

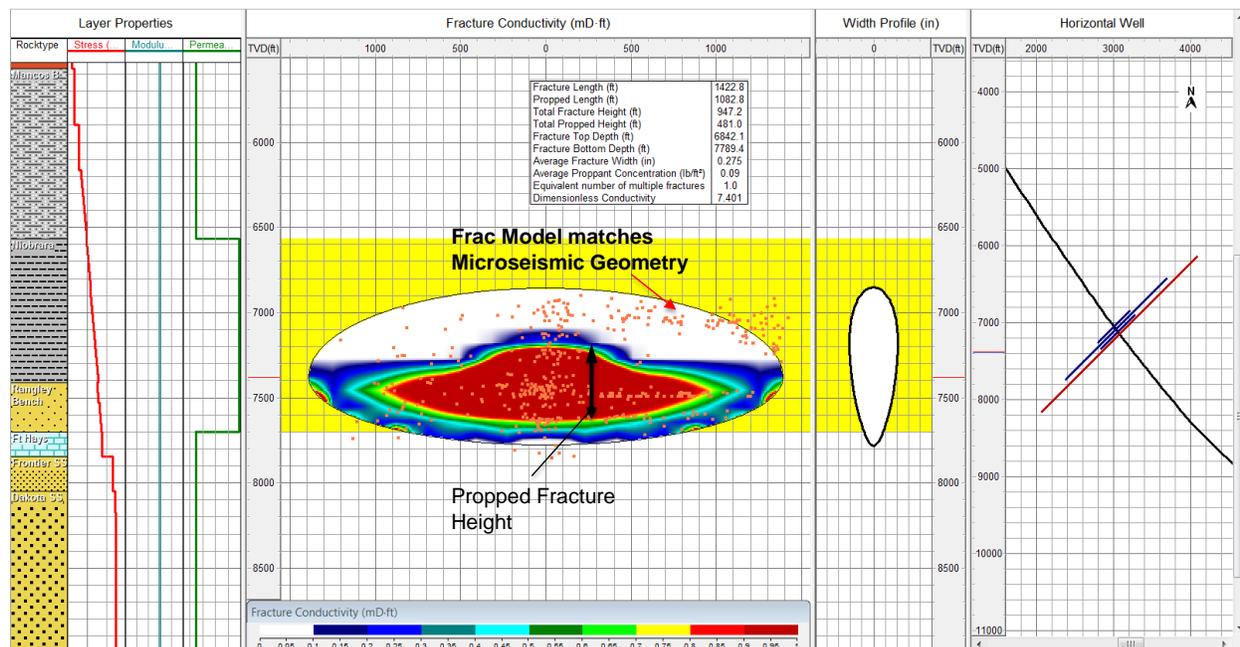
Tremendous Fracs in the Piceance

“The Mancos-Niobrara formation in western Colorado is estimated to contain 66 trillion cubic feet of natural gas”, USGS

Black Hills Exploration and Production helped substantiate the USGS estimate by completing a number of 8,000- to 10,000-foot horizontal wells in the Niobrara Formation in the Piceance Basin in Colorado. The Niobrara Formation in the Piceance Basin is a 1,200 foot thick gas-producing pay-zone of complex rock properties. The exploration program had three major items to address: the optimal zone in which to land the horizontal wells; the proper orientation of the horizontal wellbore in that zone; and how to complete the horizontal wells effectively. Black Hills believes maximum production in the Niobrara will be achieved by optimizing hydraulic fracturing operations to create the largest quality reservoir contact.

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A vertical well pilot program with production log diagnostics and detailed rock quality evaluations was used to determine lateral landing depths for the horizontal well pilot program. It was found that landing laterals in the more calcite rich stringers of the Niobrara section can be beneficial for fracture treatment placement, which will result in better well performance.

