lorenz at Sandia National Labs, was able to establish fracture orientations through paleomagnetic orientation.

With the vector for the proposed experimental horizontal leg of the UPR Rock Island 4-H set, final siting of the location came down to iterations of fracture models - and lengthy land negotiations.

It was time for the team to test the concepts.

They're Gr-r-r-r-eat!!!

The drilling environment of the deep, overpressured Frontier play is hostile, Krystinik said, with temperatures at nearly 300 degrees, 10,000 psi pressures and highly abrasive, quartzose sandstone that literally grinds up bits and drill pipe.

UPR drillers used a top-drive drilling rig, dual mud motors for additional torque and RPM, new bit designs, measurement while drilling, revised mud systems and a range of "on the fly" changes to get the vertical hole down to the kick off point in less than 65 days.

Once the well was making the turn to horizontal, GRNav, a UPR proprietary real-time geosteering technique was critical to keeping the well bore within a 20-foot drilling window.

"We will continue to push the limits of technology as we go deeper into the basin," Krystinik said. "Our depth limit in the near term will be around 18,000 feet until technology can provide us with electronics and tools capable of withstanding the temperatures we will encounter there.

"UPR also cored the horizontal leg of the well in two places," he added, "recovering what we believe to be the deepest horizontal cores in the world from the upper and lower marine benches of the Frontier Formation."

These world-record cores provided a wealth of information about the reservoir rock and the character and spacing of fracturing within the reservoir. Over 70 fractures were encountered in the cores, many open and lined by quartz and lesser amounts of clay and bitumen.

Permeabilities ranged from 2 to 50 microdarcys for rock with up to 7-13 percent porosity (very low permeability by most standards, but not bad for Frontier tight-gas rock).

"But the fractures," Krystinik said. "They were great!"

High-resolution resistivity imaging logs showed several small faults and over 400 fractures were crossed in the 1,750-foot horizontal leg. Fracture spacing varied from a few inches to nearly 20 feet - an unfractured zone wide enough that a vertical well drilled through one of these intervals might not intersect a single fracture.

"The horizontal technology was clearly a step forward," Krystinik said. "Then our petrographic lab at UPR found numerous microfractures with dissolution-enhanced porosity. We knew the microfractures would significantly enhance drainage of the matrix porosity from the reservoir into the larger fracture system and into our wellbore ...we knew we had a well.

"Now we move on with the program to see just how big the opportunity is," he continued.

Krystinik credits the project's success to the "partnership and excellent cooperation of DOE and GRI and their contractors, working as a team with UPR toward a common goal.

"It underscores the value of government/industry funded research partnerships," he said, "especially in a business environment as challenging as the one our industry faces today."