HARTENERGY

Permian Basin Wolfcamp

The 2014 Techbook

A supplement to

E&P

BroadBand Sequence

FRACTURING TECHNIQUE

BroadBand Sequence technique stimulates more clusters (blue) than conventional stimulation techniques.

Composite fluid temporarily isolates fractures at the wellbore.

Marathon Oil increases productivity in Eagle Ford Shale well by 21%.

The BroadBand Sequence* fracturing technique effectively stimulated perforation clusters that would not have produced by conventional techniques. Enabled by a proprietary engineered composite fluid of degradable particles and fibers, the BroadBand Sequence technique increased production by 21% over 115 days.

Read case study at
slb.com/BroadBand

Schlumberger

E&P

Permian Basin Wolfcamp
The 2014 Techbook

A supplement to *E&P*

HART ENERGY
1616 S. Voss, Suite 1000 | Houston, Texas 77057
Tel: +1 (713) 260-6400 | Fax: +1 (713) 840-8585
www.hartenergy.com

Editor in Chief **MARK THOMAS**
Group Managing Editor **JO ANN DAVY**
Executive Editor **RHONDA DUEY**
Senior Editor, Drilling **SCOTT WEEDEN**
Senior Editor, Offshore **JENNIFER PRESLEY**
Executive Editor, Special Projects **ELDON BALL**
Chief Technical Director **RICHARD MASON**

Contributing Editors **GREGORY DL MORRIS**
TRAVIS POLING
MJ SELLE

Associate Managing Editor **MARY HOGAN**
Associate Managing Editor, E&P **BETHANY FARNSWORTH**
Associate Online Editor **VELDA ADDISON**
Associate Editor **ARIANA BENAVIDEZ**

Corporate Art Director **ALEXA SANDERS**
Senior Graphic Designer **JAMES GRANT**
Production Director **JO LYNNE POOL**
Marketing Director **GREG SALERNO**
For additional copies of this publication, contact Customer Service +1 (713) 260-6442.

Vice President–Publishing **RUSSELL LAAS**
Vice President–Publishing **SHELLEY LAMB**
Director of Business Development **ERIC ROTH**

HARTENERGY

Editorial Director **PEGGY WILLIAMS**
President & Chief Operating Officer **KEVIN F. HIGGINS**
Chief Executive Officer **RICHARD A. EICHLER**

Hart Energy's Techbook Series

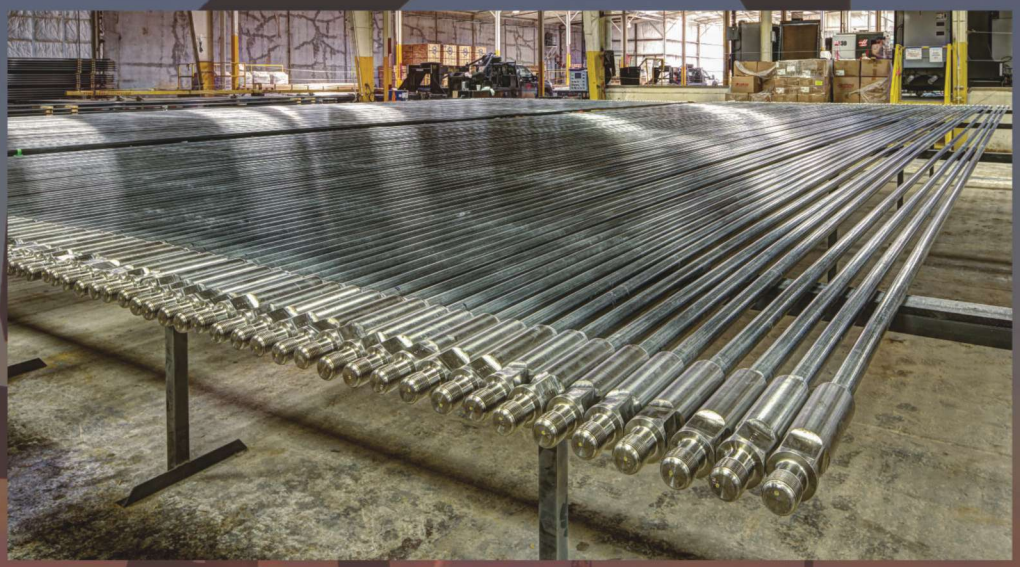
The 2014 Permian Wolfcamp Techbook is the fifth in a series of techbooks in which Hart Energy will provide comprehensive coverage of effective and emerging technologies in the oil and gas industry. Each Techbook includes a market overview, a sample of key technology providers, case studies of field applications and exclusive analysis of industry trends relative to specific technologies. **To learn more about E&P technology trends, visit *EPmag.com*.**

Table of Contents

A valve is opened on Tall City Exploration's Turner AR1H well, drilled to Wolfcamp A, at the end of fracking operations in Reagan County, Texas. *(Photo by Tom Fox, courtesy of* Oil and Gas Investor*)*

SUPEROD

Superior Fiberglass Sucker Rods



Lighter-weight fiberglass sucker rods are inherently superior in today's industry, where higher stress ratings are mandatory. Now there is a fiberglass rod with proprietary steel end fittings that make all other rods obsolete. Deep wells, high-volume loads, corrosive and other hostile downhole conditions? No problem. Solve your most challenging well problems. Run with SUPEROD®.

Now More Than:

- 6,000 Rod Strings Installed
- 22,500,000 Total Footage
- 60,000,000,000 Cycles

WITH ZERO OPERATIONAL FAILURES

It's the best rod in existence, bar none. And it comes with a warranty backed by the most experienced people in the industry.

SUPEROD personnel will design your string, deliver it on company-owned trucks, provide installation and troubleshooting services, plus guarantee performance. All for the cost of the rod string!

Best Rod, Best People, Best Price, Best Guarantee.

Corporate Office
610 Main Street
Big Spring, TX 79720
P: 432.264.7500
F: 432.714.4723

Kansas 316-882-3244

SUPEROD
The Superior Fiberglass Rod

Oklahoma 405-787-3763

www.superod.com

Plant
3408 E. 11th Place Ext.
Big Spring, TX 79720
P: 432.517.4145
F: 432.517.4528

Eagle Ford 512-626-9282

Permian Reclaims Primacy in Oil Production

Closing in on a century of production, the Permian now leads in liftings and rigs.

By Gregory DL Morris
Contributing Editor

Two developments in May loudly affirmed the position of the Permian Basin among oil and gas plays, not just in North America but worldwide. To the surprise of few, Concho Resources, a pure-play Permian independent, increased the size of a secondary public offering from 6 million to 6.5 million shares, priced at $129. Concho, along with Pioneer Natural Resources and myriad smaller players, represents the broad and deep presence of independents that have led the unconventional renaissance in the dusty old Permian.

Within days of the Concho offering, and to the surprise of some, Chevron Corp. put its mouth where its money is by holding its shareholder meeting in Midland in May. Rounding out the spectrum, the large independents are important players in the Permian as well, led by Apache Corp.

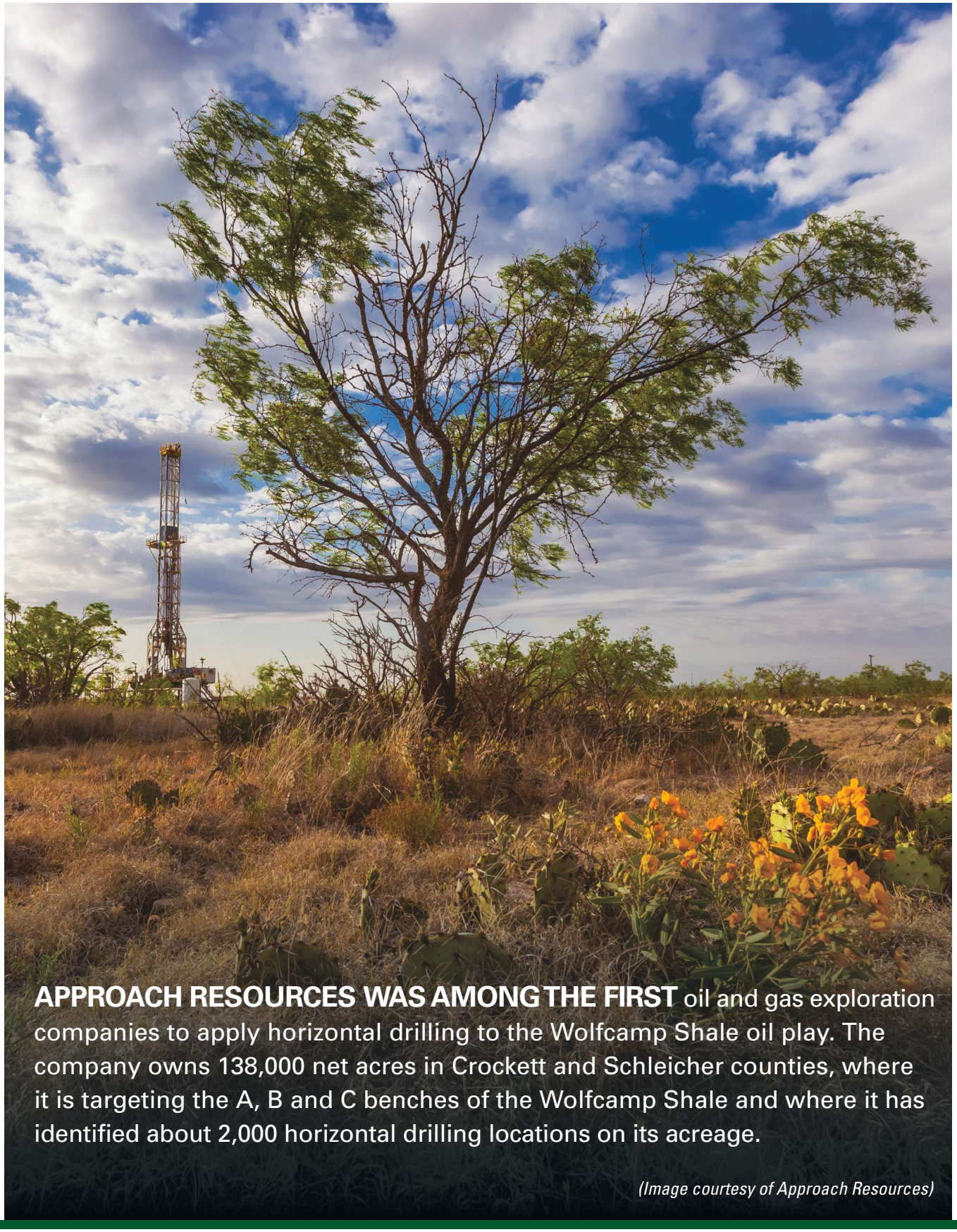
The latest oil patch chatter seems to recapitulate that everything really is bigger in Texas. The talk now is that the Wolfcamp and Cline plays will be bigger than the Bakken in North Dakota—all by themselves with the rest of the Permian excluded. The truth in that remains to be seen, but there is little doubt that the Permian is the hottest play today, and the Wolfcamp and its associated horizons are in the spotlight.

The fecundity of the Permian is legendary. More than one producer has called the basin "the gift that just keeps on giving." The basin has produced an estimated total of 31 Bbbl of oil and more than 100 Tcf of gas since it was developed in the 1920s. Today, as unconventional development has blossomed, the Permian annual output rose from 850,000 bbl/d in 2007 to 1.3 MMbbl/d last year.

According to the Texas Railroad Commission, the Permian has produced almost 30 Bbbl of oil and 75 Tcf of gas since its development. The Permian now produces nearly 15% of all crude oil in the entire U.S. Over the first half of this year, the Permian produced more oil than the Eagle Ford and is estimated to reach 2 MMboe/d in just four more years.

As reported recently in *Oil & Gas Investor*, Gene Shepherd, CEO of Brigham Resources, said that investment capital is following the rigs to the Permian. "Right now, I hear institutional investors are shorting the Williston and want to go long in the Permian, as they perceive there is more [formation] optionality in the Permian. That is, sort of, driving the valuations. There just isn't enough market cap for them all to pile into."

Unconventional operators have in many cases been able to apply the high-efficiency techniques that have made other shale plays seem like manufacturing. But to the list of hoary expressions that apply to the industry, age and cunning can overcome youth and skill. The potential is indeed vast, but the horizons are hardly uniform. The variation in depth to the Wolfcamp varies by hundreds of feet within the distance of several miles. Lateral landing zones also are variable, according to industry reports and filings.



APPROACH RESOURCES WAS AMONG THE FIRST oil and gas exploration companies to apply horizontal drilling to the Wolfcamp Shale oil play. The company owns 138,000 net acres in Crockett and Schleicher counties, where it is targeting the A, B and C benches of the Wolfcamp Shale and where it has identified about 2,000 horizontal drilling locations on its acreage.

(Image courtesy of Approach Resources)

Organic growth

In the last few years it has been incumbent on producers, especially independents, to keep a clean balance sheet and "grow from the drillbit." The recent secondary Concho offering is a textbook example of that. Net proceeds were used to reload the revolver, repaying all outstanding borrowings under the company's credit facility, with some left over for the usual general corporate purposes. For Concho, that included funding the company's three-year accelerated growth plan, capital commitments associated with a recently announced midstream joint venture (JV) and future acquisitions.

The Delaware Basin, in particular, remains Concho's most significant area of capital investment and proved reserves growth, and that said, the firm remains cautious. Concho believes the Delaware Basin is a premier oil play but has stated that "limited development history currently constrains the magnitude of proved reserves additions." During 2013, the company deployed $1 billion to the Delaware Basin, representing 63% of its total capital spent. At year-end 2013, estimated proved reserves in the Delaware Basin had increased 69% over year-end 2012 but represented only 27% of the company's total estimated proved reserves.

"The Delaware Basin will feature prominently in future capital programs, especially as we embark on our three-year plan to double production by year-end 2016," Tim Leach, chairman, president and CEO, told analysts. "Our confidence in the quality and scale of the resource opportunity in the Delaware Basin, as well as the Midland Basin, is rapidly growing as we continue to push the productive boundaries across our acreage, delineate additional zones and test the potential for increased well density. We plan to provide operational updates with more detail around resource potential and inventory depth beyond our set of engineered drilling locations."

Drillbit finding and development costs were $16.79 per boe in 2013 vs. $16.56 per boe in 2012. Concho remained one of the most active drillers in the Permian Basin with one of the largest horizontal drilling rig fleets. The company exited last year with 26 total rigs, 22 of which were drilling horizontally. At midyear, Concho was operating 31 rigs, 27 horizontally.

"The Permian Basin is experiencing a dramatic shift to horizontal drilling," Leach said. "From 2012 to 2013, we significantly increased our horizontal capital allocation from less than half to more than 70%. We expect to allocate roughly 90% of our capital budget to horizontal development across all three of our core areas." Concho drilled or participated in 633 wells (465 operated, 44% horizontal) and completed 675 wells as producer in 2013.

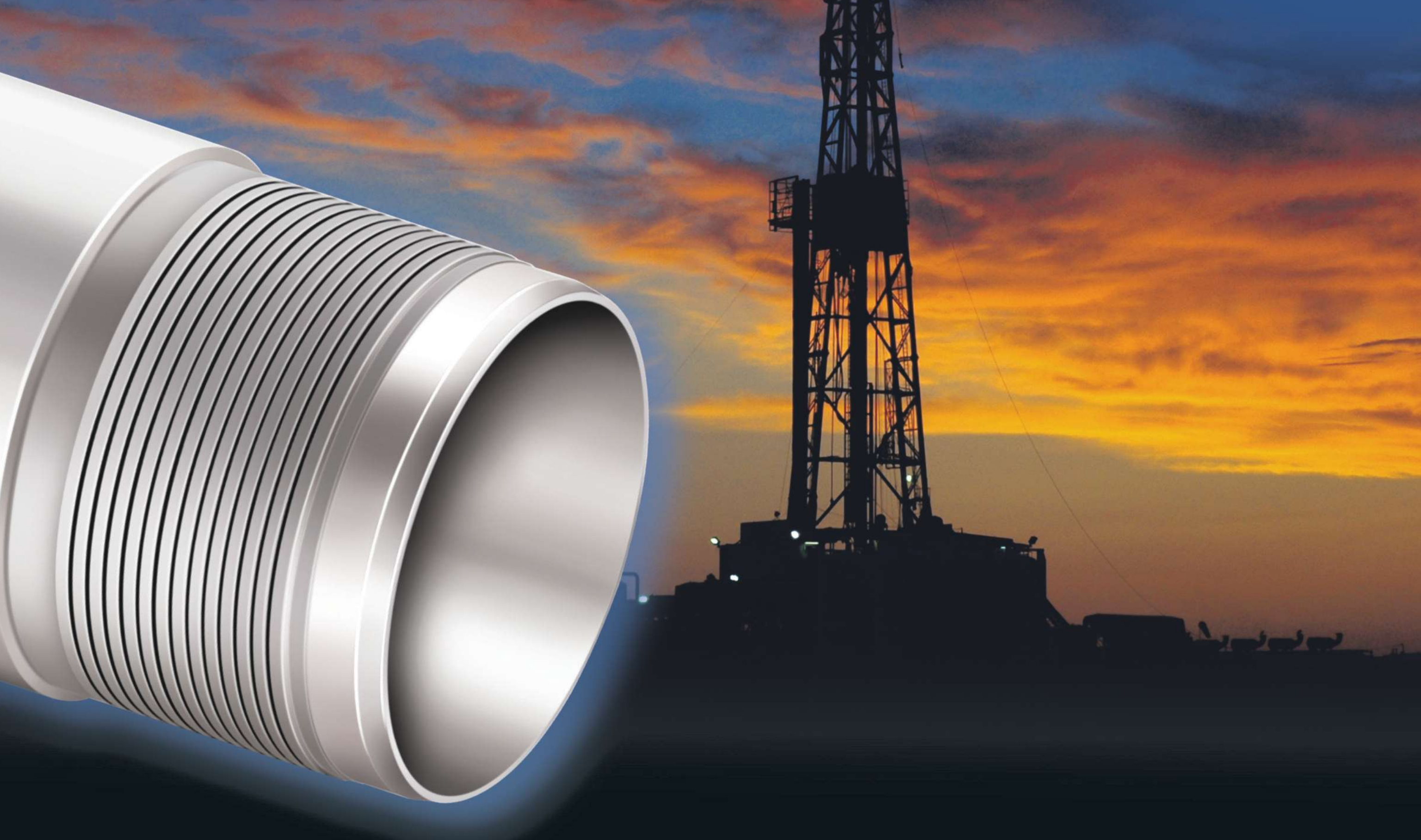
"THE DELAWARE BASIN WILL FEATURE PROMINENTLY in future capital programs, especially as we embark on our three-year plan to double production by year-end 2016."

—Tim Leach, chairman, president and CEO of Concho Resources

California dreaming

Chevron is the largest acreage holder in the Delaware Basin, with about 1.3 million total acres in West Texas and southeast New Mexico. In June 2013, Chevron reached a joint development agreement with Cimarex covering 104,000 total acres and providing access to related infrastructure. Before that, Chevron had begun drilling horizontal wells in 2012 and had three rigs running at year-end 2013. Chevron continues to participate in wells drilled by others and added more than 150 wells in the last three years.

In the Midland Basin, Chevron has more than 480,000 total acres in the Wolfcamp. At year-end 2013, those holdings included 107,000 total acres where the company has an average nonoperated working interest of about 70%. The holdings include eight rigs and more than 1,300 wells that produce



an average net of more than 20,000 boe/d. Work at the remaining acreage, which is Chevron-operated at about 97%, continued to ramp up and had eight rigs operating at the start of this year.

Chevron's mixed approach—operated, nonoperated and JV—reflects the history and the situation on the ground in the Permian. Other than the Gulf of Mexico, it is the one big domestic basin where the global majors never completely departed. In addition to Chevron, Occidental, Hess and several others kept their hands in even as they decamped from all or most of their other domestic positions.

