

A unique approach to each fracture ensures appreciable increases in per-well recoveries

STRATAGEN has developed a unique and fully interconnected strategy to customize individual frac stages by exploiting readily available mud log data response and historical frac data analysis to quantify permeabilities and reservoir quality throughout the lateral.

Bone Springs, Delaware Basin, New Mexico

Executive summary

Historically, the Permian Bone Springs formation of the New Mexico Delaware Basin essentially was a back-out zone for operators targeting the underlying Ellenburger and Morrow formations. Like many source rocks, the Bone Springs was not recognized as a viable prospect until advanced logs uncovered a pay zone thicker than that identified in earlier analyses. Consequently, following closely on the heels of the acceleration in horizontal drilling and hydraulic fracturing, operators began landing laterals with multi-stage fracs to access the then-potentially lucrative Bone Springs.

The results

Of those first horizontal wells and those that followed exceeded initial expectations. Indeed, in its July 2014 update, the U.S. Energy Information Administration (EIA) pinpoints Bone Springs as one of the primary contributors to the more than 60% production increase between 2008-2013 from the Permian Basin petroleum system. The EIA analysis said three-quarters of the increased oil production came from the Wolfcamp, the Bone Springs of the Delaware Basin and its Texas counterpart, the Spraberry.

With horizontal well construction going full throttle, this synopsis explores the evolution of Bone Springs lateral completion and stimulation designs. More specifically, STRATAGEN® examines its novel and fully interconnected strategy to customize individual frac stages by exploiting readily available mud log data response and historical frac data analysis to quantify permeabilities and reservoir quality throughout the lateral. The results of this unique frac design strategy are exemplified in appreciable increases in per-well recoveries with work currently centered on further reducing development costs.



STRATAGEN has developed a unique and fully interconnected strategy to customize individual frac stages in the Bone Springs formation by exploiting readily available mud log data response and historical frac data analysis to quantify permeabilities and reservoir quality throughout the lateral. The results of this boutique frac design strategy are exemplified in appreciable increases in per-well recoveries.

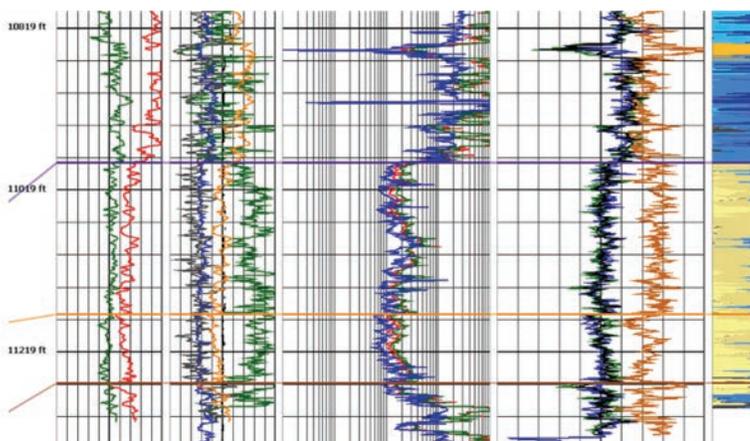
Geological deposition/composition

As currently delineated by activity, the fairway of the Permian Bone Springs (known interchangeably as the Leonard or Avalon play) underlies some 1,313 sq miles largely across the Delaware Basin of southeast New Mexico, but extending into West Texas where it carries the Spraberry designation. The complex formation, which overlies the Wolfcamp shale, the Ellenburger Group, and the Morrow at depths ranging from 6,000 to 13,000 ft, is described as a thick sequence of interbedded sandstones, carbonates and shale. Stratigraphically, each layer of the three-bench Bone Springs comprises equally productive sand carbonate layers.

Drilling, completion evolution

Prior to the rapid build-up of horizontal drilling and hydraulic fracturing, the Bone Springs source rock was largely a bypass zone of last resort for vertical wells targeting the underlying horizons then seen as far more prospective.

However, once new-generation logs revealed a much thicker pay zone than that seen in earlier logs, the once-ignored Bone Springs emerged quickly as the primary target for horizontal wellbores. In short order, the placement of laterals with several frac stages gained steam in the Bone Springs, boosted in no small part by the superb well control realized when landing the horizontal sections between mature and deeper vertical wells.



Type log of a third Bone Springs well indicating lateral landing position.

Since then, the Bone Springs has grown appreciably and is now the most sought-after prospective horizon in New Mexico. Following the commencement of horizontal drilling, the next step in the evolutionary process was isolating the most advantageous landing of the laterals, followed with generalized designs of completion/stimulation programs. The next natural phase in the Bone Springs

evolution was the wholesale change to more play-compatible ceramic proppant, augmented with stage-specific mesh concentrations. The next logical step in this methodical progression features a novel solution that allows the customization of every frac stage to maximize production and estimated ultimate recovery (EUR).

