Permian Basin
The Playbook

A supplement to

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Stretching across the plains of West Texas into New Mexico, the Permian Basin is one of the most mature plays in North America. Thousands of shallow wells dot the landscape, which stretches southwestwardly to the ultra-deep gas wells of Pecos County, Texas. Record-depth wells were drilled there in the 1970s using balanced drilling techniques. Wells were so deep that they could not be logged using conventional logging trucks because the trucks could not deploy enough electrical cable to reach bottom.

This is but one of the examples of the challenges faced by West Texas drillers over the years. But with ingenuity, they adapted offshore logging units from...
the Gulf of Mexico that could be modified with extra-large winches and high-strength cables to reach the depths being drilled. Many folks did a double-take when they came across a deepwater off-shore unit staked out on the caliche hardpan next to a drilling rig.

Today, operators are not drilling the deep Ellenburger like they once did, but challenges persist in other areas. The proliferation of shale gas plays across the continent has brought more challenges – and just as many new technical solutions. The first is reservoir contact. Pioneered in the Austin Chalk play of the 1980s, horizontal drilling has grown rapidly to the point that today there are more horizontal wells being drilled and completed than vertical ones.

Long lateral well bores brought additional challenges. Although they contacted more reservoir than vertical wells, they only lived up to their full potential when they were stimulated – principally with hydraulic fracturing. In the shale plays, hydraulic fracturing has made the difference between a gas show that quickly depleted to a commercial success. But this has led to another series of challenges.

The first hurdle is landing and placing the lateral in the best portions of the reservoir. The second is deciding how and where to complete the lateral for maximum productivity. Next, engineers had to address completion and frac designs. A wide variety of frac fluid treatments were designed, along with proppants to fit every situation. Hydraulic isolation media were developed and pumping schedules were customized for each well and stage.

The technique has become so popular that the demand has exceeded the supply, and operators are finding that it’s difficult to nail down a frac date because the available frac spreads are busy. Even when a frac date is obtained, proppant shortages can cause delays. Companies are attempting to “reserve” certain amounts of a particular proppant material in advance, but are experiencing difficulties in many cases. The latest challenge, which appears to be the “last straw,” is the shortage of water. (One would think that water shortage would be particularly bothersome in arid West Texas, but some of the biggest shortages are in the northeastern US. Water availability has been a big issue just about everywhere.) Inventive ways have been developed to deal with this latest shortage that include reusing recovered flowback water and using produced water from nearby wells. In South Texas, some folks are even drilling water wells that

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**Delta Stim Plus 20 completion service provides operators new options for completing horizontal multizone well bores to enable highly accurate placement of fractures with minimal or no intervention. (Illustration courtesy of Halliburton)***
target deep saltwater aquifers to get enough water to frac.

The experts discussed some of these challenges that are affecting their Permian Basin operations.

**Focusing on pay identification**

There are many challenges to Permian Basin operators, most of which come about from the current level of activity in the resource and shale plays such as the Wolfcamp-Spraberry (Wolfberry) in the Midland Basin and the Wolfcamp-Bone Spring (Avalon Shale) in the Delaware Basin.

Three challenges that are foremost to achieving a successful well are:

- Ability to identify the many potential pay intervals that are interbedded in long intervals of indistinguishable shale, siltstone, and carbonate rock;
- Correctly identifying the mineralogy for the purpose of selecting the most compatible stimulation fluids, the correct propping agent type, and size; and
- Developing a completion method that will stimulate the highest volume of rock as effectively and efficiently as possible.

The consequence of passing over potentially productive intervals, pumping fluids, and propping agents that are not compatible with the rock characteristics and using methods that are not effective and efficient can give results that might not meet the necessary economic criteria for continued development of the resource.

Halliburton has three specific technologies that directly address the aforementioned challenges in vertical well completions. The foundations for the solution to these challenges are the RockVision and ShaleLog. Both of these are computed products using standard openhole logging data.

These two products are used in combination to identify potential pay intervals of both the conventional and non-conventional rock types to identify mineralogy and stress profile, and for the selection of fluids and propping agents. These logs also are referenced as a guide for subdividing long intervals into discreet segments to be stimulated using a sequential stage type completion method.

The second technology is a computational method similar to the well-established limited entry calculation but with the inclusion of data from the above products in terms of the rock stress profile and factors for hardness and brittleness. Using these data in the hydraulic fracturing calculation allows for completion designs of multiple perforation clusters across several hundred feet of gross completion interval that will effectively place multiple simultaneous fractures in a single stage. This method ensures that adequate propping agent is placed in the intervals of interest across as long an interval as possible per stage.