More recently, some of the biggest multinationals, ExxonMobil and Shell, have returned to the Permian. A major reason for that has been the continuing conventional production as well as effective and widespread use of enhanced recovery. Nevertheless, it was the independents, such as Concho and Pioneer, that led the charge into unconventional development, just as they had in other basins around the country.

As a result, there are both majors and independents with decades-old operations, cheek by jowl with majors and independents new to the play. As has been observed by many industry analysts, any one of the top majors could buy most of the independent operators in the country with cash on hand. But so far, across the country and most notably in the Permian, the majors seem content to let the independents forge ahead, making deals where opportunity arises.

The long-term goals of the majors are clear. Earlier this year, George Kirkland, vice chairman of Chevron, told analysts that the company expects to make the Permian one of its top five worldwide assets by 2020.

WITH 23 RIGS OPERATING IN THE PERMIAN, Devon expects to drill about 350 wells in 2014, executing on a $1.5 billion capital spending plan.

(Image courtesy of Devon Energy)

PUMP PARTS AND SERVICE

Frac pump downtime can be extremely costly to your operation. To avoid it, we believe you should always have a ready source for reliable pumps parts and service – expert people in your area who can provide exactly what you need, when you need it, so you can keep your frac jobs working. That source is Dragon.

Yes, we have that.
Dragon has seven service centers, strategically located in every major hydrocarbon-producing region. Our centers are extensively outfitted to deliver the full range of pumps parts and services.

Make it happen.

Dragon Pumps now provides on-site training and certification classes for all of our pump equipment. frac.sales@modernusa.com

PLAYBOOK

We are here.

DRAGON®

www.dragonproductsltd.com • 866-914-8198

U.S. owned and operated for over 50 years.

Big and getting bigger

Apache is one of the largest operators in the Permian Basin, with more than 13,500 producing wells in 155 fields, including 47 waterfloods and seven CO_2 floods on more than 3.3 million gross acres. The firm has exposure to numerous plays and extensive operations in all types of development, from directional drilling and completion to EOR. At Hart Energy's DUG Permian Basin conference in May, John Christmann, Apache's executive vice president and COO for North America, called the Permian overall "a powerhouse" and for the company "a big position getting bigger."

First-quarter 2014 production for Apache in the Permian averaged a record 149,564 boe/d at 76% liquids. That was an improvement of 12% over the previous quarter. The substantial growth during the quarter was driven by successful horizontal drilling programs across the basin and led by the Wolfcamp Shale.

"THE WOLFCAMP SHALE is a vast, tight-oil resource with tremendous potential. The presence of multiple stacked pay zones creates the potential for capital-efficient horizontal development, and the proximity to XTO's ongoing Wolfcamp operations will offer operating cost efficiencies."

—Randy Cleveland, president of XTO

The company had an average of 38 rigs running on its behalf in the Permian, which was a decrease of three net rigs from the previous quarter. Individually, there was one additional rig drilling horizontal wells and four fewer rigs drilling vertical wells. Overall Apache's drillers spudded 202 gross operated wells during the quarter, including 80 horizontal and 122 vertical.

Play by play, the company has an estimated 502,000 gross acres (401,000 net) prospective for the Wolfcamp Shale. The Barnhart area of Irion County, Texas, remained extremely active, ramping back up to six horizontal rigs. First-quarter activity focused on drilling 12 Upper and eight Middle Wolfcamp wells, all with laterals drilled to 1.5 miles.

Apache also was active in Reagan and Uptown counties of the southern Midland Basin. Seven rigs were drilled across three main development fields: Powell, Scottish Rights Hospital and Weatherby. In the Cline, the company has an estimated 640,000 gross acres (510,000 net) prospective. The Lower Cline inventory continued to grow as the company tested various alterations to completion and fracture stimulation parameters to maximize the rate and reserves recovered. A total of 35 gross wells are planned for 2014.

Apache has an estimated 1.8 million gross acres (850,000 net) in the Central Basin Platform. The company continues to report success targeting the Wichita Albany play where three horizontal wells were spudded and six were completed during first-quarter 2014.

Apache has about 115,000 gross acres (95,000 net) in the Yeso play of the Northwest Shelf. Three rigs remained active during first-quarter 2014 and 25 wells were spudded, including four horizontal and 21 vertical. Completion operations on the Cedar Lake horizontal program began late last year. As most of those wells have cleaned up, they began reaching their peak rates by the end of first-quarter 2014. The company plans to drill about 20 horizontal and 75 vertical by year-end 2014.

Apache has an estimated 550,000 gross acres (215,000 net) in the Delaware Basin. The company entered the first quarter running three rigs in the Pecos Bend Field, spudding a total of five wells and completing four targeting three landing zones: the Second and Third Bone Spring, and Wolfcamp.

The empire strikes back

The enduring productivity of the Permian is highlighted by the fact that the largest oil producer in Texas is not an Eagle Ford ariviste, but Occidental

FASTER RIG-UPS AND SAFER OPERATIONS...

UNCONVENTIONALS

...FROM THE INDUSTRY PIONEERS.

Faster and safer rig-ups equate to efficient well interventions. Halliburton's Boots & Coots service line– the coiled tubing experts – introduce their next-generation Enhanced QuikRig® (EQR) system. Suitable for work in new and mature fields and ideal for unconventional markets, this system can be rigged up in half the time of a conventional unit. Plus, the QuikRig system's unique design featuring pre-assembled well control equipment—capable of deploying extended bottom hole assemblies, and coupled with a latching mast design—helps provide safer operations by significantly reducing the risk of working under suspended loads.

Faster rig-up. Safer operations with fully supported loads.

What's *your* well intervention challenge? Boots & Coots is ready to go.
To learn more, visit at **Halliburton.com/boots-coots**

HALLIBURTON

Boots & Coots

Solving challenges.™

Before dawn, floor hand Colby Skinner, left, and derrick hand Blake Sepulvado move pipe during drilling operations on H&P 232 at RSP Permian's Crossbar Ranch #3025H in Midland County. *(Photo by Tom Fox, courtesy of Hart Energy's* Oil and Gas Investor*)*

(Oxy), based primarily on its long-standing Permian liftings. Oxy is also one of the largest land holders, with almost 2 million prospective acres. Reflecting the rise of unconventional development, Oxy has allocated about two-thirds of its $2.2 billion capex for the Permian for tight oil. The rest will go to conventional operations, primarily EOR in the form of CO_2 flooding.

In contrast to Oxy's steady-Eddie approach, Shell sold out of the Permian in the mid-90s but made a high-profile reentry to the play late last year with its $2 billion acquisition of Chesapeake's 618,000 net acres and production of 26,000 boe/d. In a separate transaction, Chevron also bought some Chesapeake Permian assets.

Shell is working from Chesapeake's former offices in Midland, Texas, with plans to expand the facilities. It has brought in personnel from all over the world to kick-start operations that had been in a holding pattern as Chesapeake got its affairs sorted. For the long term, Shell has put out the call for hires at all levels. The drilling program had seven rigs working in Loving, Reeves, Ward and Winkler counties in Texas, with plans to take that to 10 rigs.

The missing major in the Permian might seem to be the biggest of all, ExxonMobil, but the company has gotten in the game in subtle ways that would have made John D. Rockefeller proud. In February, working through its domestic upstream subsidiary

Frac-specific experience.

Frac-specific technology.

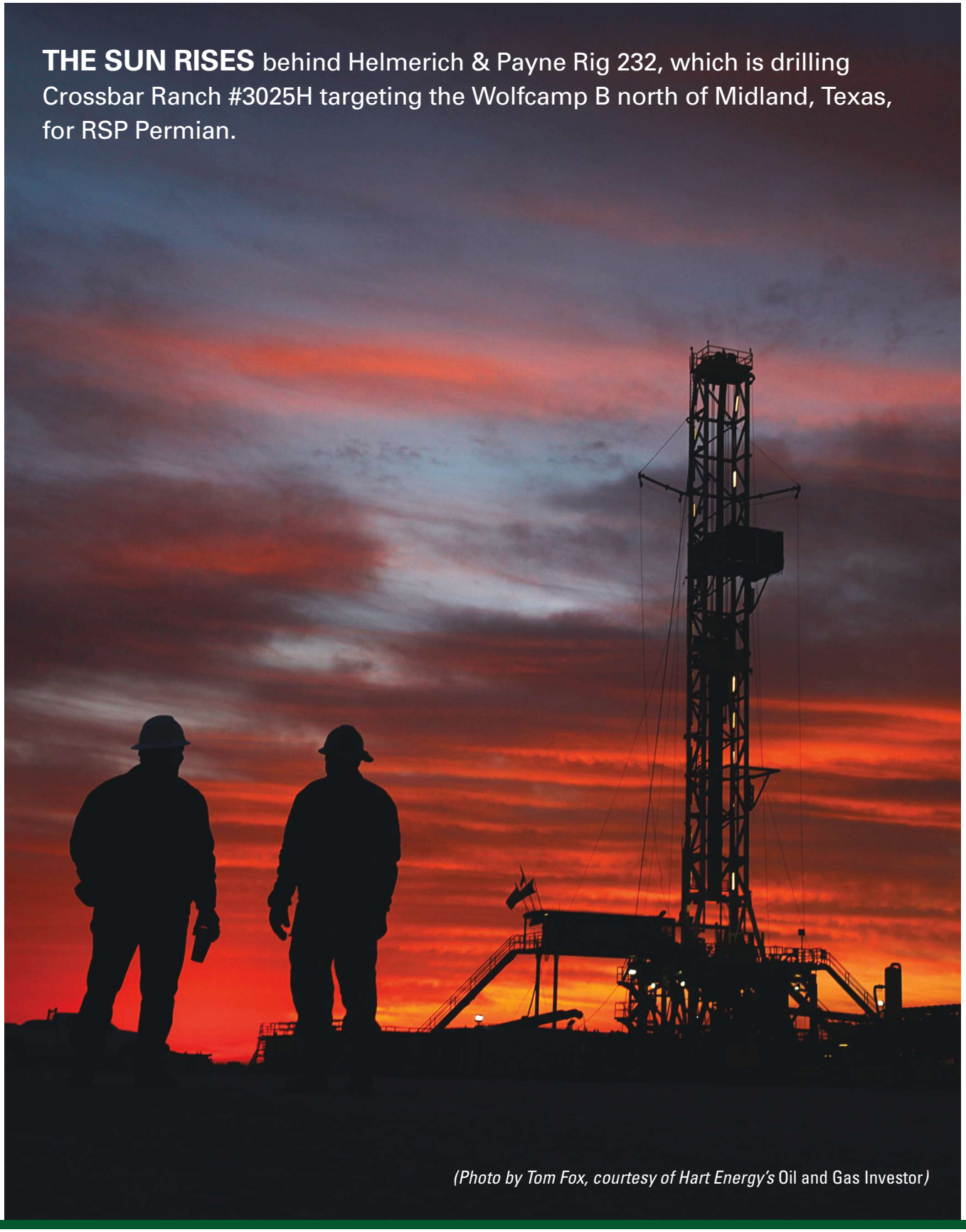
Get where you want to be faster.

In the race to save time and increase efficiencies in fracturing operations, FMC Technologies delivers the goods: Our patented isolation sleeve protects multiple wellhead components from extreme pressures and erosion. Our frac-specific valves have built-in sand traps that protect primary sealing surfaces. And with service facilities near all major shale plays, we provide the support you need to complete your well on time and on budget.

www.fmctechnologies.com

FMC Technologies

We put you first.
And keep you ahead.



THE SUN RISES behind Helmerich & Payne Rig 232, which is drilling Crossbar Ranch #3025H targeting the Wolfcamp B north of Midland, Texas, for RSP Permian.

(Photo by Tom Fox, courtesy of Hart Energy's Oil and Gas Investor*)*

XTO Energy, ExxonMobil began backing Permian development through an agreement with Endeavour Energy Resources, a private operator. The agreement increases XTO's holdings in the Permian Basin to more than 1.5 million net acres.

Under the Endeavour arrangement, XTO is funding development and will gain "substantial operating equity" in about 34,000 gross acres of the Wolfcamp in Midland and Upton counties. Endeavor will continue to operate shallow production while XTO will drill and operate horizontal wells in the deeper intervals.

"The Wolfcamp Shale is a vast, tight-oil resource with tremendous potential," said Randy Cleveland, president of XTO. "The presence of multiple stacked pay zones creates the potential for capital-efficient horizontal development, and the proximity to XTO's ongoing Wolfcamp operations will offer operating cost efficiencies."

A Wolfbone in its teeth

Pioneer Natural Resources has made the Permian Basin's Spraberry Field its focus of attention, and that has moved the needle on national rig counts. The Spraberry has the most rigs running of any play—313 as of May—according to the Baker Hughes count. The entire Eagle Ford was a distant second at 218, and the Permian's Delaware Basin a close third at 204. The Williston Basin of the Bakken was fourth at 184. Those numbers underscore the projections for swelling production out of the Permian.

The Spraberry was discovered in 1949 and encompasses eight counties in West Texas. Oil produced in the Spraberry is West Texas Intermediate Sweet, and the gas produced is casinghead gas with an average energy content of 1,400 Btu. The field is about 150 miles long and 75 miles wide at its widest point.

Oil and gas resources are produced from multiple formations—including the upper and lower Spraberry, Jo Mill, Dean, Wolfcamp, Atoka, Strawn and Mississippian—at depths ranging from 6,700 ft to 11,300 ft. Based on extensive geologic data and successful drilling results to date, Pioneer estimates the Spraberry Field contains more than 75 Bboe, making it the largest U.S. oil field and second largest oil field in the world.

Pioneer estimates it has more than 8 Bboe of net resource potential from vertical and horizontal drilling and more than 35,000 drilling locations. Taking a closer look, the company estimates that it has more than 3 Bboe net recoverable resource potential from six stacked intervals across its 600,000 gross acres in the northern Spraberry/Wolfcamp acreage. The majority of this acreage is held by production. The highly prospective stacked intervals are the middle Spraberry Shale, Jo Mill, lower Spraberry Shale, Wolfcamp A, Wolfcamp B and Wolfcamp D formations. Additional zones, such as the Clearfork, Wolfcamp C, Atoka, Barnett and Woodford, might also be tested horizontally in the future.

Pioneer plans to drill about 140 wells in the northern acreage during 2014. As of June 2014, the company was operating 16 horizontal rigs in the area, with most using three-well pads.

Just a year ago Pioneer closed a JV transaction with Chinese state oil company Sinochem to sell 40% of its interest in 207,000 net acres of the horizontal Wolfcamp play in the southern portion of the Spraberry Field.

Pioneer continued as operator and retains its current working interests in all formations shallower than the Wolfcamp horizon. The $1.7 billion transaction allows Pioneer to accelerate development in its southern acreage position and add significant production and reserves while enhancing shareholder value. Through year-end 2013, about 100 horizontal Wolfcamp wells were drilled in the JV area, and 23 more were drilled in first-quarter 2014.

Pioneer's Spraberry vertical wells produce 70% oil and account for about 40% of the company's total production and about 55% of its total proved reserves. The company projects a multiyear drilling inventory of more than 24,000 locations.

Strictly old school

A critical part of the E&P business of Energen Resources is its ability to rejuvenate older fields with new technology. That has been particularly true in the Permian Basin plays. The original oil resource in the Permian Basin reservoirs was estimated at 95 Bboe, the company said. But until recently many thought as much as two-thirds of that oil would be stranded.

Energen used waterflood operations to revive the North Westbrook Unit, a field it acquired in 2005. Since then, production jumped from 900 bbl/d to nearly 5,000 bbl/d, close to the field's peak production in 1985, when Chevron operated it.

The Westbrook Field also is home to a piece of West Texas history: the Permian Basin's oldest oil producing well, W. H. Abrams #1, which commenced drilling in February 1920. That well and the thousands that followed are credited with fueling the growth of Midland and Odessa from cow towns to boomtowns. Both towns have ridden booms and busts over the years, but they are once again bustling, thanks to Permian oil and liquids production.

Energen, a conglomerate that includes utility operations, has about 71% of its proved reserves in the Permian, including 99% of the company's oil reserves. The firm is all in for the Permian. It allotted about 94% of its 2013 capital budget to development of its Permian Basin properties and 99% of the 2014 capex.

Equity analysts took note earlier in the year when Energen announced it had tested four new Wolfcamp wells, including its first in Martin County, which put up some record IP rates for similar wells in the county. That came on top of strong well numbers from late last year. In a virtuous cycle, Energen stock rose, and the company said it would increase its capex and production projections.

The next Permian name poised to pop could be a familiar one in the oil patch: ConocoPhillips. In something of a David-and-Goliath story, ConocoPhillips is mostly active in the Spraberry and so has been in the shadow of Pioneer, a much smaller company. While Pioneer has been a Wall Street darling this year, the bigger firm has not gotten the same love. The analysts' explanation of the oversight is that legacy Conoco assets in the Eagle Ford have taken precedence, but there is an expectation of a rotation to the Permian.

At the Barclay's CEO Energy Conference in September 2013, CEO Ryan Lance said that ConocoPhillips has more than 1 million acres, mostly legacy holdings, putting it in the company of the biggest land holders in the basin. More specifically, the company has 89,000 acres in the Ozona Arch region of the Wolfcamp.

"THIS OIL-TARGETED ACQUISITION provides entry into the Permian Basin and a new core area with growth potential in well-delineated assets."

—Jim Craddock, chairman, president and CEO of Rosetta Resources

Breaking in, looking up

Around the same time in May as the big dogs were floating shares and holding annual meetings, the independents were just as busy. Rosetta Resources, for example, closed on its previously announced acquisition of Permian Basin assets from Comstock Resources.

The total value of the deal was $811 million, which includes the $768 million purchase price and $43.3 million in closing adjustments. Rosetta funded the acquisition from a debt issue and from its revolving credit facility. After the deal was done, the company had $100 million outstanding with $700 million available for borrowing under the revolver.

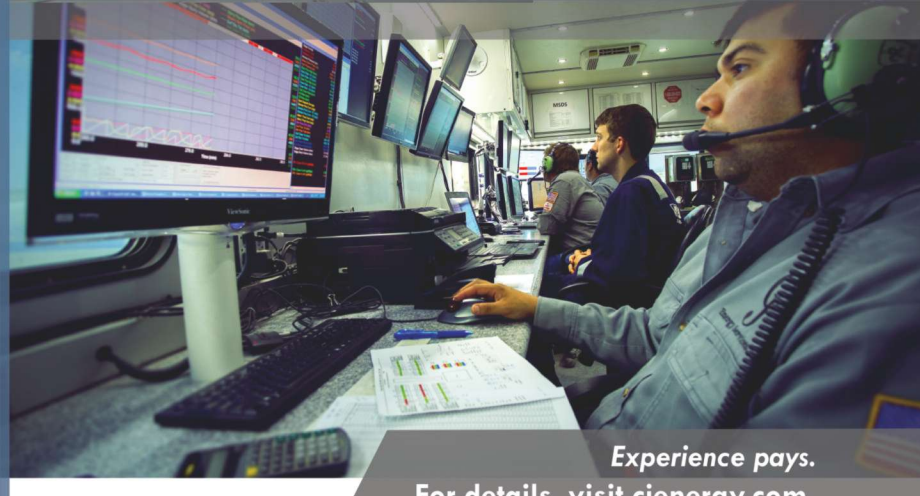
"This oil-targeted acquisition provides entry into the Permian Basin and a new core area with growth potential in well-delineated assets," said Jim Craddock, Rosetta's chairman, president and CEO at the closing. "The transaction adds a significant number of oil well locations to our project inventory and further advances Rosetta's long-term unconventional resource development strategy."

WHERE IN DEPTH EXPERIENCE COMES STANDARD.

You want it all: Industry-leading frac experience, high performance equipment, and enhanced efficiencies and production. Welcome to C&J.

While the deep experience level of C&J's veteran management and field personnel truly sets us apart from the herd, so does our approach to your well. Because in every operating environment, no matter how complex the well, it's standard C&J procedure to examine challenges on a well-by-well basis—never assuming every well or zone requires the exact same methodology, equipment or treatment.