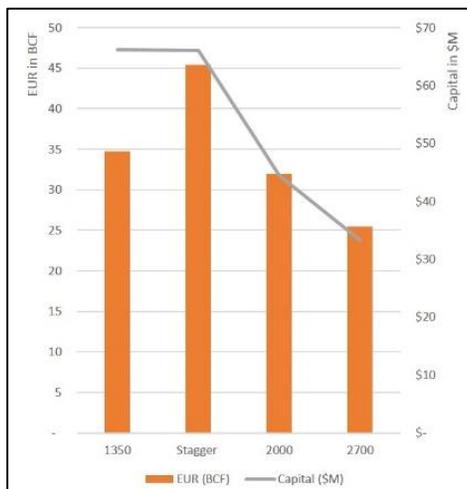
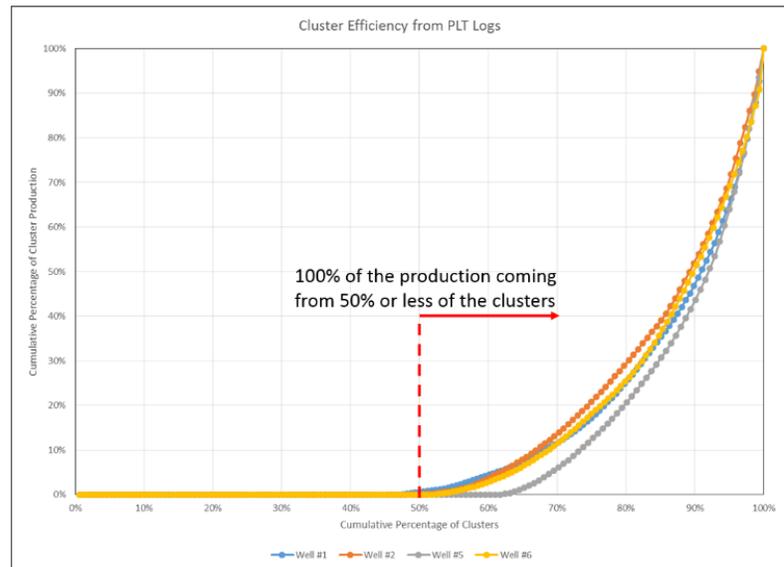


Working as a team with Liberty, Black Hills used an iterative methodology for evaluation, modeling, completion, and production diagnostics, which will help determine the best field development and completion strategies in this play. The study included six horizontal wells from two pads. Black Hills went “all out” in an attempt to prove up the play, with very large fracture treatments, placing a total of about

13 MMlbs of 100 mesh and 40/70 proppant (up to 1,500 lbs/ft) with over 600,000 bbls of slickwater per well. Fracture dimensions were estimated with microseismic and tiltmeter mapping, showing very long fractures with up to 2,000 ft frac half-length and 800 to 1,000 ft fracture height. Liberty calibrated a fracture model by honoring microseismic, tiltmeter, fracture pressure and production log data.

Production results and production

logging suggested inter-well conductivity across the current 1,350 ft well spacing, thus providing opportunities for further well spacing and completion design optimization. Additionally, PLTs indicated that perforation cluster efficiencies are between 37% and 50%. In other words, 100% of the production is coming from just half of the clusters at best. This provides ample room for improvement by utilizing diverting agents and various pump schedules to attempt to activate more clusters within a stage.



A detailed reservoir modeling study was performed that evaluated different well spacing scenarios (1,350 ft to 2,700 ft) including staggered wells (at 1,350 ft spacing) as well as perforation cluster efficiency. The figure to the left shows a summary of the combined EURs in conjunction with capital investment requirements for each multi-well scenario. The conclusion was that the most prudent development strategy is prioritizing cluster efficiency through enhanced diversion and perforation/staging strategies. The highest PV10 was achieved for the staggered lateral landing scenario but highest ROR for the 2,000 ft and 2,700 ft well spacing. Further optimization through a combination of PV10 and ROR metrics will affect well spacing

and/or parallel versus staggered lateral landing strategies.

More information

URTeC paper 2435473: "Optimizing Well Placement and Completion Strategies in the Piceance Basin Niobrara Formation", by Ningning Li et al.

SPE paper 184848: "Optimizing Well Spacing and Well Performance in the Piceance Basin Niobrara Formation", by Ningning Li et al.