The third technology is combined with the previous two into a complete design. This part also uses the stress, hardness, and brittleness factors to specify the charge type, shot density, and physical placement of the perforation clusters within the stage interval. This design method concludes with a plan that will stimulate the largest possible interval with the least number of stages.

In addition, the gun lengths are configured to facilitate a single gun and bridge plug run per stage, thus reducing the overall time required to complete many successive stages.

The multiple cluster completion method currently is in its third year of application. During these years, every effort has been made to improve and refine the process in response to post-treatment data, cutting and core analysis, and well response.

Most of the operators that have applied this completion method over the past several years have acknowledged favorable results when compared to previously used completion methods.

**New ideas take hold**

Although these three technologies have been applied primarily to vertical wells, the concept and process are equally applicable and have been applied to horizontal wells.

In a horizontal well, the multiple clusters become multiple fracture points along the length of the lateral. Wireline perforating and bridge plugs often are used in the same way, but the operational risk is much higher.

Recent enhancements in external packer sliding sleeve methodology now allow for 20 or more fracture points offering improvements over existing
methods. This interventionless stimulation technology, Delta Stim Plus 20 completion service, has been used in the Williston Basin and in the Northeastern US as a cost-effective means of completing horizontal wells. While new to the Permian Basin, the Plus 20 system should prove equally effective for operators in this region.

Another technology not yet introduced in the Permian is a new hybrid system that provides the ability to use combination strings of larger diameter jointed tubing and coiled tubing under live well conditions. Halliburton’s PowerReach system provides the ability to perform well stimulation and remedial operations in long horizontal wellbores without the limitations of small-diameter coiled tubing units. A downhole valve has been developed that enables the capability. The system has been tested effectively in a completion that created 17 individual fracturing stages using the PowerReach system to implement Halliburton’s SurgiFrac service.

‘Knowledge is power’

When confronted with a broad array of challenges like those of the diverse Permian Basin, BJ Services relies on its “Understand the Reservoir First” process. Treatment designs are enhanced by detailed foreknowledge of the reservoirs being treated. Much knowledge is obtained from the operator, but BJ also has developed deep parallel knowledge from researching cores, logs, and geological studies of the region through its collaboration with IHS Inc. databases. It uses its PowerVision system to map and link all wells, highlighting those wells on which BJ has firsthand knowledge.

The company has recognized the shortages of equipment, water, and proppant, and is proactively working to minimize their effects. It also recognizes that many of its clients are challenged to meet the terms of their lease agreements; in most cases, they must prove up on their leases before a predetermined deadline expires. BJ is sensitive to this issue and works with its clients to ensure that the most critical wells are serviced in time to avoid defaulting on the lease.

Some of the initiatives being taken by the company include strategic staging of personnel and equipment to meet demand. In addition, efforts are being made to ensure supplies of raw materials do not run short. To address recent concerns, “green” slurry polymers are being offered as alternatives to those seen as potential pollutants in some areas.

BJ Services recognizes that there is no “one-size-
fits-all” solution for the geologically diverse Permian Basin, and it is using its deep knowledge base to develop the best solutions for each well. For example, in many cases, it has found that crosslinked fluids achieve superior results compared to slickwater fracs in some areas. Knowing which areas react positively to these treatments helps execute fracs that result in sustained reservoir performance.

There still are a lot of vertical oil wells being completed in the Permian Basin Wolfberry play, particularly in southeastern New Mexico. Some of these have several thin pay zones that can be isolated and individually stimulated using “plug ’n perf” techniques.

A relatively new play is the Bone Spring. It is one that has switched to horizontal wells to exploit the long, thin reservoirs. The Bone Spring laterals are stimulated using eight to 15 stages. In the past, many treatments in horizontal wells over-treated the heel of the well and starved the toe. The Direct Stim technique solves this problem. Generally designed for openhole completions, the system is a highly efficient and reliable way to ensure each zone of a multizone completion
receives the proper treatment. It is effective particularly in horizontal completions.

Presently, the company is looking at new developments in Reeves County, Texas, where wells are being drilled to tap both the deep Wolfcamp and the shallower Bone Spring formations. The plan is to commingle production, but this means that treatments must be optimized. This is a perfect example where reservoir foreknowledge will enable the best design to be developed and implemented in each reservoir.

**Multidiscipline technology for optimum completions**

Formation heterogeneity and anisotropy have been identified as some of the main causes of suboptimal completions and treatment designs. According to Dan Bordelon, vice president, Southwest Basin, Schlumberger, “Schlumberger has focused its efforts on working with the operators to achieve maximum well productivity at the best return on investment. It is difficult to properly characterize a reservoir simply by attempting to cross-correlate between wells. We recommend running the proper formation evaluation suite to solve reservoir challenges that have the highest likelihood of affecting productivity.”