The result? Greater efficiencies. Significant time saved. More rewarding production from your wells.



Experience pays.
For details, visit cjenergy.com.

WINNER
OIL & GAS AWARDS
2013
Gulf Coast

C&J Energy Services

COILED TUBING | HYDRAULIC FRACTURING | PRESSURE PUMPING | PERFORATING | WIRELINE LOGGING | THRU TUBING | PIPE RECOVERY

The acquisition comprised 53,306 net acres (87,373 gross) in Reeves and Gaines counties. The Reeves County assets in the Delaware Basin include 40,182 net acres and 74 producing (52 operated) primarily Wolfbone wells. Total current net production is about 3,300 boe/d of which more than 73% is oil.

Rosetta projects significant growth potential for the area based on an estimated 1,300 gross, or nearly 800 net, well locations targeting the Wolfbone on 40-acre vertical well spacing. The company estimates total net risked resource potential of 145 MMboe of which 67% is oil and 82% liquids.

Potential upside also exists from further vertical well downspacing and potential horizontal drilling, including the Wolfcamp Formation, none of which currently is included in the resource estimate. The company would be the operator of the majority of the Reeves County assets.

The Gaines County assets in the Midland Basin cover 13,124 net acres and were undelineated at the closing. Potential exists for multiple exploratory opportunities in the area. Laredo's resource estimate for the Permian Basin acquisition excludes potential future resources from the Gaines County acreage.

"This oil-targeted acquisition is an important next step in Rosetta's strategy to pursue new growth opportunities and build our inventory of long-lived, oil-rich resource projects. These assets complement our Eagle Ford properties and are a good fit with the experience and technical knowledge of our operations team," Craddock said. "The addition of new capital project inventory provides competitive options as we prepare to deploy the free cash flow generated by our Eagle Ford assets."

Smaller operators with big plans

Laredo Energy's Permian activities are centered on the eastern side of the basin about 35 miles east of Midland in Glasscock, Howard, Reagan and Sterling counties in Texas. The overall Wolfberry interval, the principal focus of Laredo's drilling activities, is an oil play that also includes a liquids-rich natural gas component. The firm's E&P fairway extends about 20 miles wide and 80 miles long.

Exploration and drilling efforts in the southern half of the acreage block have been centered on the shallower portion of the Wolfberry, including the Spraberry, Dean and Wolfcamp formations; the emphasis in the northern half has been on the deeper intervals, including the Wolfcamp, Cline Shale, Strawn and Atoka formations. Considering the geology and the reservoir extent of each contributing formation, Laredo said it has identified significant potential throughout the total acreage block for the entire Wolfberry interval from the shallow zones to the deepest zones.

The company has expanded its drilling program to include a horizontal component targeting the Cline and Wolfcamp shales. The drilling of the Cline, in the lower Wolfberry, was initiated after extensive technical review that included coring and testing the Cline separately in multiple vertical wells. Laredo said it believes the Cline exhibits similar petrophysical attributes and favorable economics compared to other liquids-rich shale plays operated by other companies, such as in the Eagle Ford and Bakken. The company is in the process of acquiring and processing additional 3-D seismic data to assist in fracture analysis and the definition of the structural component within the Cline.

Resolute Energy's Texas properties were acquired in 2011 and are in Reeves, Howard and Martin counties. In Reeves County in the Delaware Basin, Resolute controls about 28,200 gross (12,800 net) acres, prospective primarily for Wolfbone. In the Midland Basin, the company owns leasehold covering about 11,900 net acres with infill drilling and uphole recompletion potential.

Resolute placed six gross (4.6 net) wells on production late last year, bringing its total producing well count to 203 gross (175.4 net). Additionally, at year-end 2013 there were two gross (1.1 net) wells drilled and waiting on completion and hookup, which are expected to be on production during first-quarter 2014. A continuous drilling program is maintained in the basin, and at the end of the quarter two gross (1.3 net) wells were still drilling. As of year-end 2013, Resolute has 44,100 gross acres (24,700 net) with about 20 MMboe in proved reserves. ■

COMMITTED TO THE LONG-TERM SUCCESS OF YOUR INVESTMENT

Cudd Energy Services (CES) is more than an oil and gas service provider; we are your partner, committed to the optimization of your investment through the complete lifecycle of your well. We approach each project with the long-term health of your assets in mind by delivering integrated solutions personalized to your needs. With a team of experienced engineers and specialists at the helm of each project, you receive unparalleled expertise that you can trust.

Visit us at www.cudd.com for more information.

STIMULATION | COILED TUBING & E-COIL | HYDRAULIC WORKOVER
NITROGEN | INDUSTRIAL NITROGEN | SLICKLINE & BRAIDED LINE | ELECTRIC LINE
WATER MANAGEMENT | SPECIAL SERVICES | WELL CONTROL

CUDD
ENERGY SERVICES

PROVEN EXPERIENCE. TRUSTED RESULTS.
WWW.CUDD.COM

The Permian Pad Paradigm Shift

The move to horizontal drilling of multiple stacked formations from a single well site is revitalizing the Permian Basin.

By Richard Mason
Chief Technical Director, Upstream

The Permian Basin is preparing a warm West Texas welcome for pad drilling and batch completions, the industry's most popular drilling and completion trend.

Pad drilling represents slightly less than half of horizontal wells in the Permian—well below the 70% to 80% market penetration found elsewhere. However, the Permian Basin will serve as a laboratory to fashion the next evolutionary step in the pad drilling movement as operators embrace multiple wells targeting multiple formations from a single well site. Think of a 3-D factory methodically working its way through the earth's crust, harvesting hydrocarbons from a geologic column with 1,200 ft or more in stacked-oil or gas-bearing formations (Figure 1).

That next-step in evolution—targeting multiple stacked formations—is the latest in a long line of innovations following pad drilling's initial debut onshore more than 40 years ago in Alaska. Pad drilling established a foothold in the modern tight formation era in 2004 as a method for drilling directionally to target multiple tight sands lenses in the topographically rugged Piceance Basin and was modeled on practices used on offshore platforms. Subsequently, pad drilling followed tight formation development to the Barnett Shale in Texas and ultimately to the Marcellus Shale.

In its earliest manifestations, pad drilling was a way to drill more wells under federal land use and wildlife regulatory restraints out West. It became a solution to exploit the Barnett Shale in an urbanized environment in North Texas and later gained traction in the Marcellus as operators dealt with sensitive community-related land issues in Pennsylvania.

But in 2012, the modern iteration of pad drilling took an important step forward in the Eagle Ford Shale. Large land parcels allowed operators to build bigger locations and drill multiple horizontal wells from a single well site. In the Eagle Ford, pad drilling evolved from a niche solution to overcome specific regulatory and urban issues into the primary means of extracting full economic value from an oil shale formation.

The Permian iteration will add one more innovation to pad drilling: the ability to access multiple stacked formations horizontally from a single well site. While this concept has been explored in individual plays in Canada and is the focus of experiments in the Denver-Julesburg Basin's Niobrara Shale, the Permian Basin offers the greatest opportunity for a broad-based multitarget regional approach to tight formation hydrocarbon development. This evolution, still in gestation, will allow the process of pad drilling and batch completions to reach full economic blossom in the Permian Basin, providing access to resources in place estimated as high as 75 Bbbl of oil in just the Midland Basin alone.

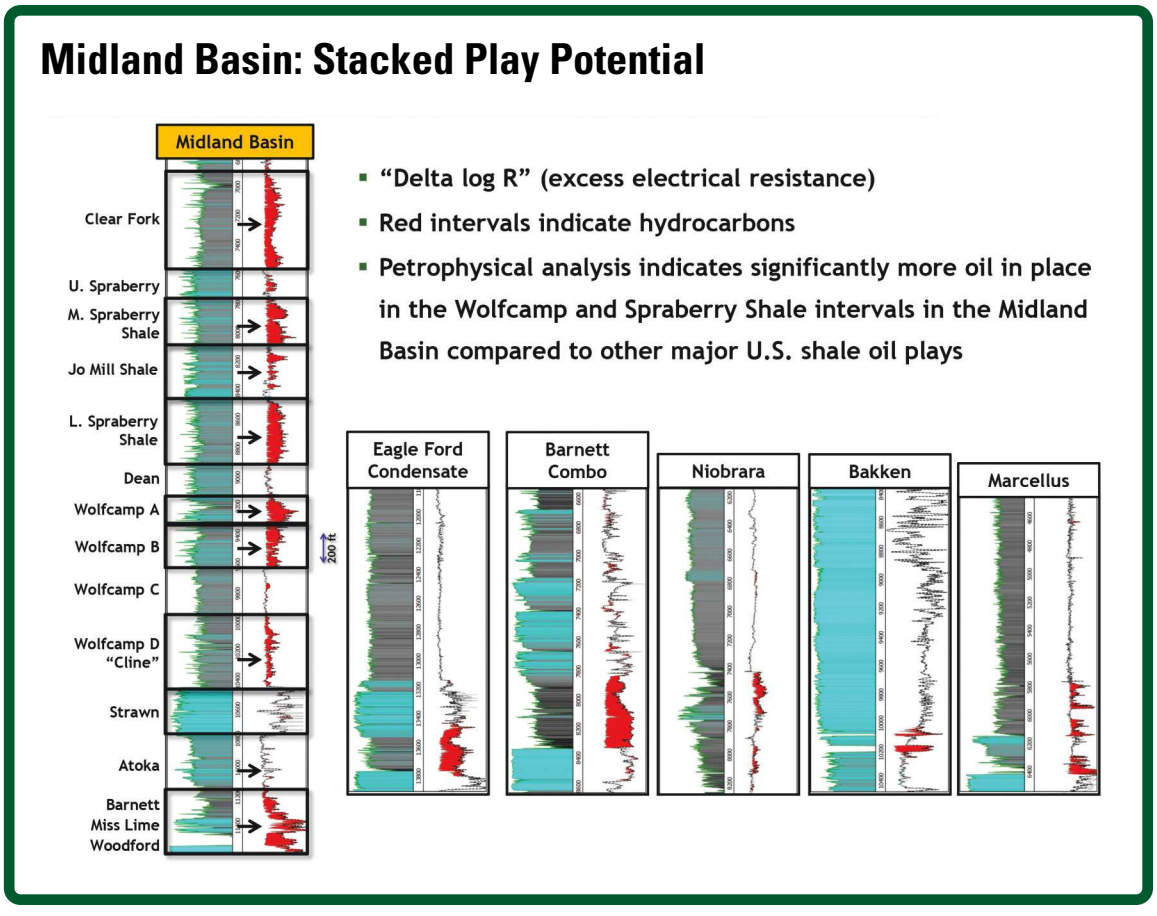


Figure 1. Developmental potential in the Permian Basin spans multiple stacked hydrocarbon-bearing columns. The size of the prize is evident when viewing the stacked geologic column in the Permian with other tight formation plays domestically. *(Image courtesy of Pioneer Natural Resources)*

For perspective, the Eagle Ford Shale has an estimated 30 Bbbl of resource in place.

Pad drilling and batch completions will play the major role in increasing Permian Basin oil production from about 1.5 MMbbl/d of oil in mid-2014 to a range from 2.5 MMbbl/d of oil to 3.2 MMbbl/d of oil in 2025, according to ITG Investment Research, as operators embrace downspacing, locate sweet spots and improve drilling and completion efficiencies. Add in NGL and associated gas and the Permian productive potential tops 3.8 MMboe/d by 2025. The move to pad drilling and batch completions in a stacked-play environment has the potential to double the 30 Bbbl of oil the Permian Basin has produced conventionally over the last nine decades. That's a global needle mover.

Getting there is possible, though not easy. The road ahead assumes stable commodity prices in an unstable geopolitical and economic world. Additionally, the U.S. government will have to approve crude oil exports. Otherwise, a flood of light, sweet crude from North Dakota and Texas will swamp the U.S. refinery complex and negatively rationalize drilling efforts on the basis of lower commodity prices. Finally, operators will have to demonstrate that they can successfully execute a multiwell stacked-lateral program exploiting multiple horizontal targets, each with its own completion idiosyncrasies.

But the game is afoot. The Permian Basin, and the Midland Basin in particular, leads all hydrocarbon plays in value per acre thanks to the stacked-play nature of the region. A May 2014 Credit Suisse report pegs per acreage value in the Midland Basin at $210,615 from a geologic layer cake including the Spraberry, Wolfcamp and vertical Wolfberry (com-

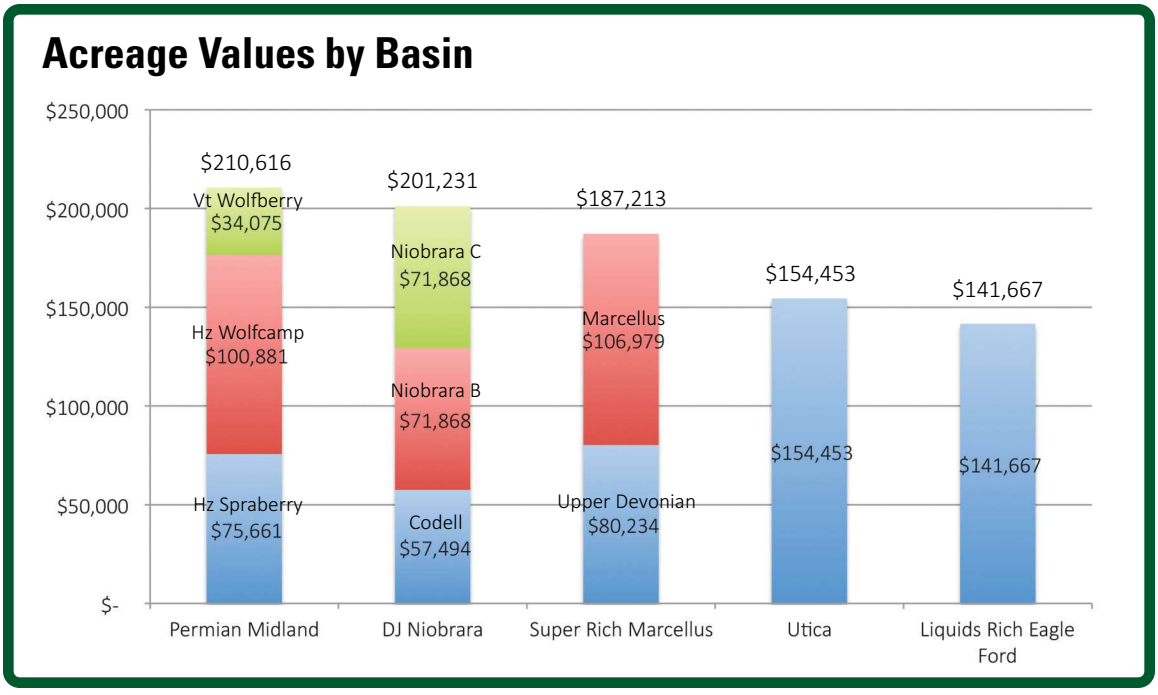


Figure 2. The graph shows estimated per acre values by tight formation play, including breakouts when available by specific formation. At $210,616, the Midland Basin holds significant value for stacked-well development. *(Source: Credit Suisse Research)*

mingled Spraberry/Dean and Wolfcamp formations). This compares to $201,231 in Colorado's stacked Wattenberg/Niobrara play or $187,213 in the super rich Marcellus, the next two leading stacked-play cores domestically (Figure 2).

Nor is Permian potential confined to the Midland Basin. Farther west, across the Central Basin Platform, operators are delineating horizontal targets in the Delaware Basin across 10,000 sq miles and addressing infrastructure constraints including takeaway and processing capability, the learning curve for oilfield services and more prosaic issues such as housing in a sparsely populated area of the country. However, the potential is there. The Delaware Basin's horizontal Bone Spring (a geologic analog to the Midland Basin's Spraberry/Dean formations) provides the Permian Basin's highest rates of return, according to a Howard Weil January 2014 study. Meanwhile, operators are still in the early stages of delineating the Wolfcamp Shale in the Delaware Basin.

As the scope of the stacked horizontal play becomes better understood, Permian Basin oil and gas operators find drilling inventories growing into the tens of thousands of wells regionwide. At current drilling levels, that inventory spans a generation. A Wood Mackenzie presentation at Hart Energy's DUG Permian Conference and Exhibition in May 2014 outlined 35 years of drilling inventory for the Wolfcamp Shale alone along with $115 billion in potential capex.

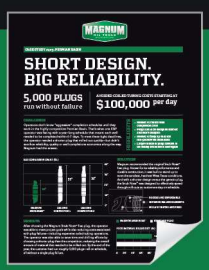
The Permian Basin is still early in delineating and optimizing its tight formation potential. The industry passed an important milestone in fourth-quarter 2013 when the number of rigs drilling horizontal wells first exceeded the number of rigs drilling vertically, according to Baker Hughes Inc. During midsummer 2014, more than 320 rigs were drilling horizontally in the Permian with total regional rig count approaching 550 units. Permian horizontal rig count now represents the largest concentration of horizontal drilling activity in North America with more to come. The Permian Basin represents about 27% of total U.S. rig count, according to Baker Hughes, but only about 20% of horizontal rig count, signifying that the region is still in the earliest innings of the tight formation developmental arc (Figure 3).

ALWAYS PACK A MAGNUM IN THE PERMIAN BASIN

Challenging environments. Tight schedules. An extremely competitive landscape. Only one completion product was designed to handle these Permian-specific challenges more efficiently: the Snub Nose™.

GET A SMARTER COMPLETION TOOL ON YOUR SIDE.

Magnum completion products are designed with specific challenges in mind, so you hit the mark on every project. Learn more about the Snub Nose™ - along with our complete line of tools - at **magnumoiltools.com**



Read the **Snub Nose™** case study now!

Find it on the Snub Nose™ product page of magnumoiltools.com

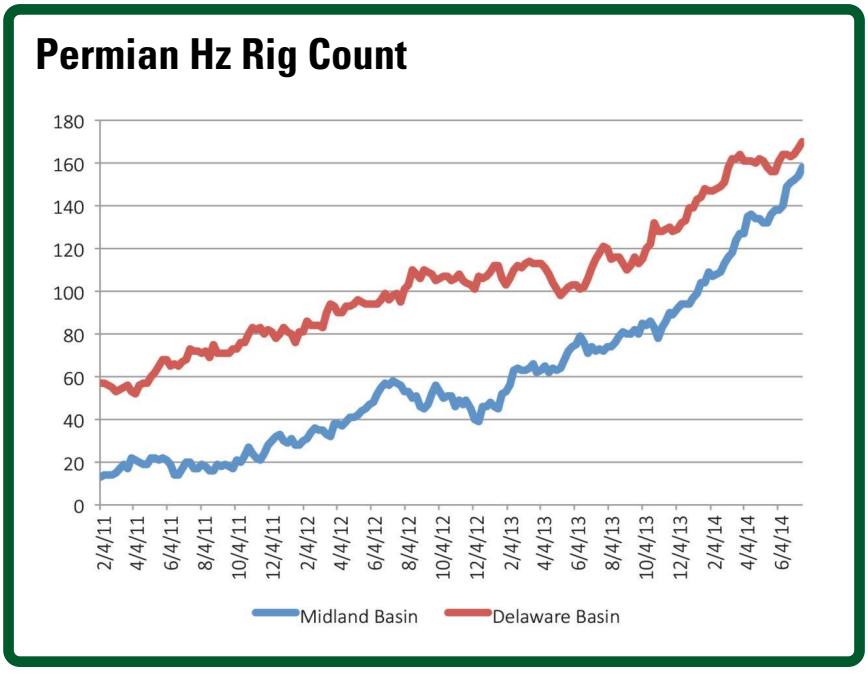


Figure 3. Horizontal exploitation developed critical mass earlier in the Delaware Basin as operators exploited the Bone Spring. However, operators began targeting the horizontal Wolfcamp Shale in both basins with horizontal drilling in 2013, which is evident in the rapid increase in respective rig counts. *(Source: Baker Hughes Inc.)*

As Permian operators de-risk acreage, they are transitioning to the next phase in regional development, which involves moving from the horizontal drilling of individual wells to drilling multiple horizontal wells from a single well site. That evolution should mature during the next two years.