State-of-the art: quantifying reservoir quality across the lateral

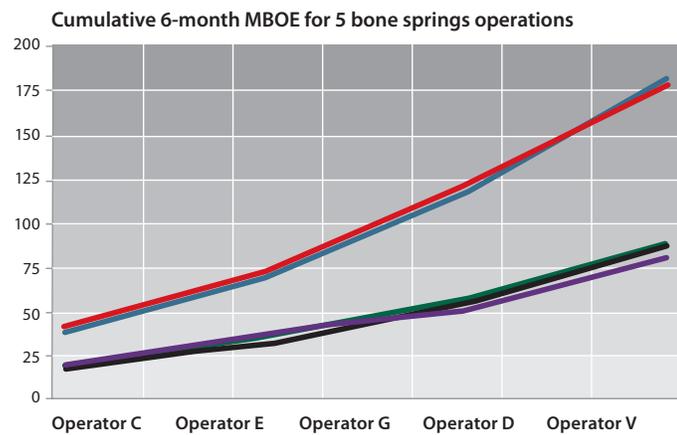
At the onset of the Bone Springs horizontal play, operators shied away from the expensive logging suites employed in vertical wells, largely because of the sticking risks and difficulty in accessing extended reach targets. Furthermore, owing to the then-consistent uniformity of every frac stage across a lateral, operators questioned the inherent value of using premium, and risky, logging technologies.

It soon became apparent that the typical homogeneous strategy defined with identical stimulation of every frac stage resulted in inadequate coverage of the total pay. Specifically, fracing uniformity across the lateral left little opportunity to optimize stage efficiencies, as both lower and higher permeability zones were equally stimulated, thereby considerably restricting cumulative reservoir drainage. Therefore, the key to optimizing production and maximizing asset value is to precisely determine the permeabilities in each zone of the lateral, and tailor each frac stage to capitalize on the identified degree of permeability in individual zones. And, to do so without reliance on premium logging suites.

The foundation of the STRATAGEN Bone Springs completion/stimulation solution is the engineering of unique designs for every frac stage, using readily accessible mud logging response data. In simple terms, mud log data response, which is corrected to account for human error, is used to characterize the permeability, and hence reservoir quality across the entire lateral. STRATAGEN then uses the data to tailor the design of each stage to match the measured permeability of the individual zones.

With our STRATASTIM™ customized workflow, in conjunction with FRACPRO® fracture design and analysis software, STRATAGEN consultants use the mud log response data to precisely plot distinct reservoir permeabilities. This is accomplished by randomly selecting stages and conducting a step-rate test with shut-in to capture the fluid leak-off of individual zones. Based on the leak-off data set, FRACPRO software is used to develop a closely corroborated numerical equivalent of rock characteristics, including stresses, permeability and reservoir pressure. A primary objective of this exercise is to precisely quantify the relationship between permeability and closure grade, which is tied directly to other key reservoir properties.

STRATAGEN is working closely with operators during the well planning stage to modify lateral placement and ensure the thickest and richest pay zones are thoroughly covered and exploited. Incorporating permeability models during the well design phase has proven highly effective in designing completion and stimulation programs, including stage-specific ceramic proppant placement and concentrations, designed to frac and prop the maximum extent of the sweet spot.



STRATAGEN served as a consultant for Operators "C" and "E" wells, and helped deliver appreciable production increases compared to operators "G", "D" and "V."

The evolution continues: optimizing placement, perf efficiencies

Going forward, the STRATAGEN steadily evolving and fully interconnected Bone Springs completion and stimulation optimization strategy is concentrated on lateral placement, specifically oriented to enhance the cost-reward ratio. Work is continuing on evaluating all the pertinent components, including optimizing net pressure to maximize the most cost-effective proppant placement to deliver optimal propped frac height.

Complementing ongoing research on fluid properties and frac design, further evaluation also is required in improving the pervasive deficiency in perforation efficiency. Specifically, attention is focusing on increasing the proportion of open perforations in conventional linear entry perf clusters.

Select literature

- *University of Texas, Bureau of Economic Geology*
- *Wood Mackenzie, August 2013 update on key North American shale plays*
- *IHS, "Herold Bone Spring Regional Play Assessment," March 2012*
- *Darrell Lohoefer, et al, "Open-hole, multi-stage verticals surpass conventional plug-and-perfs in Permian basin," World Oil, June 2014*

To learn more about how the unique technologies of STRATAGEN in combination with the experience and expertise of our fracturing specialists can optimize your Bone Springs completion and field development strategies, contact your nearest STRATAGEN representative.

Talk to STRATAGEN to find out how we can help you enhance your production.

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