Using a systematic approach, Schlumberger acquires the necessary information and presents it in real time to the directional driller who lands and steers the well through the highest-quality volumes of the reservoir. In the meantime, the information gathered during drilling is used to optimize the stimulation design, by first selecting the best zones to treat and then designing the best treatment technique. It uses real-time microseismic fracture monitoring to monitor fracture growth and deploy diveters where necessary to avoid geohazards. It then monitors flowback and cleanup phases to obtain reservoir performance data which are correlated to the dynamic reservoir model.

Both formation heterogeneity and anisotropy are addressed by the Sonic Scanner acoustic scanning platform and CMR combinable magnetic resonance log, and formation mineralogy and clay content are resolved using the ECS elemental capture spectroscopy sonde. The Sonic Scanner log helps resolve formation stress orientation and magnitude so both perforation and treatment design can take stress anisotropy under consideration. Well placement is facilitated by the PeriScope bed boundary mapping service that provides real-time steering information to the driller, and PowerDrive rotary steerable systems (RSS) can accurately steer the wellbore through the most prolific zones.

“So far in 2010, well placement services have been used to construct 25 wells with laterals averaging 3,600 ft. In the Third Bone Spring Formation, target zones average only 12 ft in thickness, so utilizing the proper technologies to stay in the formation is of prime importance,” Bordelon said. “A total of 90,000 ft of laterals have been drilled successfully through mid-September of this year.”

Recently, Schlumberger introduced the HiWAY flow-channel hydraulic fracturing technique. The new fracturing technique combines placement methods, materials engineering, completions techniques, and process-control equipment to create stable flow channels, which are connected from the tip of the fracture back toward the wellbore. The productivity of the fracture is decoupled from the actual permeability of the proppant used, so rather than flowing through the proppant pack, hydrocarbons flow through stable channels that have effective, infinite fracture conductivity.

The company reports better flowback and cleanup, especially in multiphase flow regimes. Fracture performance has been verified using the Flow Scanner horizontal and deviated well production logging system.

Schlumberger TerraTek geomechanics and core analysis uses a systematic approach to provide accurate rock mechanics data to integrate into well and completion designs. The basis of the approach is timely, accurate measurements that support optimum designs and real-time decision-making.

**Diverse products and services for total well solutions**

By integrating its diverse product and service offerings, Baker Hughes strives to deliver a complete solution to its clients from well construction through completion and production. According to the company, two Permian Basin areas are commanding high operator interest these days: the Third Bone Spring Formation of Ward and Reeves
counties in Texas, and in New Mexico; and the Wolfberry play that includes the Spraberry and Wolfcamp formations in Martin, Midland, Upton, Reagan, and Ector counties in Texas.

For the Third Bone Spring Formation, Baker Hughes recommends its Auto-TrakG3 RSS with AziTrak 360-degree deep azimuthal resistivity LWD system with Quantec PDC bits. Most wells here start with a vertical logged pilot hole so the kickoff point and landing zone can be located; then the curve section and lateral are drilled using the Reservoir Navigation real-time steering services and StarTRAK imaging. Operators can monitor progress using the WellLink RT service and the BEACON collaboration center in Oklahoma City, Okla. Laterals range from 4,000 to 5,000 ft in length. In the thin Bone Springs sand, accurate steering is essential; many operators that have drilled out of section have stuck their bottomhole assemblies.

In the Wolfberry, all wells have been vertical to date, but one horizontal well is being planned presently. As of the end of August 2010, 65% of the 332 rigs operating in the Permian Basin are drilling the Wolfberry. The technique is to log select vertical wells using comprehensive wireline suites to get a clear picture of the target formation. For these wells, the company is recommending its FLex Formación Lithology Explorer elemental capture spectroscopy service to identify the best levels to initiate fractures. The XMAC F1 service provides formation stress analysis and the MReX magnetic resonance tool evaluates the fluid-filled porosity. A comprehensive Rockview interpretation presents lithology and mineralogy along with a complete petrophysical analysis in a single view. Once the reservoir has been characterized adequately, development wells can be drilled using minimal correlation logging. According to the company, Rockview results are increasingly important for unconventional reservoirs, which can be quite complex. Formations heterogeneity and anisotropy can make formation evaluation and completion design extremely problematic. In shale gas reservoirs, the ability to quantify and map the distribution of organic carbon, kerogen, is critical in identifying the most productive zones. Rockview can make the proper allocation between the organic carbon associated with the minerals, and the organic carbon in the pore space.