Getting so much better all the time

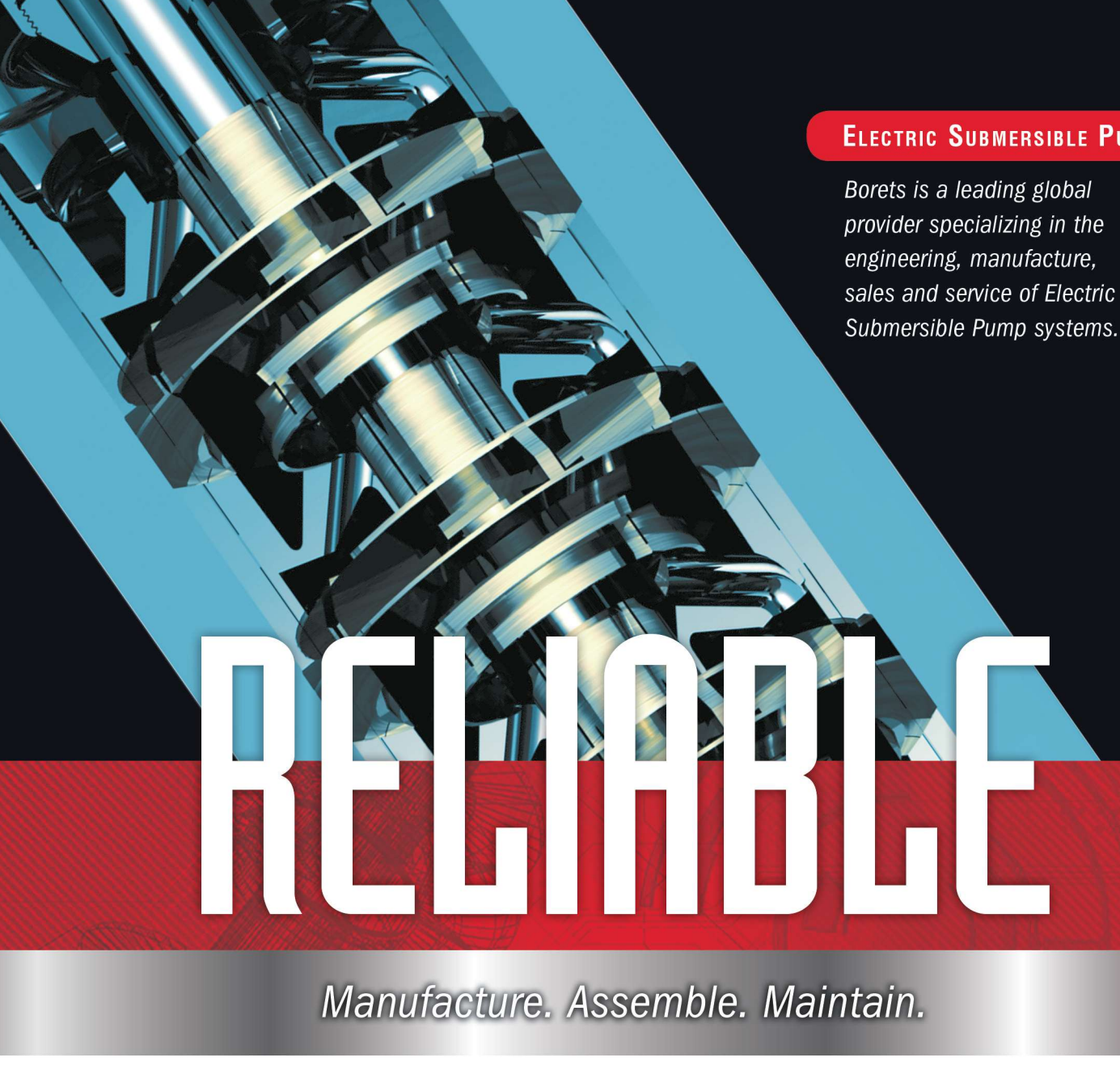
According to a July 2014 RBC Capital Markets review of domestic tight formation markets, Permian drill days, as measured by spud-to-rig release, averaged 30 from third-quarter 2012 through fourth-quarter 2013. During that time the percentage of multiwell pads remained below 30%. As the share of multiwell pads grew toward 50% in mid-2014, drill days dropped to the low 20s. In comparison to other regions, the Permian remains lower in terms of pad marketshare and higher than other regions in terms of spud-to-rig release metrics.

In other words, there is still significant running room on efficiency improvement as the Permian transitions to pad drilling. Multiple case studies abound but are similar to the narrative John Christmann, Apache Corp.'s North American COO, told attendees at Hart Energy's DUG Permian Basin Conference. In its Irion County Wolfcamp Shale program, Apache reduced drilling costs by 26% year-over-year on a dollars-per-foot basis following the move to pad drilling in third-quarter 2012. Time on location dropped from 34 days at the commencement of the program in 2012 to 17 days currently with the company targeting 15 days or fewer.

Apache's Irion County program involves pad drilling, extended laterals and other advanced horizontal drilling techniques. On its Scott Sugg and Clinch leases, Apache drilled five wells with an average 30-day IP of 729 boe/d on an average lateral length of 7,901 ft. The company forecasts average EURs of 667 Mboe from the wells and will run a six-rig, pad drilling program in the play in 2014. Cost per well is estimated at $6.3 million. The company's production has grown from zero in January 2012 to 21,000 boe/d in 27 months on the 95 wells Apache has turned to production.

Farther north, toward the deeper part of the Midland Basin, Pioneer Natural Resources Co. has moved to three-well pads in its northern Spraberry/Wolfcamp program in Midland and Martin counties. Spud to placed-on-production time for the three-well pads is now 145 days. Each well involves an 8,200-ft lateral with total costs under $9 million per well.

Both companies are still early in the transition from optimization to resource harvest via pad drilling and batch completions. The evolution of pad drilling to incorporate multiple stacked plays in resource harvest mode offers potential for stunning recoveries. Laredo Petroleum Inc. has developed a corridor model for harvesting production out of multistacked formations. According to the model, one rig drilling on pads spread across three sections of land can drill 64 total wells accessing four different formations—the Wolfcamp A, B, C and Cline, sometimes referred to as the Wolfcamp D—proving up 44 MMboe, according to a November



Electric Submersible Pumps

Borets is a leading global provider specializing in the engineering, manufacture, sales and service of Electric Submersible Pump systems.

RELIABLE

Manufacture. Assemble. Maintain.

From the **foundry** to the **factory** to your **well**, Borets knows ESPs! **10,000+** systems manufactured annually and an installed base of **45,000+**, our **experience** speaks for itself. ESPs are our business.

Borets develops, manufactures, assembles and maintains ESP systems that enables cost-efficient performance and higher production rates, resulting in lower lifting cost for our customers.

You provide the well, we'll provide the Pump Power.

BORETS™

RELIABLE – FLEXIBLE – INNOVATIVE

www.borets.com/ESP

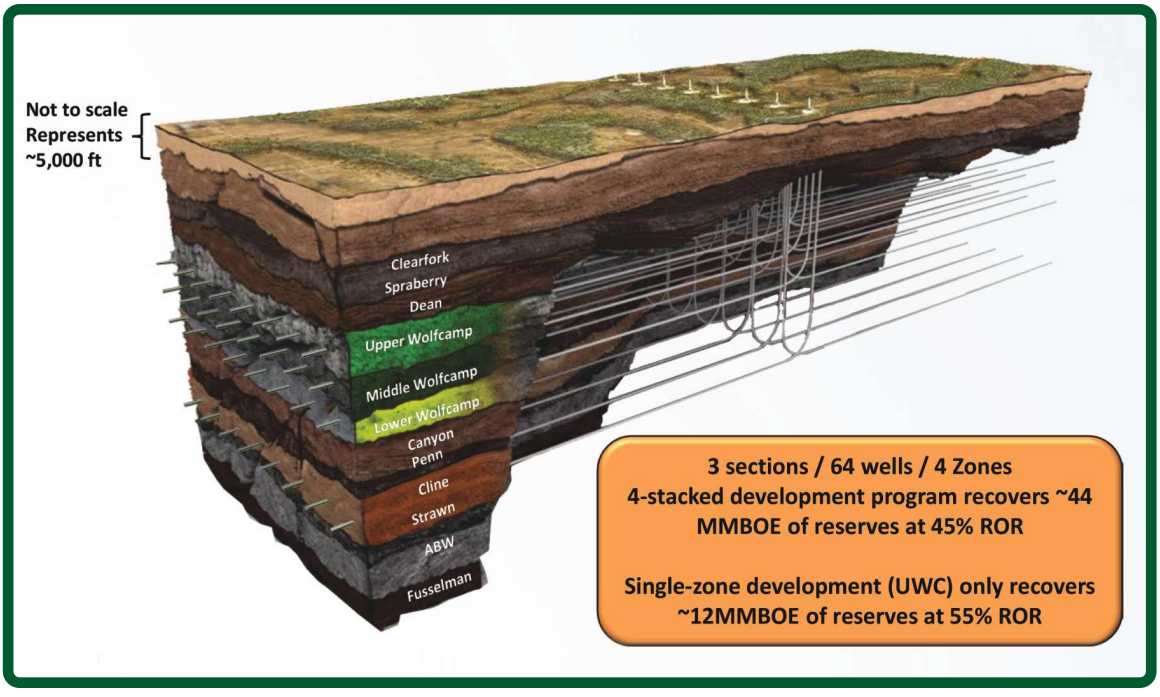


Figure 4. Laredo Petroleum Inc.'s corridor project will access up to four Permian zones horizontally, targeting 44 MMboe in 64 wells from multiple pads across a three-mile corridor in Reagan County, Texas. *(Image courtesy of Laredo Petroleum Inc.)*

2013 ITG Research report. Further hydrocarbon potential is available in the underlying Pennsylvanian-aged Strawn and Atoka formations (Figure 4).

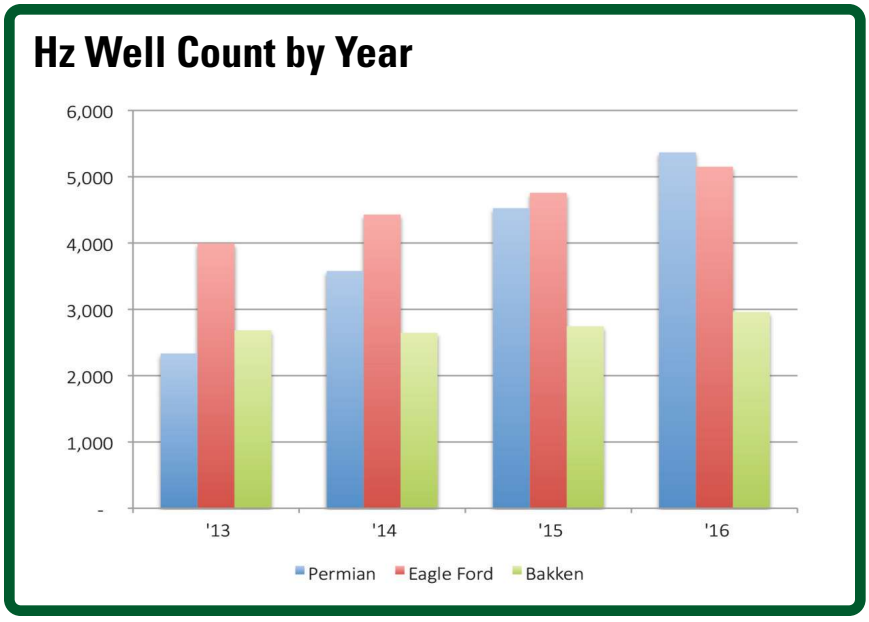


Figure 5. Annual horizontal well count forecasts call for the Permian Basin to overtake the Eagle Ford by 2016. *(Source: RBC Capital Markets)*

Laredo offers a glimpse of the Permian's pad drilling future, and that future might be getting closer. In 2013, the Permian Basin ranked third in annual horizontal well count at 2,335, behind the Eagle Ford (3,995) and the Bakken (2,684), according to a July 2014 RBC Capital Markets study. That same study forecasts the Permian will move into second place in 2014 with 3,580 wells vs. 4,430 in the Eagle Ford and will approach equality with the Eagle Ford in 2015 with 4,525 horizontal wells vs. 4,760 wells in the Eagle Ford (Figure 5).

The scale of Permian momentum is worth noting. On a percentage

Serving the Industry for over FIVE Decades . . .

J-W POWER COMPANY
432-332-0111
www.jwenergy.com

Established field offices conveniently located to serve the Permian Basin with fast, efficient energy solutions.

J-W WIRELINE COMPANY
432-943-4448
www.jwwireline.com

J-W POWER COMPANY
Compression Services

J-W Power Company specializes in designing and fabricating compressors to our customers' unique needs, providing a variety of exceptional and cost-efficient energy services.

We have the resources to deliver what we promise, along with the expertise to service and manage virtually any compression package, regardless of the application and operating condition.

Leasing | Sales | Service | Compression | CNG

J-W WIRELINE COMPANY
Cased-Hole Wireline Services

J-W Wireline Company excels in cased-hole logging and perforating, including multi-well pump-down plug and perforating operations with radio frequency safe equipment capabilities.

We deliver a broad expertise of quality services and customer satisfaction, while focusing on safety, professional care and cost efficiency.

Logging | Perforating | Slickline | TCP

basis, the pace of Permian horizontal well growth leads the domestic tight formation sector at 53% in 2014 compared to 2013 and will lead again in 2015 with additional growth of 26%. While most domestic basins are flattening at the top of the development curve, the Permian is forecast to climb through 2015, according to the RBC Capital report. Sometime in 2016, the Permian Basin will lead the domestic market in the highest number of completed horizontal wells on a quarterly basis. If the Permian mirrors other markets, more than 70% of those wells will be drilled on pads.

Batching it

The pad drilling and batch completions concept involves multiple features. Typically, an initial well is drilled to capture acreage. Afterward operators return to the original well site to drill an additional one to three horizontal wells. In today's model, a finished well site often hosts four wells with two sets of opposing parallel laterals, though that number varies due to lease configurations or other issues. The number of wells per pad tends to be higher in gassier plays vs. oil shales, which traditionally feature four wells per pad.

While the number of wells per pad is small in the Permian—often no more than two currently—the region will see that average ultimately mimic numbers found in oil shale plays like the Eagle Ford or Bakken as the pad drilling transition unfolds. However, the stacked nature of the Permian suggests well numbers per pad might grow into multiples of the four-well model that currently dominates the market.

Pad drilling and batch completions provide operators a number of ways to approach a multiwell target from a single well site. These include rig specialization or the use of two rigs to drill a well in which a smaller unit drills the vertical portion of one or more wellbores followed by a specialized horizontal rig, which is brought in afterward to drill the horizontal laterals. In other cases, operators employ a single rig with walking capabilities to move from well to well on the pad site.

Similarly, there are varying ways to complete horizontal laterals in batch mode. Zipper fracks, or fracture stimulating parallel stages in alternating stair-step fashion along two horizontal well bores, represented two-thirds of horizontal completions in the Permian in June 2014, according to Hart Energy telephone surveys of operators and service providers. Zipper fracks increase efficiency by making better use of downtime during the completion process and increase completion effectiveness by generating a larger stimulated reservoir volume (SRV). In theory, this leads to greater hydrocarbon recovery.

Operators also fracture stimulate individual laterals with coiled tubing (CT) units. The latter are becoming more common in the Permian and feature more stages, smaller in size. CT completions work well with laterals less than 5,000 ft in length.

Ultimately, it's important to view pad drilling and batch completions holistically or as an interwoven series of drilling, completion and processing practices that produce incremental individual efficiencies through standardizing operations and facilities, aggregating processes such as water procurement, transportation and flowback, automation, and choreographed scheduling for services, equipment and bulk commodities such as sand or water. Added together, incremental individual efficiencies in pad drilling and batch completion operations can compound into significant timesavings for the process and generate cost reductions per well as high as 20% once a program takes hold.

As demand increases, prices rise

One poorly understood impact of the transition to pad drilling in the Permian Basin is its impact on the supply of oilfield services nationally. Recently, the supply and demand balance for pressure pumping services flipped to a balanced market from an oversupplied market following the massive capacity buildout in 2011 to 2012 (coupled with the 2012 collapse in natural gas prices).

Service providers across the U.S. have been relocating pressure pumping equipment to meet high operator demand in the Permian, removing the surplus from the exporting regions. Equipment rotating into the Permian has boosted the installed level of hydraulic horsepower (HHP) to 2.4 million HHP in June 2014 vs. 2 million HHP at year-end 2013. Additionally, stronger demand for pressure pumping services is generating higher utilization for previously underutilized equipment as contractors add crews to create additional pressure pumping fleets.

Fracturing

Powered With Natural Gas

DUAL FUEL

Experienced Innovative Horizontal Hydraulic Fracturing

Fracturing
Cementing
Acidizing

Director of Sales
Jeff Wilkinson
817.688.8738
Jeff.Wilkinson@univpp.com

West Texas – Midland
Mark Acklin, Sales Manager
432.238.6880
Mark.Acklin@univpp.com

North Texas & South Texas
Harry Littleton, Sales Manager
940.389.4999
Harry.Littleton@univpp.com

UNIVERSAL
PRESSURE PUMPING, INC.

www.universalpressurepumping.com

Consequently, pricing for pressure pumping services reversed a three-year decline and has moved up 5% to 10% since the first of the year, according to Hart Energy telephone surveys. In addition, well stimulation companies are beginning to buy more pumping equipment to expand capacity and to meet growing demand.

Pad drilling and batch completions will tighten the market further. Previously a frack crew was on location for one week, completing a single lateral and up to 25 stages. As the transition to pad drilling occurs, the Permian will reflect more mature markets where crews are on location for three to four weeks at a time, completing 125 to 150 individual stages spread across multiple laterals. This essentially removes equipment from the market through utilization even as demand for services grows, further tightening the domestic well stimulation market.

As the batch completion process spreads, operators are experimenting with different methods to capture hydrocarbons. The Permian has seen the arrival of the upsized frack in which operators push lateral length when acreage availability permits and add more stages spaced more closely together, typically between 200 ft and 300 ft per stage. Operators also increase the volume of proppant per stage, typically doubling traditional volumes, but sometimes increasing proppant volume by a factor of four or five times traditional levels. That proppant finds its way toward SRV through more perforation clusters per stage. Variations on the technique include clustering stages in areas that feature the most promising rock. The result has been a breakthrough in IP metrics. It is routine for 30-day IPs in upsized fracks to exceed 1,000 boe/d and sometimes exceed 2,000 boe/d in both the Midland and Delaware basins.

Operators also are experimenting with 100-mesh sand in massive slickwater fracks as part of the upsized methodology. Upsized fracks include both slickwater and hybrid treatments involving crosslink gels. Operators demonstrate a variety of proppant preferences across grades, although greater use of 100-mesh sand in slickwater treatments is a developing trend in 2014. Imagine sprinkling 120 tons of talcum powder or more per stage. Now imagine doing that a couple dozen times in a lateral—and 100 times or more on a multiwell pad. That image illustrates the greater downhole intensity that the industry will witness in the transition to pad drilling and batch completions.

Examples of upsized frack testing include Cimarex Energy Inc., which has 13,700 net acres prospective for the Avalon Shale in the Delaware Basin of West Texas and eastern New Mexico. The company is employing upsized fracture stimulation on a potential 20-well horizontal program in 2014. To date, the company has identified more than 200 locations prospective for the Avalon Shale, or an eight- to 10-year drilling inventory.

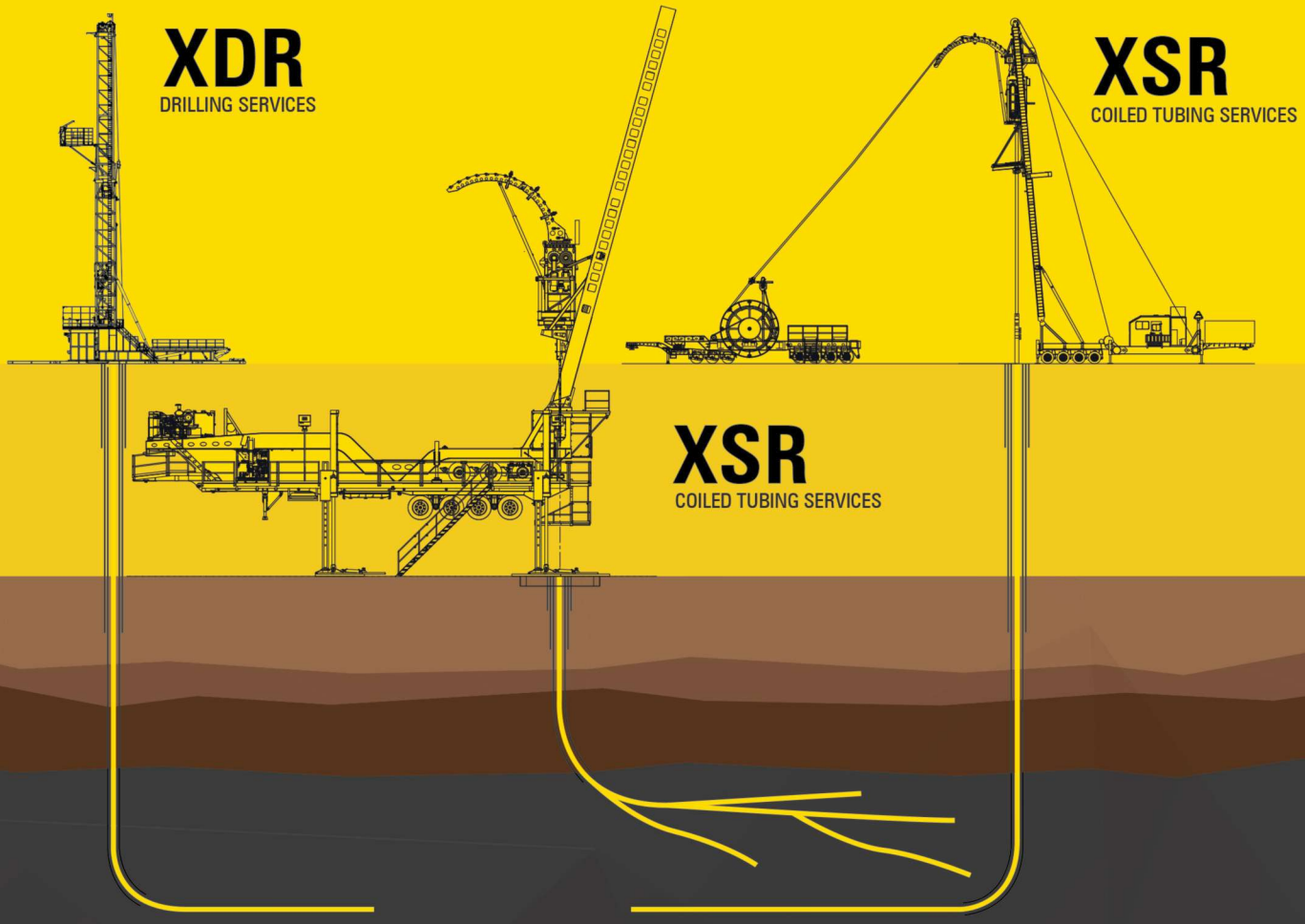
Farther west across the Delaware Basin, Cimarex has drilled 47 Wolfcamp Shale wells on its acreage in Culberson County, Texas. Until last year, most wells entailed 4,500-ft laterals with 10 to 12 frack stages. In 2014, Cimarex is adding more stages and proppant vs. traditional completion methods. Previously, the company used 4 MMlb of sand in 12 stages, including 400 Mlb of 100-mesh sand, pumping at a rate of 100 bbl/min, according to a presentation the company made in March 2014 at the Howard Weil Energy Conference in New Orleans. The company's upsized frack design employs 6 MMlb of sand in 20 stages, including 2 MMlb of 100-mesh sand, and is pumped at a slower rate of 40 bbl/min to 60 bbl/min.

"We put a well into the [Wolfcamp] A interval, and we used one of these upsized fracks, a 20-stage frack, and got ourselves a 1,250 boe/d 30-day average completion," Joseph R. Albi, COO at Cimarex, told attendees at the Howard Weil Conference.

The company subsequently deployed the upsized frack methodology to the lower Woflcamp D interval.

"Our first well out of the shoot: 1,520 boe/d," Albi said. That represented a 30% uplift in production and created favorable drilling economics, creating additional inventory. The company next deployed the upsized frack concept using a 10,000-ft lateral in the Wolfcamp D bench. "We got ourselves a 2,800 boe/d well, [which is] nearly double the rate we saw for the 4,500-ft completion," Albi said. The lateral produced a commodity mix that was 40% gas, 27% oil and 33% NGL.

The company is now at work on a stacked-lateral test of the Wolfcamp Shale, a harbinger of how pad



NEW BENCHMARKS. NO BOUNDARIES.

REDEFINING WHAT'S POSSIBLE IN DRILLING, COMPLETIONS & RE-ENTRY

To find out how our record-breaking performance can improve your production, contact us at sales@xtremecoil.com or call 281-994-4600 (U.S.) or 403-262-9500 (Canada).

www.xtremecoil.com

XTREME
DRILLING AND COIL SERVICES

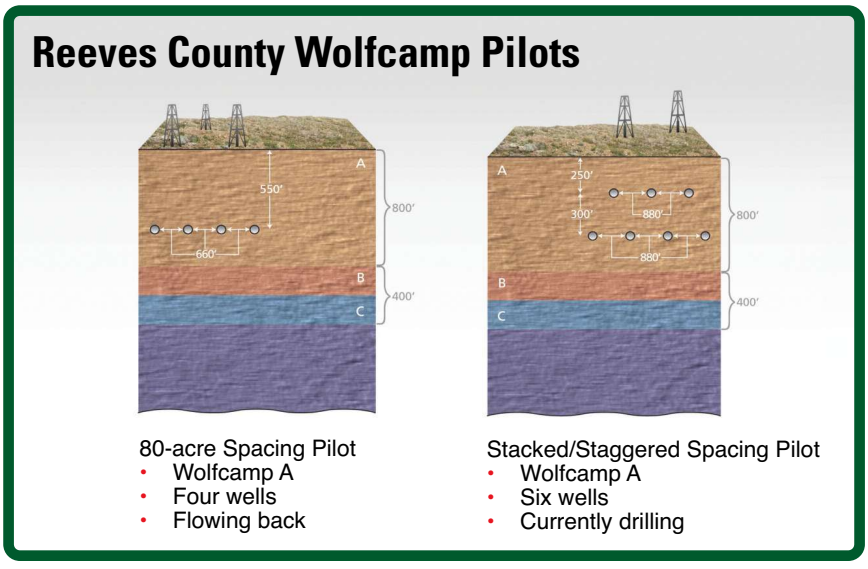


Figure 6. Cimarex Energy Inc. is conducting a six-well pilot test in Reeves County, Texas, involving both downspacing between laterals and stacked-lateral exploitation of the Wolfcamp Shale A bench in the Delaware Basin. *(Image courtesy of Cimarex Energy Inc.)*

drilling and batch completions will alter the Permian's growth trajectory. Cimarex will drill two stacked laterals into the C and D sections of the Wolfcamp Shale and complete both together to test for interference. The company also is conducting two pilot tests in Reeves County, Texas, including one targeting the upper A interval with three laterals and three additional laterals targeting the lower A interval (Figure 6).

The upsized frack offers both greater production and a slower decline rate. The first upsized fracture stimulation job added $700,000 to well costs vs. the traditional $8 million on a 4,500-ft lateral with 10 to 12 stages. However, the rate of return moved from 30% pretax on the traditional approach to 77% on the upsized frack methodology, Albi said.

Exploiting stacked formations

Stacked laterals is where the story gets interesting. The Permian and its two major sub-basins, the Midland and Delaware, feature eight identifiable formations eligible for fracture stimulation—possibly as many as 13—spread across 85,000 sq miles. While the Eagle Ford or Bakken might have better rock in a single formation, the Permian offers many layers of access to rock that's good enough to yield hydrocarbons economically.

So the Permian should be viewed not only in terms of its hydrocarbon potential but as the next big thing after production in the Eagle Ford and Bakken peak later this decade. Think of the Permian as a factory mining operation that uses a small surface footprint to extract energy from multiple downhole zones. An individual acre essentially turns into a multiple of four or five times actual surface size in inventory. This kind of extraction provides multiple opportunities to capture efficiencies, reducing cost per barrel and breakeven price. While Permian rock productivity might not match sweet spots in the Eagle Ford or Bakken in terms of original oil in place for a specific reservoir, it does exceed both shale plays in terms of potential volume. It also means, should commodity prices fall, that fieldwork can continue at a lower price deck.

So how close is the Permian to realizing that potential? One clue is found in the flurry of upstream energy IPOs that energized the energy equity markets after August 2013. Six of seven IPOs were centered on the Permian and Appalachian basins. Two attributes made these IPOs unique vs. traditional public offerings. First, the overwhelming majority were single-basin companies, in some cases with a focus on just a couple counties in West Texas or southwest Pennsylvania. Three of the seven (Athlon Energy Inc., Parsley Energy Inc. and RSP Permian Inc.) were Permian-focused companies. All have performed above peers, both in stock price appreciation, but more importantly in execution, with several companies demonstrating best-in-class well performance in comparison with neighbors.

That leads to the second characteristic. These are companies often run by young management teams with a decade or more experience from other companies, sometimes in EOR projects. Some teams originated as a result of consolidation. Others began as a way to take on farm-outs from companies with large acreage positions and an inability to fully develop inventory. All have very competent technical staffs that developed expertise typically from vertical drilling and fracture stimulating multiple

Forum has assembled some of the most well-known brands in the industry to offer an integrated package of innovative products to customers worldwide. But, at the end of the day, we know that it's not about the products we provide. It's about the solutions you need. We're ready to hear about the challenges you face and how we can help you tackle them.

Talk to us at **f-e-t.com/yourforum**

It's your Forum.
Let's talk.

Subsea Technologies

Well Construction & Completion Tools

Valve Solutions

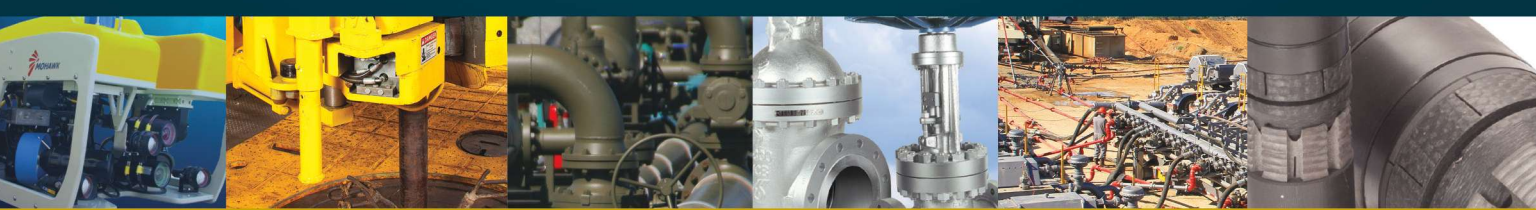
Drilling Technologies

Surface Production & Process Equipment

Stimulation & Intervention Products

FORUM™
ENERGY TECHNOLOGIES

Smart Solutions. Powerful Products.



To learn more about our exceptional products and services, visit us at f-e-t.com

formations. All are now turning from vertical to horizontal completions.

Although repeatability is the most often used term when it comes to resource plays, the technical teams at these high-performing startups treat each well as an individual unit, tailoring completion techniques to specific formations. That versatility results in high-performing wells in comparison to peers. It is crucial information for optimizing the transition from fracture stimulating multiple vertically stacked formations into fracture stimulating individual formations in a stacked-play horizontal program.

Of note, these new startups also have extensive experience in the Wolfberry play, which came to life over the last decade when operators began drilling vertically through the Spraberry and Dean formations into the Wolfcamp Shale. Operators fracture stimulated multiple targets and commingled production. Several companies, such as Pioneer Natural Resources Co. and Athlon Energy Inc., took the process a step farther, extending vertical wellbores deeper and testing underlying Pennsylvanian or Mississippian-aged formations such as the Atoka and Mississippi Lime.

In the case of the Forth Worth, Texas-based Athlon, drilling and completion expertise was essential as the company sought to capture acreage through production after its launch in 2010. The company gained expertise drilling vertical Wolfberry wells by tailoring its completion recipe to each individual well. In general, Athlon employed larger proppant volume in upsized slickwater fracks, larger casing, additional stages and more perforation clusters. Boosted by private-equity cash infusions from Apollo Global Management, Athlon began acquiring acreage and fine-tuning its operational expertise in the field. In 2013, the company began generating substantial cash flow and more liquidity as rates of return increased to 45% in the western Midland Basin and to 35% in the shallower eastern Midland Basin.

Additionally, the rate of return for horizontal drilling started exceeding return rates from vertical wells in 2013 as the horizontal Wolfcamp play moved north from the lower Midland Basin into the deeper central basin core. ITG Research, for example, finds average recoveries of 70 boe/d per 1,000 ft of lateral at an average 6,100 ft of true vertical depth in the southeast Midland Basin, where the horizontal Wolfcamp play began in 2010, to 155 boe/d per 1,000 ft of lateral at 9,400 ft of true vertical depth in the central Midland Basin in 2013.

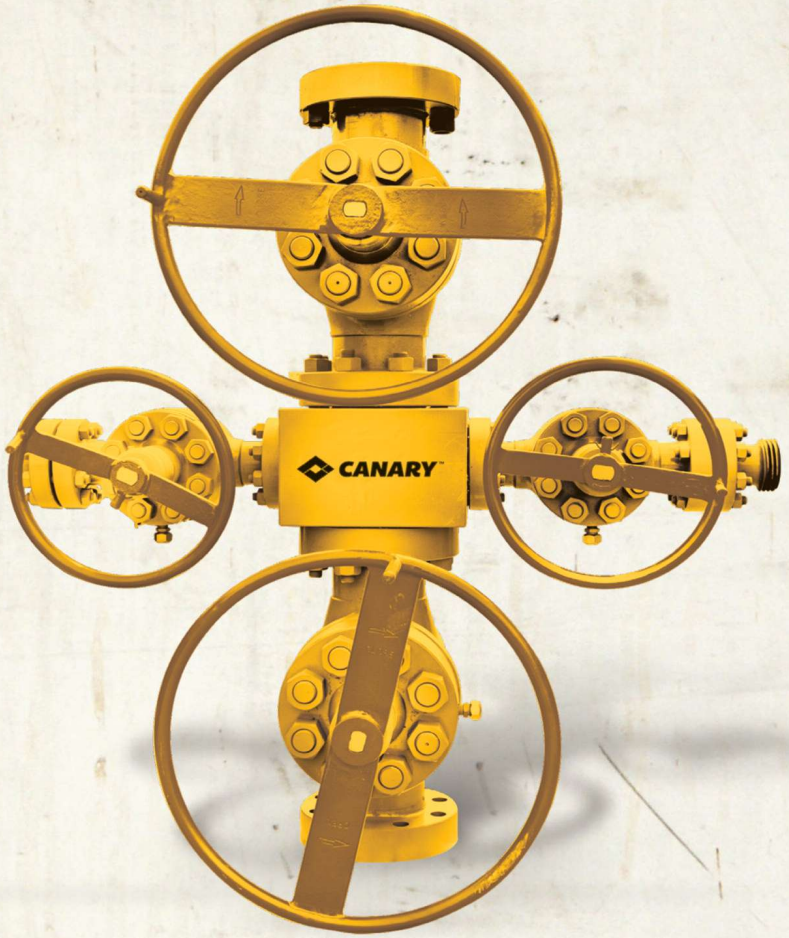
Several of those higher producing wells are coming on extended laterals in the vicinity of Athlon's core acreage in Howard County, Texas. Consequently, Athlon is transitioning its largely vertical program to horizontal tests. The company has $725 million budgeted for capex in 2014. To date, the company's technical team has fracture stimulated more than 3,500 stages on 350 vertical Wolfberry wells. The company released data on its first five horizontal tests in second-quarter 2012. All averaged return rates exceeded 85%. Meanwhile, the company has spent $973 million on six acquisitions in 2014 and now has 134,000 net acres and an expanding Midland Basin drilling inventory.

Athlon is one case study of many. The ability to acquire land, execute on exploitation and fine-tune the drilling and completion process into top tier performance might represent early examples of the industry on the threshold of a new era in pad drilling and batch completions.

When RSP Permian Inc. paid $259 million for 6,552 net acres in July 2014 in Glasscock County, Texas, the deal looked expensive. Removing production of 1,100 boe/d from the transaction still resulted in a price of $29,000 per acre. However, the property has four horizontal targets, including the Spraberry, Wolfcamp A and B benches and the Wolfcamp D, or Cline. That stacked-play potential turns 6,650 surface acres into 19,370 prospective acres through stacked horizontal development and reduces the price to roughly $9,950 per acre. RSP cited potential resource in place at 125 MMboe. Currently one rig is drilling vertically on the acreage. At 20-acre spacing, the acreage provides an inventory of 264 vertical wells. RSP will begin horizontal exploitation of the parcel in 2015 with an inventory of 156 horizontal targets spread across four formations.

Even in a market of $100 oil and record equity prices, the transition to pad drilling and batch completions on multistacked formations suggests a paradigm shift is at hand in the Permian Basin. ■

THE OILFIELD IS UNFORGIVING



IT'S NO PLACE FOR EQUIPMENT THAT CAN'T TAKE PUNISHMENT.

Canary is constantly innovating new products and equipment, while fine-tuning oilfield services to take advantage of new trends in technology, efficiency, and safety. With locations in every major shale play, Canary locally builds reliable, high-quality wellheads that ensure maximum production and profitability for America's largest energy firms.

CANARY™

UNLEASHING AMERICA'S ENERGY

WELLHEADS ◆ FRAC EQUIPMENT ◆ PRODUCTION SERVICES ◆ MANUFACTURING

CANARYUSA.COM

Wolfcamp Boosting Operators' Outlook

Stacked pay zones in the Permian Basin are the gift that keeps on giving as billions of dollars develop the region.

By Travis E. Poling
Contributing Editor

When it comes to oil and gas resources in the Permian Basin—to modify a tried and true ad slogan—they're stacked deep, but they're not selling them cheap.

The same technology that has made shale plays, such as the Eagle Ford, Bakken and Utica shales, hot areas for oil and gas production has given new life to even wider areas of the well-established Permian Basin, a 250-mile by 300-mile area of West Texas and the southeastern portion of New Mexico.

The play, centered in the Midland-area of West Texas, has become the largest shale opportunity in the U.S. by far.

Favorable pricing and access to liquids-rich reserves, particularly in several layers of Wolfcamp and Bone Springs formations, have drawn billions of dollars in investment into horizontal drilling and hydraulic fracturing.

While some companies are standing fast on acreage they have held for years and are now taking advantage of liquids-rich shale with horizontal drilling and better technology, properties have become chess pieces in the wider emerging shale plays nationwide.

H&P's skinner and motor man Mark Ingelharte (right) handles pipe on RSP Permian's Crossbar Ranch #3025H. The Wolfcamp B well will have a total measured depth of 17,200 ft with a 7,500-ft lateral; it is the second of four planned wells targeting different zones on the pad. *(Photo by Tom Fox, courtesy of Hart Energy's* Oil and Gas Investor*)*

Acreage in the Permian Basin has been in play, with some companies selling a portion of their holdings to capitalize horizontal drilling in what they consider more promising areas of the shale, while others, such as Chesapeake Energy, left the play entirely with a sale to Shell in 2012.