While vertical wells are treated using conventional plug 'n perf staged techniques, the highly efficient Frac-Point service has been used with good success on lateral completions in the Permian Basin. The technique can support up to 24 stages in a single trip into the well, isolating in openhole using swellable packers, and treating through ball-actuated sliding sleeves.

On the production side, Permian Basin operators have been challenged to maximize uptime for their artificial lift systems. Baker Hughes is helping with its Vision Expert Service, by which wells are monitored remotely by experienced production engineers at the BEACON Center. Pumps are monitored in two areas: pump performance and well performance. The first enables optimization of uptime and electrical efficiency and the second allows production to be adjusted for optimum sustained well performance. To date, on wells where the Vision service has been applied, production uptime has increased 4%, electrical power costs have been cut 5.5%, and, most importantly, interventions have been reduced 50%.
Recently, the Vision service has been integrated with monitored and optimized AddFRAC balanced chemical treatments that help reduce scale and wax deposition as well as corrosion, leading to greater uptime.

Proper completion design starts with understanding the rock, and Baker Hughes rotary coring service is a leading enabler. Far less costly and time-consuming than conventional coring, the rotary coring device can cut and retrieve 60 cores in a single trip. Coring depths are precise (within inches), which is essential when dealing with thinly bedded formations. The recently developed MaxCor tool will take cores 1½-in. in diameter by 2½-in. long.

**Focusing on drilling and production**

After years of service in the Permian Basin, Weatherford’s drilling services group has established specialists in various technologies including slimhole, short-radius horizontal re-entry, underbalanced directional and straight-hole, mud-pulse survey services.

The company’s directional services group in Midland, Texas, has drilled over 550 short-radius, re-entry wells during the past seven years. These wells are horizontal with the curve radius ranging from 85 to 135 ft, hole sizes between 3½ and 4½ in., and target zones of roughly 10 ft in thickness.

More than 35 directional wells have been drilled in underbalanced conditions in the last three years using both the company’s conventional electromagnetic (EM) MWD telemetry and extended-range EM MWD telemetry. The system has been run in the Permian area to 12,781 ft true vertical depth. During the same period, Weatherford has drilled more than 200 wells using its drift measurement tool inclination-only surveys and azimuth measurement system inclination-and-azimuth surveys. Straight-hole survey times are reduced to 2.5 minutes regardless of depth, which decreases survey-related downtime and increases daily rate-of-penetration.

Weatherford used a BHA consisting of a 4¼-in. performance motor and its hostile-environment LWD system with azimuthal gamma ray, and real-time drilling support services to geosteer through a 10-ft hydrocarbon-bearing zone in a 6.125-in. horizontal well for Manzano Oil & Gas in Lea County, New Mexico. The curve was built at 15 degrees/100 ft and a total vertical section of 4,368 ft was drilled in about 148 drilling hours. The lateral was drilled in two runs, one for the curve and one for the lateral, and all tools performed well.

Working on a client’s first-ever horizontal well, in Cochran County, Texas, Weatherford re-entered 5½-in. casing and exited via whipstock, using 3½-in. performance motors and EM MWD with LWD gamma ray sensors. The curve was built at 20 degrees/100 ft. The curve and lateral were drilled in one run. A total of 4,230 ft of total vertical section had been drilled by total depth, with the well bore remaining in the zone the entire time. A total of 4,525 ft of curve and lateral were drilled in 64.75 drilling hours.

Weatherford production services feature Maximizer and Maximizer II pumping units that have been applied heavily in the Permian Basin over the last three years. Manufactured for high-productivity, low-cost maintenance and long oilfield life to meet operator performance requirements, the units claim improved efficiency and additional benefits in a wider range of applications than other conventional units. The Maximizer II pumping unit provides enhancements not typically found in pumping units, such as rear-mounted pumping geometry, higher mechanical efficiency that allows more crank rotation during the upstroke for better pump fillage, and a counterbalance moment that is phased to optimize the lifting cycle. Operators in various regions have complimented the solid performance of both systems.

The Ampscolt unit is a more conventional pumping unit that is used commonly throughout the Permian Basin as well. This high-quality unit provides operators with a wide range of size options. Another Permian Basin compatible option is the Rotaflex pumping unit. This product is a slow, long stroke pumping unit that operates efficiently particularly in deep, troublesome, and high-volume wells.

Operators have applied Weatherford’s critical velocity reduction system in the Permian Basin as well. The technology is designed for extended perforated-interval gas wells. It combines the best attributes of flow area reduction and foam-lift assistance by reducing surface tension and density of produced water. These solutions reduce the well’s critical velocity and improve production rates.