Whiting Petroleum Corp., once considered a solid player in the Permian, sold its acreage there in October 2013 to focus attention on northern shale plays such as the Williston Basin and the Niobrara region of the Denver-Julesburg Basin. Comstock Resources Inc. divested in West Texas in early 2013 with an $811 million sale to Rosetta Resources Inc. and turned its focus to the Eagle Ford Shale in South Texas and plays in Mississippi and Louisiana.

Another major player to move out of the Permian is Range Resources, which has been amassing assets in the Appalachian region. In June, the company completed a deal to trade 73,000 net acres and 900 producing Permian wells to EQT Corp. in exchange for 138,000 net acres, $145 million in cash and remaining interest in a gathering system in the Nora Field of Virginia.

Much of the early growth was driven by smaller, more agile companies, but giant, worldwide energy firms with legacy holdings in the region have returned to leverage their acreage for a better bottom line.

For example, ConocoPhillips has begun a horizontal drilling program in the most promising parts of its long-held 1 million acres in the Permian. Chevron is opening a $150 million regional headquarters in Midland and has teamed up in a joint development agreement with Cimarex for development of 104,000 acres with a heavy focus on Wolfcamp drilling.

Of the many formations in the broad Permian Basin, six are responsible for most of the surge in crude oil production, according to a July report from the U.S. Energy Information Administration (EIA).

Thanks to the Spraberry, Wolfcamp, Bone Spring, Glorieta, Yeso and Delaware formations, the region has become the most prolific oil-producing area in the country and was responsible for 18% of U.S. crude oil production in 2013, according to the EIA. Three-quarters of the increase came from the pay dirt of the first three of the six main formations, the EIA said, and most companies in the region are focusing their drilling programs on those three areas.

The Wolfcamp Formation, with several defined upper and lower levels A through D, runs underneath the whole region. IP rates from Wolfcamp, Spraberry and Bone Springs have been comparable to the already-hot Bakken and Eagle Ford Shale, the EIA reported.

The Independent Petroleum Association of America (IPAA) dubbed the region "the Imperishable Permian Basin" in a report and said more than one-quarter of U.S. drilling rig activity is now in that region thanks to operators flooding in since 2010.

"One key [to unlocking the once uneconomic reserves] has been finding the right technological approach with the ability to take advantage of the multiple productive zones, both conventional and unconventional, in the same well," the IPAA report observed.

The industry organization also cautioned that technology use and development were key to continuing profitable development in a responsible manner. "The industry must continue to improve drilling and completion efficiencies, management of water use, optimal staffing of operations and cost reduction in a region with a long history of natural gas production, while also remaining sensitive to impacts on the local communities."

Key Players

Anadarko Petroleum Corp.

- *245,000 net acres in the Permian Basin*
- *More than 80 well completions planned for 2014*

Anadarko Petroleum, a worldwide E&P company based in The Woodlands, Texas, has been operating in West Texas for three decades, but it took horizontal drilling and hydraulic fracturing techniques to free up the potential of the once impenetrable Wolfcamp Shale.

The company now has an ambitious program of drilling more than 80 wells with eight to 10 rigs in 2014, and more than 1,000 horizontal drilling sites have been identified for future development, according to a company presentation to investors at the UBS Global Oil and Gas Conference in May.

Production in the Permian's Delaware Basin for Anadarko is coming from the Bone Spring and upper and lower Wolfcamp formations in Ward, Reeves and Loving counties of West Texas with liquids composition at greater than 85% in the oil-rich area of the play.

Net sales volume in the second quarter for Anadarko's Delaware Basin operations averaged about 27,000 boe/d, according to an operations report from the company. Liquids accounted for 18,000 bbl/d, representing an 89% improvement over the same period in 2013.

As of June 30, Anadarko has spudded 63 wells in the Wolfcamp and was producing from 32, primarily in the Wolfcamp A bench. Initial testing in the upper and lower reaches of the Wolfcamp B bench is ongoing.

"The company is testing spacing, lateral lengths and completion designs with four operated Wolfcamp rigs within the high-confidence area of the play," the company reported in its second-quarter operations summary. "Anadarko expects to use data generated from these activities to design a development program. Another four operated Wolfcamp rigs continue to test acreage outside of the identified high-confidence area. Based upon the strong initial 30-day gross-processed production rates ... the company is very excited about the expanding opportunity set in this emerging oil play."

Apache Corp.

- *3.3 million gross acres in the Permian Basin*
- *Operating 24 horizontal and 13 vertical drilling rigs in the region*

Apache is one of the largest operators in the Permian Basin with the Wolfcamp Formation being one of the top producing areas for the company alongside the Bone Springs and Yeso regions.

Permian production at the end of second-quarter 2014 was 155,244 boe/d, up by 27,000 boe/d from the same quarter last year, according to the company's second-quarter operational update. Oil production was 90,536 bbl/d, up from 68,811 at the end of the quarter last year.

"Record-setting performance by our Permian region continues to drive strong results for the company," Apache Chairman and CEO G. Steven Farris said in a late July news release commenting on second-quarter 2014.

Apache operates about 13,500 producing wells in 155 Permian fields and is operating 37 rigs there now with 24 dedicated to horizontal drilling. In the second quarter alone, the company drilled 74 horizontal and 90 vertical wells in the targeted regions.

Of those wells drilled, 37 were in the Wolfcamp Shale in Irion, Reagan and Upton counties. The company reported that it drilled 15 wells to 1.5-mile lateral lengths and four at 2 miles in the upper and lower Wolfcamp in Irion County's Barnhart area.

Reagan County Wolfcamp wells in the Southern Midland Basin drilled in the second quarter showed strong IPs including one at a rate of 1,184 boe/d and another at 812 boe/d.

In the Midland Vertical area, the company is seeing strong Wolfwood results, partly because of a combination of Strawn and Wolfcamp Formation potential. The company also is active in the Cline Shale, the Central Basin Platform and the Northwest Shelf in New Mexico.

Drilling also continues on acreage in the Delaware Basin, where Bone Springs and Wolfcamp formations are being tapped.

Approach Resources Inc.

- *138,000 net acres in Crocket and Schleicher counties*
- *Targeting Wolfcamp A, B and C benches through 2,000 potential horizontal drilling sites*

As one of the earliest players doing horizontal drilling in the Wolfcamp Shale of the Permian Basin, Approach has been pursuing an aggressive drilling program with three rigs drilling horizontal wells in the Wolfcamp A, B and C benches.

In its second-quarter earnings report, the Fort Worth-based company said it planned on drilling 70 horizontal wells in the Permian in 2014. As of early August, the company reported proven reserves of 115 MMboe, of which 99% is in the Permian.

In second-quarter 2014, the company completed 16 horizontal wells, with most in the lower B and C benches of the stacked Wolfcamp play.

"In the second quarter of 2014, Approach reported record production, revenue and our sixth consecutive quarter of record EBITDAX. Notably, since first-quarter 2014, our average daily oil volumes grew by 15%, in line with our expectations, while our average daily gas and NGL volumes grew by 20% and 24%, respectively, exceeding our expec-

Serving the Oil and Gas Industry since 1965.

For almost 50 years Balon has established itself as a leader in valve manufacturing. Our commitment to safety and quality is our legacy. We have built a solid reputation by protecting our customers and the environment. Made in the USA with 100% American components, Balon valves are dependable, durable, and maintenance free. Specify Balon.

Ball Valves

Check Valves

Needle Valves

BALON. VALVES

Tel: 405.677.3321 www.balon.com

tations," said Approach CEO J. Ross Craft in the quarterly earnings statement.

For that reason, the company has adjusted its total 2014 production expectations from 4.79 MMboe to 4.95 MMbbl. About 70% of production is expected to come from liquids, according to the report.

The company boasts one of the lowest drilling, completion and lift costs in the Permian thanks to its early installation of infrastructure in Crockett and Schleicher counties including transfer lines for water and oil, gas-lift lines, water wells, saltwater disposal wells and other equipment to automate the process.

In an investor presentation, the company said it had increased its borrowing base to $450 million and had liquidity of $404 million, which gives Approach capital and financial stability to continue well development in the oil-rich Wolfcamp Shale.

BHP Billiton

- *Announced in October 2013 that it would sell 250,000 acres in the Delaware and Midland basins*
- *Maintaining another 250,000 acres for development*

The Australian mining giant BHP Billiton entered the Permian Basin shale play in 2011 with the acquisition of Petrohawk Energy. By 2013, the company had determined that some areas were not as productive as others and launched the sale of half of its 500,000 acres of holdings including acreage in the Wolfcamp. As of late July, no deal with a buyer had been struck.

The company is focusing its efforts on high-value areas. In a December presentation to investors in Houston, BHP Billiton's Tim Cutt, president for the petroleum and potash units, said the evaluation of the Permian operations "has successfully identified a focus area where


OUR LIFE'S WORK IS THE LIFE OF THE WELL.™
RELIABILITY
POWERED BY
THE PEOPLE
OF
BASIC
APPALACHIAN | ARK-LA-TEX | GULF COAST | MID CONTINENT | PERMIAN BASIN | ROCKY MOUNTAINS
BASIC ENERGY SERVICES
- Well Servicing
- Fluid Services
- Pumping Services
- Contract Drilling
- Rental / Fishing Tools
- Coil Tubing
- Wireline
- Tubing Services
- Snubbing Services
- Water Solutions Services
Ensuring every job is done safely and properly.
At Basic Energy Services, working the safe way is the only way. We empower every team member with a wide range of safety programs, policies and support to ensure all activities are conducted safely and reliably to protect people, property and the environment.
www.basicenergyservices.com
Rated 1st in Total Satisfaction OILFIELD PRODUCTS Customer Satisfaction 2013
Rated 1st in Performance & Reliability OILFIELD PRODUCTS Customer Satisfaction 2013

we are actively pursuing a 100,000 barrel of oil equivalent per day development."

The early stage of that development and the evaluation were expected to lead to a depreciation charge of about $600 million in the fiscal year ended June 30, 2014, Cutt said in a news release after the investor meeting. BHP's operational overview showed capex of $3.9 billion in fiscal year 2013 and $3.6 billion in fiscal year 2014 for the Permian Basin and Eagle Ford Shale combined.

Chevron

- *Largest holder of acreage in the Delaware Basin with 1.3 million acres*
- *More than 480,000 Wolfcamp Shale acres in the Midland Basin*

In May, one of the world's largest energy companies broke with tradition and held its annual shareholder meeting at the Permian Basin Petroleum Museum in Midland, Texas, far from Chevron's California headquarters.

Although the company has been active in the Permian for 88 years, the new oil boom there is increasing the region's importance in Chevron's portfolio. Chevron is the second largest producer in the Permian and is building a $150 million regional headquarters in Midland, the *Odessa American* newspaper reported.

Chevron officials said in a conference call with analysts earlier this year that the company has plans to drill 500 wells in the Permian in 2014, including its first horizontal wells in the Midland Basin.

The company started drilling horizontal wells in the Delaware Basin in 2012 with three rigs operating there by year-end 2013, according to the Chevron website. It also is participating in wells drilled by other operators in the region. In June 2013, to help accelerate its horizontal drilling program, Chevron struck a joint development agreement with Cimarex Energy on 104,000 acres in the Delaware Basin.

At year-end 2013, Chevron had 480,000 acres in the Midland Basin, including 107,000 acres where the company had a nonoperator interest averaging 70%. That included eight drilling rigs and 1,300 wells producing an average of 20,000 boe/d.

On the remaining acreage, Chevron is operator and 97% owner. The company reported eight drilling rigs operating at year-end 2013.

The company continued to ramp up Permian operations in 2014 and reported in its second-quarter earnings presentation that it had 27 active rigs in the Permian with 265 wells drilled year-to-date. That includes Wolfcamp horizontal drilling in the Midland Basin.

Cimarex Energy Co.

- *Developing 104,000 acres in the Delaware Basin with Chevron*
- *Completed 81 Permian Basin wells in first six months of 2014*

Cimarex Energy made capital investments of $964 million in first-half 2014, with 71% sunk into Permian Basin development, the company reported in its second-quarter earnings release on Aug. 5.

With 81 gross Permian wells completed in the first half of the year, 22 additional wells awaiting completion as of June 30, and continued aggressive drilling for the year, Cimarex management issued an outlook of 2014 production reaching 860,000 MMcf/d to 875,000 MMcf/d of gas. Oil volumes by the end of the third quarter are expected to increase 22% to 25% in 2014 from the previous year. The company produced an average of 33,319 bbl/d of oil in the second quarter.

Much of the Permian drilling in the first half of the year was in the Bone Spring formations, all coming in rich in liquids and producing anywhere from 905 boe/d to 1,170 boe/d for 30-day average gross production.

Wolfcamp horizontal wells continue to be a focus for Cimarex with drilling into multiple benches in Culberson, Reeves and Ward counties. In the second quarter, Cimarex completed 26 gross wells with a net of 21 wells in the Wolfcamp Shale. This amount included "four long laterals to the Wolfcamp D in Culberson County," the company said in its earnings release.

Cimarex also is producing from three out of four downspacing pilots it began in the Wolfcamp in 2014.

Part of the activity has been spurred by a major joint development partner in Chevron. In June 2013, Cimarex agreed to jointly develop about 104,000 combined acres in the Delaware Basin in Culberson County.

"Collaborative development of this 'checkerboard' acreage ownership makes perfect sense. Optimal well placement for both Second Bone Spring wells and longer-lateral Wolfcamp Shale tests can now be achieved," Cimarex CEO Tom Jorden said in a news release issued when the deal was struck.

Under the terms of the eight-year agreement, Chevron contributes acreage and about $60 million to gain a half interest in wells drilled on the land in 2013 and in the Triple Crown gas gathering and processing system built by Cimarex.

Clayton Williams Energy Inc.

- *Plans to spend $440 million on exploration and development in 2014, including adding a fourth drilling rig in the Delaware Basin*
- *17 horizontal Wolfcamp A wells*

Midland-based Clayton Williams Energy (CWE) sold 95% of its Andrews County Wolfberry acreage in April 2013 but has been aggressively pursuing its Wolfcamp horizontal exploration and development program in Reeves and Ward counties.

CWE horizontal wells in Reeves County have been averaging about 756 boe/d, with more recent wells producing at higher levels. The company now has 17 horizontal Wolfcamp A wells and was in the process of drilling two Wolfcamp C-bench wells when the company last updated drilling details. The company said it plans to drill additional Wolfcamp C wells in 2014 "to delineate the extent of the Wolfcamp C target over its acreage block," according to information provided to investors on the company website.

In early August, the company issued financial guidance for the year and revised its earlier esti-

Clayton Williams' new pipeline in the Permian Delaware Basin has cut down the need for trucks to move crude oil from the field. Infrastructure in the area has not kept up with demand. *(Images courtesy of Clayton Williams Energy)*

mates on barrels of oil per day downward by 3%. According to the company, that revision "was driven by production shortfalls in certain step-out delineation wells in our Delaware Basin and Eagle Ford Shale plays. We believe the causes of these production shortfalls are isolated and can be corrected through improved completion techniques."

CWE also has opened a new pipeline in the Delaware Basin. "It is most valuable especially in that area, due to the increased activity and lack of infrastructure," said Patti Hollums, director of investor relations for the company. "Since we have it in place, we don't have the need to truck our product, something other operators are having to address currently."

ConocoPhillips Co.

- *1 million net acres in the Permian*
- *29,000 bbl/d of oil production average in 2013*

Although ConocoPhillips didn't provide specific details of its operations when executives laid out financial results for first-half 2014, it did point to exploration and development in the Permian Basin and other unconventional plays as driving growth in the U.S. lower 48 in 2014 and going forward. Other plays cited were the Eagle Ford and Bakken.

At year-end 2013, the company reported its Permian Basin production at 53,000 boe/d, making it the second largest area of production in the continental U.S. for ConocoPhillips, topped only by the South Texas Eagle Ford Shale at 119,000 boe/d.

A company fact sheet on the corporate website said ConocoPhillips holds about 1 million net acres in the Permian and drilled 151 wells in 2013 across several plays in the region. Drilling there in 2014 is focused on the Central Basin Platform, the Eastern Shelf and the Northwest Shelf. Exploration and more drilling were slated for acceleration in 2014 for several unconventional plays in the Delaware Basin.

ConocoPhillips said there is an estimated 1 Bboe in resources available on its legacy leasehold.

X-Frac™ Ball Launcher

When a major operator gives you a testimonial like that, the least you can do is explain.

Our new skid-mounted remote control panel can run two units at a time via pneumatic umbilicals linked to the actuators. Thanks to our quick-connect wellhead connector, you can easily stack two or more units which accommodates six balls per unit.
Powered by a diesel air compressor with nitrogen backup, the unit gives a clear signal when the ball has been dropped. But if there's ever a problem, our optional MS Ball-dropping unit prevents the time-consuming breakdown and reassembly of the unit formerly required to manually override the system.

Add to these benefits the fact that the TEAM Ball Launcher works with any ball-activated system, you may be next to give it a glowing review.

Watch the Video

Learn more at info.teamoiltools.com/ball-launcher

TEAM Oil Tools

Devon Energy expects to grow its Permian Basin oil production by more than 20% during 2014, to average more than 50,000 bbl/d. *(Image courtesy of Devon Energy)*

Devon Energy Corp.

- *1.3 million net acreage in the Permian Basin*
- *140,000 prospective acres in the Delaware Wolfcamp Shale and 117,000 in the Midland-Wolfcamp*

Devon Energy has major investment in the Permian Basin with emphasis on the Wolfcamp Shale, Bone Spring, Delaware and Wolfberry areas with 23 rigs in operation and 2014 plans to drill 350 wells and spend $1.5 billion, according to a company presentation in April at the IPAA Oil and Gas Investment Symposium.

Overall, Devon anticipates an increase of about 20% in oil production in 2014 from the area to more than 50,000 bbl/d, a company spokesman said.

An initial horizontal well in the Ward County portion of the Delaware Wolfcamp Shale produced an average of 950 boe/d in the first 30 days, with about 85% coming from crude oil. Devon has a total of 140,000 acres around it for prospecting.

The Midland-Wolfcamp area also is ripe for exploration, and the company plans to drill a total of 140 wells in that region in 2014, according to the investor presentation.

A 10-rig development in the Midland Basin is showing positive results in the Wolfcamp. That development work is in partnership with Sumitomo.

In the Delaware Basin, Devon is working 12 rigs in Southeast New Mexico and Eddy and Lea counties, mostly in the Bone Spring Formation and Delaware Sand. The Leonard Shale and Wolfcamp also are in the mix for drilling there. Total lease holds by formation in the Delaware total about 500,000 net acres.

After a full assessment of the area, Devon has identified more than 5,000 locations for possible

Delivering Award-Winning, Technology-Driven, Engineered Solutions to the Oil & Gas Industry

WINNER OIL & GAS AWARDS
WATER MANAGEMENT COMPANY OF THE YEAR 2013 Southwest

OIL & GAS AWARDS
WINNER
Rocky Mountain
2013

WINNER OIL & GAS AWARDS
WATER MANAGEMENT COMPANY OF THE YEAR 2012 Northeast

World-Class Pre/Post-Frac Services

Water Transfer, Storage, and Treatment
After-Frac Flow Back and Production Testing
Completion Fluids and Displacement Systems

Focused on Energy.
Dedicated to Service & Safety.

TETRA®

tetratec.com

sales@tetratec.com

drilling—an increase from the previously identified 2,200 sites.

The Oklahoma City-based firm considers the play a low-risk development, because its acreage has been held for years, and modern drilling techniques have opened it for exploration of high-margin liquids from wells with years of future production.

Devon's oil production growth in the Permian grew by 28% in 2013 compared to the previous year, and 2012 growth was 31% over 2011.

Diamondback Energy

- *85,000 net acres in the Midland Basin, pending completion of an acquisition*
- *Running five horizontal rigs with plans to have eight working in the Permian by second-half 2015*

In July, Diamondback agreed to purchase 13,136 net acres with 94 producing wells in the Midland Basin for $538 million. Net production from the producing wells is about 2,173 boe/d as of May, according to a news release.

The pending acquisition would bring Diamondback's Midland Basin holdings to 85,000 net acres. The sellers of the leasehold interests in Glasscock, Midland, Reagan and Upton counties were not disclosed. The deal was expected to close in early September but is subject to due diligence.

In the additional acreage, the company sees prospects for horizontal drilling in the Wolfcamp A, B and D benches as well as the Lower and Middle Spraberry and Clearfork formations.

The pending acquisition "offers a tremendous opportunity for the company [to] develop highly prospective acreage," said Diamondback CEO Travis Stice. "Much of the value in these assets resides in the undeveloped acreage, and ... we believe we can more cost-effectively convert this resource potential into cash flow."

Stice said the acreage could be some of the company's best inventory, including some that offsets Diamondback's Gridiron well.

The company also has confirmed "a new development horizon" with a test of the Lower Spraberry Formation in Upton County.

Diamondback completed 15 wells in second-quarter 2014, including 12 in the Wolfcamp B bench putting the total drilled by the company in that formation in first-half 2014 at 23, according to a July operations update released by the company.

Management said the company expects to complete 18 to 22 wells per quarter for the remainder of 2014 and added a second hydraulic fracturing crew on July 1 to help achieve that goal.

Energen Corp.

- *$1.4 billion in capex and drilling expenditures estimated for 2014, mostly in the Permian Basin*
- *18 net wells drilled in first-half 2014 in the Glasscock County Wolfcamp development*

Wolfcamp was the highlight for Energen's second-quarter earnings release and operations update at the end of July. New tests came in strong, and the liquids-rich shale bench in the company's Permian Basin acreage delivered production that ranged from 78% to 84% oil.

The Birmingham, Ala.-based company reported that it tested five new Wolfcamp exploratory wells in the Permian Basin including a Wolfcamp B bench test in the Delaware Basin region. That test in Ward County showed a 24-hour peak IP of 1,896 boe/d.

The first four Wolfcamp development wells performed above company expectations. Also on tap for this year are two Delaware Wolfcamp wells with 7,500-ft laterals and tests into the Wolfcamp C bench. Lateral lengths of 10,000 ft will be tested in three exploratory Wolfcamp wells in Glasscock County. In all, Energen expects to complete 14 Wolfcamp A, B and C wells in the Delaware by year-end.

In the Midland Basin, the company said it plans to drill 22 exploratory wells, including eight Wolfcamp A wells, five into the B shelf, four in the C, three Cline Formation wells and two in the Lower Spraberry.

EOG Resources

- *Operating in the Midland and Delaware Wolfcamp formations and the Bone Spring Sand and Leonard formations in the Delaware Basin*
- *24 wells in 2014 in the Wolfcamp*

Wolfcamp Shale development for EOG in the Delaware Basin includes 134,000 net acres with an estimated reserve potential across multiple pay targets of 800 MMboe/d. The company has identified

1,100 net drilling locations and said it plans 14 wells in that part of the formation in 2014, according to an Aug. 5 investor presentation packet.

Wolfcamp development for EOG in the Midland Basin plans for 10 wells in 2014. The company anticipates more than 75 years of drilling activity available in the Delaware Wolfcamp and more than 50 years in the Midland Wolfcamp.

In its second-quarter earnings release in August, the company said its four State Apache 57 wells were completed in Reeves County with daily IP rates of 590 bbl/d to 1,600 bbl/d of oil mixed with 200 bbl/d to 460 bbl/d of NGL and 1.3 MMcf/d to 3 MMcf/d of natural gas.

Two wells on the State Harrison Ranch 56 saw daily production of 660 bbl/d to 665 bbl/d of oil and associated NGL and natural gas.

In the Second Bone Spring Sand of the Delaware Basin, EOG has drilled and participated in 16 wells since 2013, with production from each ranging from 500 boe/d to 1,400 boe/d. Nine wells are planned there in 2014 according to the presentation for investors.

The company has 73,000 acres for exploration and development in the Leonard Shale of the Delaware Basin, where it is operating a two-rig operation with about 1,600 sites identified.

EP Energy Corp.

- *$2 billion capital budget in 2014 that includes Wolfcamp, Eagle Ford and Altamong plays*
- *Identified about 3,800 Wolfcamp A, B and C drilling locations on existing acreage*

EP Energy entered the Wolfcamp Shale in 2010 with a 138,000-acre lease on the University of Texas Land System and added offset acreage by acquisition totaling 37,000 net acres in Reagan and Crockett counties in the Southern Midland Basin. The buy in April added about 143 MMboe to the firm's expected reserves.

The Houston-based company said it sees opportunity in the Cline Shale on some of the same acreage.

In second-quarter 2014, EP reported record oil production of 79,000 bbl/d of oil, which was 172% higher than the same quarter last year, according to the company's earnings release Aug. 6.

The company completed 23 wells in the Wolfcamp development areas in the second quarter. A fourth drilling rig was added in the first quarter, which led to production increases in the quarter ending June 30. EP's first Wolfcamp A wells were drilled in second-quarter 2014, and the company expects to announce the results of those wells later in the year.

ExxonMobil

- *Acquired 25,000 additional Midland Basin acres from Linn Energy in a trade through its XTO Energy Inc. subsidiary*
- *300,000 net acres in the Midland Basin*

ExxonMobil has increased its position in the Midland Basin to 300,000 net acres through a trade with Linn Energy. Assets in the Permian now include 100,000 net acres in the northern Wolfcamp core, according to a May news release from the company. The company also picks up another 1,000 acres in the Lea County, New Mexico, portion of the Permian's Delaware Basin.

"This Midland Basin leasehold is in a prolific area where we expect rapid, profitable development of multiple horizons in the Wolfcamp and Spraberry formations," said Randy Cleveland, president of XTO Energy. The company had previously picked up a stake in the liquids-rich part of the Permian through an acquisition from Endeavor Energy Resources.

Overall, the company will have 1.5 million net acres in the Permian with about 90,000 boe/d of production, Cleveland said in the news release. The company added two rigs to develop the Permian holdings in first-quarter 2014 for a total of 10.

Forest Oil

- *Merging with Sabine Oil & Gas*
- *Sold nearly half of its Permian acreage in 2013*

If a deal to merge Forest Oil and Sabine Oil & Gas goes through as planned in fourth-quarter 2014, the company will be a major player in East Texas and the Eagle Ford Shale. It also brings a significant Permian Basin prospect to the deal.

Under the plan, Forest would be run by Sabine executives and shareholders, and Houston-based Sabine would hold 80% of the merged company. While both companies are most active in East and South Texas, Forest owns 68,250 mostly undeveloped acres in the Permian Basin counties of Pecos and Reeves. The company sold 58,200 acres of its

Permian holding to an undisclosed party in the later part of 2013, according to a company news release. Forest executives haven't announced any immediate plans to drill in the Permian.

Laredo Petroleum

- *144,107 net acres in the Midland Basin*
- *Identified proven reserves of 1.6 Bboe in four stacked zones*

In first-half 2014, Laredo Petroleum operated seven horizontal drilling rigs. Five of those were drilling stacked laterals into the various formations from multiple well pads, which company management said is an efficient and cost-effective way to recover the most resources.

The Tulsa, Okla.-based company focused most of its E&P in the Permian Basin.

The company has a $1 billion capital investment plan for 2014. By the end of the first quarter, the company had completed a total of 100 horizontal wells and set a record for total average production per day from the Permian with production of 27,041 boe/d.

"To support the acceleration of the recovery of these resources, we have made significant progress in the buildout of the first of our four initial production corridors. These corridors will facilitate cost-effective development drilling for hundreds of horizontal wells for many years to come," said Laredo Chairman and CEO Randy Foutch in a news release and operational update after the first quarter. "As we build assets that reduce costs in the long term and transition to drilling stacked laterals on multiwell pads, Laredo is truly at an inflection point in our multiyear process to accelerate the full-scale development of our Permian-Garden City asset."

The focus has been on horizontal drilling in the Upper Wolfcamp, Middle Wolfcamp and Cline benches in the company's Permian-Garden City acreage. Laredo said earlier in the year that it expected to complete another 15 to 20 horizontal wells in the second quarter.

In early 2014, Laredo began operating its first production corridor out of several it is developing to send oil and gas off site to move it to the most favorable markets. The pipeline corridors also will move water on and off site.

Linn Energy

- *Acquired Berry Petroleum Co. in December 2013*
- *Traded about 25,000 net acres in the Midland Basin to ExxonMobil for a share in the natural gas Hugoton Field*

Linn Energy gained a greater foothold in the Permian Basin with the acquisition of Berry Petroleum at year-end 2013 but has been leveraging its acreage and production in the hot area to obtain other properties outside the Permian.

In May, Linn said it was trading 25,000 Midland Basin acres primarily in Midland, Martin, Glasscock and Upton counties to ExxonMobil. In return, Linn gets a part interest in the Hugoton natural gas field of Oklahoma and Kansas, where Linn already has a significant presence.

Linn's remaining 30,000 net acres in the Midland Basin with prospective Wolfcamp horizontal drilling is now up for possible trade or sale.

Occidental Petroleum Corp.

- *Occidental accounts for 15% of the oil produced in the Permian Basin*
- *Permian production averaged 150,000 bbl/d of oil between the Permian resource and Permian EOR units*

With 1.9 million net acres in the Permian, Houston-based Occidental is one of the biggest players in the region, where it became active in 2010 in developing plays in the Avalon Shale, Bone Spring, Wolfbone, Wolfcamp, Spraberry, Cline, Wolfberry and Delaware.

Although the company has diversified operations internationally, the Permian development is considered Occidental's flagship asset. In fact, 22% of Occidental's estimated $10.2 billion in 2014 capital spending is targeted to developing assets in the Permian, according to an executive presentation during the Sanford C. Bernstein Strategic Decisions Conference in May.

As the company shifts its focus in the Permian to horizontal drilling in liquids-rich shale, it is forecasting production increases of 13% to 16% in 2014 and more than 20% per year in the future.

"Our Permian resources production comes from about 9,500 gross wells, of which 54% are operated by other producers," the company reported at the

May conference. "On a net basis, we have 4,400 wells of which only 15% are nonoperated. This has given us the opportunity to observe the results achieved by other operators in the basin, learn from those results and optimize our approach to maximize the opportunity set on our acreage."

The company added 200,000 net acres to its Permian holdings in 2013 in its unconventional plays portfolio, bringing total prospective acres there to 1.9 million. Occidental said it has identified about 4,500 drilling locations with a total of more than 1.2 Bbbl net of resource potential.

The company drilled 49 horizontal wells and 286 vertical wells in the Permian in 2012. Estimated 2014 drilling splits the activity with 172 horizontal and 172 vertical wells planned with an average rig count of 21.

In the Midland Basin of the Permian, Occidental drilled 12 horizontal wells into the Wolfcamp B Formation, and production is yielding 91% liquids from those wells. In the Texas Delaware Basin, Wolfcamp wells drilled are giving about 88% liquids.

Parsley Energy

- *Building toward a large-scale horizontal drilling program in the Permian's Midland Basin*
- *Possible horizontal will target Parsley's Southern Delaware Basin acreage, with a focus on the Woodford and Wolfbone formations*

In May, Austin-based Parsley began trading on the New York Stock Exchange in an IPO aimed at raising $737.9 million to pay off preferred interest holders in Parsley, pay down debt on a revolving credit line, and for the development and acquisition of additional Midland Basin acreage, according to a company news release.

The company had 73,356 net acres in the Midland Basin with estimated proven reserves of 54.8 MMboe, which is about 77% oil in the liquids-rich region, according to a company filing with the U.S. Securities and Exchange Commission (SEC) in advance of the IPO. It also reported net acreage of 22,300 in the Delaware Basin of the Permian but showed no proven reserves at the time.

At year-end 2013, the company had identified 1,362 potential vertical drilling locations on 40- to 80-acre tracts, 1,694 possible locations on 20-acre tracts and

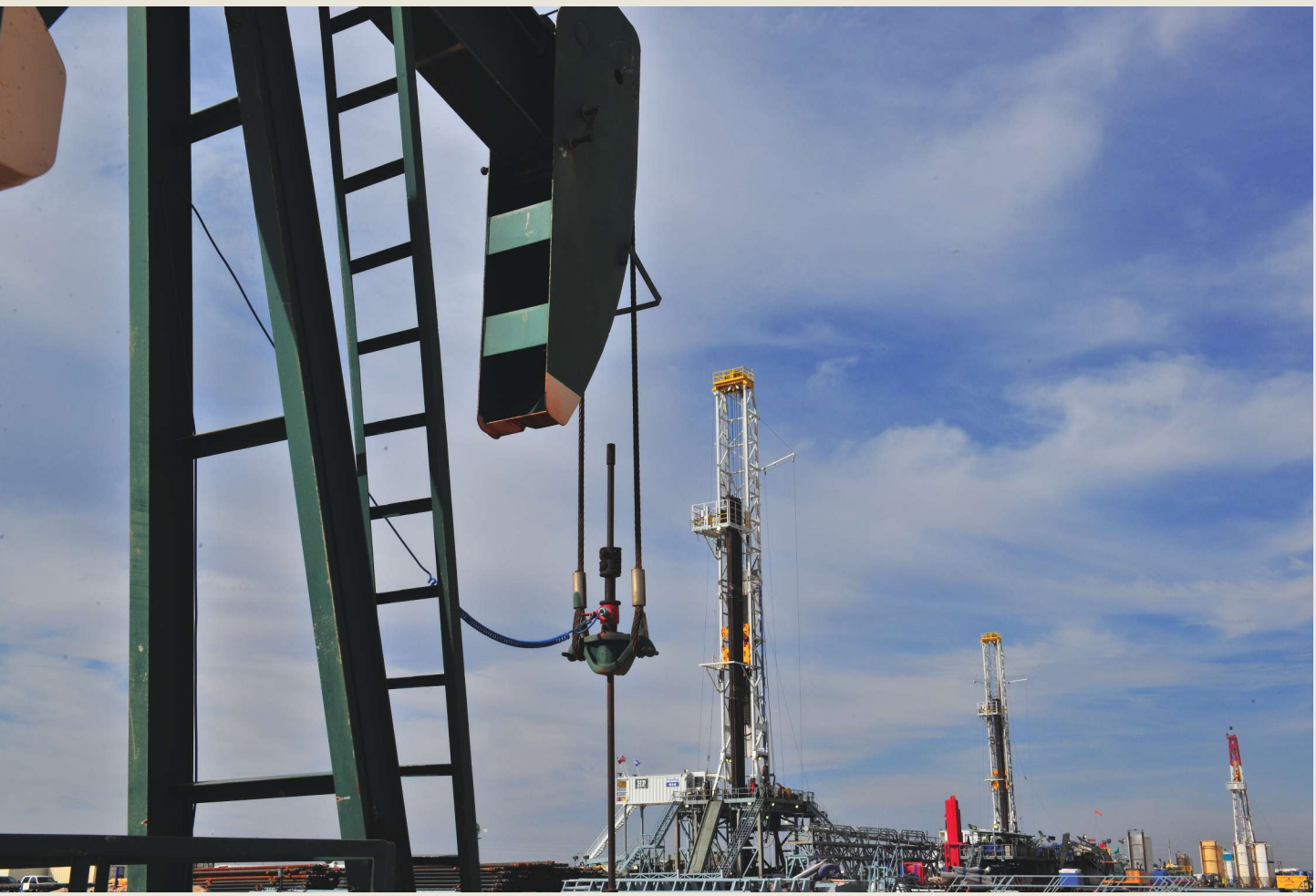
1,315 possible horizontal drilling locations on existing acreage. More are expected as evaluations of the undeveloped portions of the Midland and Southern Delaware basins continue, according to the SEC filing.

"We intend to target multiple benches within the Spraberry, Wolfcamp, Upper Pennsylvanian [Cline] and Atoka shales with horizontal wells and believe our horizontal drilling program may significantly increase our recoveries per section as compared to drilling vertical wells alone," company management wrote in the IPO registration filing. "We have reduced the average time from spud to rig release for our vertical Spraberry and Wolfberry wells from approximately 18 days during 2011 to approximately 16 days in the fourth quarter of 2013." The company's average total depth of wells drilled in 2013 was 11,354 ft. Parsley also reduced its total drilling, completion and facilities costs from a peak average of $2.4 million per well in first-quarter 2012 to an average of $2.1 million per well in fourth-quarter 2013. "This decrease was driven primarily by a reduction in hydraulic fracturing costs and efficiencies gained through economies of scale over this time period," according to the filing.

Pioneer Natural Resources Co.

- *825,000 gross acres in the Wolfcamp and Spraberry*
- *Put 40 horizontal wells on production last year and in first-half 2014*

One of the companies credited with taking the horizontal drilling plunge early into the Permian with advanced drilling and recovery technologies is Irv-



Pioneer has three-well pad drilling on its D.L. Hutt lease in Midland County as of April 2014. *(Image by Sands Weems, courtesy of Pioneer Natural Resources)*

CoolSet™

Curable Resin-Coated Proppant

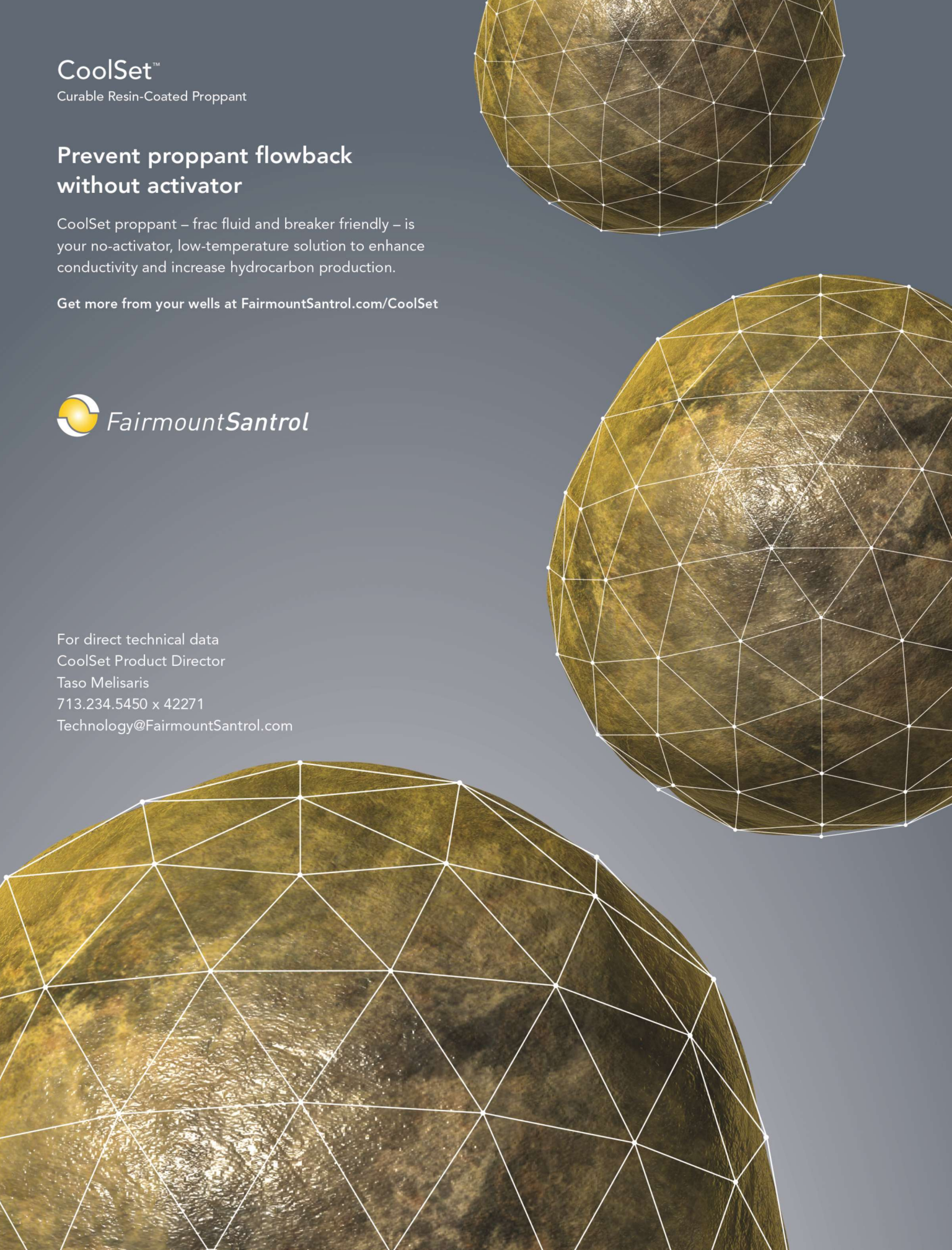
Prevent proppant flowback without activator

CoolSet proppant – frac fluid and breaker friendly – is your no-activator, low-temperature solution to enhance conductivity and increase hydrocarbon production.

Get more from your wells at FairmountSantrol.com/CoolSet

FairmountSantrol

For direct technical data
CoolSet Product Director
Taso Melisaris
713.234.5450 x 42271
Technology@FairmountSantrol.com



ing, Texas-based Pioneer Natural Resources, the largest holder of acreage focused in the Spraberry and Wolfcamp formations.

In 2013 and first-half 2014, the company drilled 27 wells in the Wolfcamp A, B and D benches and seven in the lower Spraberry Shale. Also in first-half 2014, Pioneer drilled three horizontal wells each in the Jo Mill Shale and the Middle Spraberry.

In the company's second-quarter earnings release, Pioneer indicated it is transitioning from appraising horizontal opportunities in 2013 to an active development program with as many as 93 wells planned in 2014 in the northern portion of its Spraberry and Wolfcamp acreage. The company increased from five rigs in the northern Spraberry/Wolfcamp to 16 in early 2014.

"Looking beyond 2014, we expect to continue to ramp up our horizontal rig count in the Spraberry/Wolfcamp by five to 10 rigs per year," said Pioneer Chairman and CEO Scott D. Sheffield.

Additionally, the company plans to put about 100 wells into production in 2014 in the southern Wolfcamp joint venture area.

Although 200 vertical wells are planned for 2014—primarily in the deeper Strawn and Atoka formations—Pioneer expects to reduce its vertical rig count to six by early 2015. This will allow more capital to be pumped into horizontal drilling, which has a higher rate of return in the unconventional plays. The estimated 2014 drilling capital companywide is $3 billion.

The company reported second-quarter production from its Spraberry and Wolfcamp wells at an average of 92,000 boe/d.

QEP Resources Inc.

- *Acquired 25,519 net acres in the Permian's Midland Sub-basin in February 2014*
- *Seven rigs drilling in the Permian, including two for horizontal drilling in Wolfcamp A and D*

QEP Resources Inc. paid $950 million for entry into the Permian Basin shale plays, landing more than 25,000 net acres in late February in mostly Martin and Andrews counties. Existing production on the acquired properties totaled 6,700 boe/d from the Midland Basin.

In the two quarters since, the Denver-based company has set out to expand the development with five rigs drilling vertical wells and two rigs focused on horizontal drilling in the Wolfcamp benches.

The company now operates 284 vertical wells there and completed 14 in the second quarter with an average gross peak rate of 358 boe/d, with 70% oil. QEP also completed a horizontal well in the second quarter and tested multiple horizontal benches. The Wolfcamp B horizontal well had a 30-day average production rate of 637 boe/d.

Production in the second quarter for QEP's holdings in the region rose to 7,700 boe/d, with 78% from liquids.

The company said in a news release that it estimates there to be 47 MMboe in reserves and about 300 MMbbl of recoverable resources in as many as nine stacked pay zones. QEP has identified as many as 775 horizontal drilling locations on the acreage.

Quicksilver Resources Inc.

- *90,000 gross acres in Pecos, Crockett and Upton counties in the Midland Basin*
- *Jointly developing another 52,000 gross acres with Eni to include five horizontal wells*

Quicksilver has been focused on the Barnett Shale in Texas and two Canadian plays, but the Fort Worth-based company is becoming more involved in the Permian beginning in the second quarter.

With a heavy focus on Wolfcamp and Bone Spring formations, Quicksilver has entered into an agreement with Eni, which has committed to spending as much as $52 million on developing 52,000 gross acres held by the company. To date, one well is nearing completion and a second is being drilled.

The firm also has a joint agreement with an undisclosed company drilling a well on 7,500 nearby acres. Quicksilver has a 12.5% stake in that partnership.

In its second quarter earnings release, company officials said they were focusing Permian development on 90,000 gross acres in the Midland Basin.

Rosetta Resources

- *Acquired Permian assets from Comstock Resources in 2013 in an $811 million deal*
- *On pace to drill 24 horizontal wells in the upper Wolfcamp in 2014*

Rosetta Resources, through a 2013 acquisition and a 5,000-acre bolt-on buy, now has 53,000

acres in the Permian Basin, with 40,000 acres in the Delaware and 13,000 in the Midland region. As of May, the nine-year-old Houston-based spin-off of Calpine operated 120 wells averaging 7,000 boe/d in the Permian, according to a company presentation at Hart Energy's DUG Permian Basin conference.

With 1,200 locations to drill horizontally in the Wolfbone Formation, the company has resource potential of 288 MMboe, with about 82% coming from liquids.

Four horizontal drilling rigs are staying busy in the field, and four Wolfcamp wells were completed in the three quarters after Rosetta's entry into the Permian, according to the company presentation. The company maintains field offices in Pecos and Midland, Texas.

The key target areas for drilling in the stacked play of the Delaware Basin are the lower reaches of the Wolfbone Formation and the upper layers of the Wolfcamp.

Rosetta has put several efficiencies in place related to water and simultaneous construction at several sites to trim the cost per well from $10.5 million to $7.8 million and drilling time from spud to completion from about 57 days to 35 days, according to first-quarter estimates given by the company.

Rosetta now is exploring additional bolt-on acreage acquisition for future growth. The company, which also is active in the Eagle Ford Shale of South Texas, has a credit facility to borrow nearly $1 billion to fund capital growth and recently completed a public offering to pay down debts.

Going forward, Rosetta is continuing testing of Wolfcamp benches, additional Bone Spring possibilities and accessing potential for acreage it holds in Gaines County in the Midland Basin, according to a presentation for investors presented in mid-May.

SandRidge Energy

- *70 Permian wells drilled in the second quarter*
- *Most activity in the Permian is done under an obligation to the SandRidge Permian Trust*

SandRidge Energy has remained a key player in the Permian Basin, although most of its work is now performed on assets owned by the SandRidge Permian Trust. Under the agreement with the trust, SandRidge Energy has an obligation to drill 230 wells on 16,000 Permian acres in 2014.

The trust assets produce nearly 6,000 boe/d with 88% coming from oil, according to a company presentation to analysts.

Legacy properties in West Texas still held by SandRidge Energy produced about 5,900 boe/d, with 1% from oil and the rest from natural gas, according to the company's second-quarter operations update.

Low gas prices are making that land uneconomical to drill, but SandRidge COO David Lawler told analysts in March that there is a broad resource base of CO_2 that comes with the West Texas Over-

thrust gas, which he thinks will have significant value to someone down the road.

After trust properties, what's left to do in the Permian? Lawler said there are active plans for 2015 and 2016 to drill 30 to 40 horizontal wells on its acreage.

Shell

- *Acquired Chesapeake's assets in 2012 in a nearly $2 billion deal*
- *Hopes to grow in Permian Basin while leaving other shale plays such as Eagle Ford*

Shell has had disappointing U.S. upstream results in recent years, and the company is hoping its development of 618,000 net acres in the Permian from Chesapeake Energy will help remedy the situation.

While the company is beginning to pull away from dry gas plays, it is planning to spend on the liquids-rich shale plays like those in the Midland and Delaware basins of the Permian.

In a March presentation to investors, Shell CEO Ben van Beurden said upstream profitability in the Americas has been hurt by losses in resource plays such as shales and said the company would shrink that portfolio and cost base. Spending in that arena will drop 20% in 2014 compared to 2013. The company plans to "redirect onshore investment to the lowest-cost gas acreage with the best integration potential and into ongoing exploration in liquids-rich shales," according to a company recap of the conference remarks.

Developing the company's new acreage in the Permian is seen as part of that strategy. When Shell bought the assets two years ago, production was 26,000 boe/d and the assets were considered to have "significant growth potential," a company news release said.

A report on the Permian horizontal development from investment firm Howard Weil indicated that Shell was among the companies targeting development in the southern Delaware Basin with an emphasis on the Bone Spring Formation.

Just one mention was made of the Permian holdings during the conference call after second-quarter earnings were released in late July. "Around 60% of our near-term resource plays investment in North America will continue to be directed at liquids-rich shale acreage," van Beurden said. "This will be in appraisal drilling in potentially material liquids-rich positions in the Permian and Western Canada."

W&T Offshore Inc.

- *50,000 gross acres in the Yellow Rose Field of the Permian Basin*
- *Proven Permian reserves of 38.25 MMboe*

True to its name, W&T Offshore derives most of its production and income from offshore properties, but, beginning in 2011, the company began an aggressive effort to ramp up its onshore production by turning to the liquids-rich plays opening up in the Permian Basin.

Production in the Yellow Rose Field of the Permian Basin, with about 50,000 gross acres for development by the company, now accounts for 7% of W&T's daily production, according to an investor presentation at the GHS Energy Conference in late June. The 2014 budget for exploration and development included $144 million—about one-third of the capital budget—dedicated to the Permian Basin.

"In the Permian Basin, the value of our Yellow Rose Field continues to grow as W&T and other nearby operators demonstrate the productivity of the numerous reservoirs that underlie our acreage. We believe that the industry is beginning to realize the potential value of horizontal development of the Permian Basin," said W&T CEO Tracy Krohn in a news release.

The company is working to determine the potential for horizontal drilling on the acreage, including prospects in the Wolfcamp Formation.

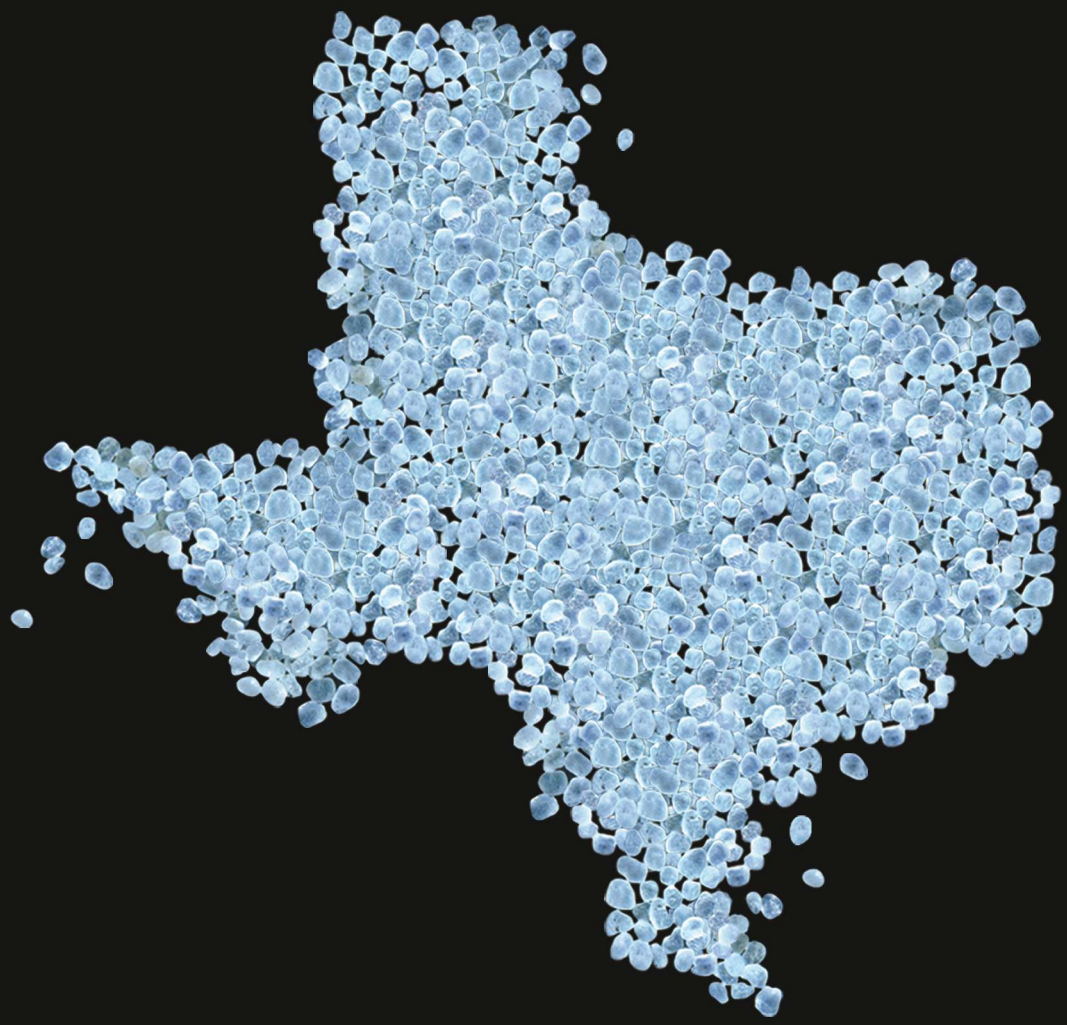
W&T is running three rigs in Yellow Rose with two dedicated to vertical drilling and the third focused on horizontal wells into the various layers of the Wolfcamp Formation.

W&T's first Wolfcamp B well, the Chablis 9H, reached a peak rate of 549 boe/d and averaged 342 boe/d for 30 days after completion of the well. Its jointly operated horizontal Wolfcamp B well had a peak rate of 703 boe/d and averaged 444 boe/d during June 2014. Adjusting for lateral length, these wells had very similar profiles, the company said in a written statement.

The second and third operated Wolfcamp B horizontal wells, the Chablis 13H and the Chablis 10H, have both been drilled from the same pad and are in the process of being completed. ■

PREMIUM FRAC SAND

Born & Raised in Texas.



While the rest just get here as quick as they can.

Our premium 40/70 and 100 Mesh frac sand is Texas made for Texas plays. Greater conductivity, lower transportation costs, zero transload or storage fees. Proven with over one and a half billion pounds successfully pumped in the Eagle Ford and Permian Basin. Reserve volume in our 20 million pound storage facility by contacting us today.

325.265.4400 WWW.ERNAFRACSAND.COM INFO@ERNAFRACSAND.COM

ERNA FRAC SAND

Finding the Sweet Spots

A variety of measurement tools can help operators land their completions more effectively.

By Rhonda Duey
Executive Editor

The pattern seems to repeat itself over and over—operators move into a new unconventional play, drill like crazy to hold their acreage and then start to evaluate what they're actually working with. It's a system necessitated by leasing rules, but many of these operators will discover that those initial wells were not completed optimally.

The Permian Basin is still in this phase or is just coming out of it, depending on the area and the operator involved. Companies that move there from the Eagle Ford Shale find a very different geology, one characterized by stacked pays that in some areas extend more than 1,000 ft into the subsurface. It's proving to be a tough nut to crack.

"We just really got started [in the Permian], and right now we're figuring out where the best acreage is," said Bradley Robinson, vice president of reservoir engineering and CTO for Matador Resources, at Hart Energy's recent DUG Permian Basin conference. "Once we figure out where the better acreage is, we'll go into development mode."

Development mode will, in many cases, involve the gathering of different types of measurements that can help target the best places to perforate.

Seismic acquisition and processing

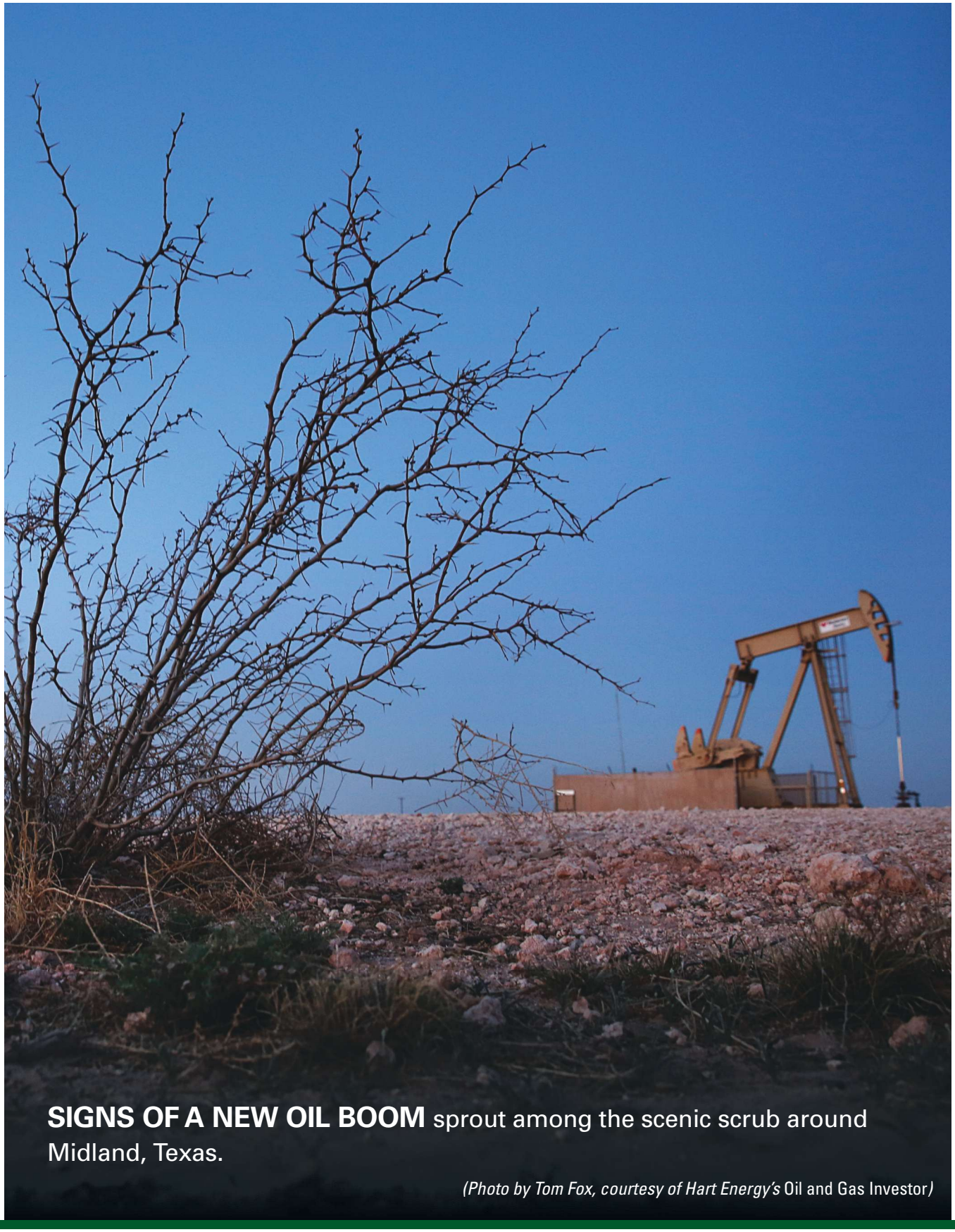
High-resolution 3-D seismic surveys have proven their worth in several shale plays since interpreters can use a variety of seismic attributes to infer such qualities as brittleness and ductility—useful features when cracking the rock is such an important part of the production process. Multicomponent seismic also can be used to infer natural fracture direction since the shear wave often "splits" into a fast and slow direction, with the slow shear being perpendicular to the fracture.

In an article titled "New Method Characterizes Naturally Fractured Reservoirs" published in the August issue of *E&P*, Ran Bachrach and Colin Sayers of Schlumberger said that many operators have been acquiring wide-azimuth (WAZ) surveys in unconventional plays to gain initial information about porosity, total organic carbon, natural fracture density and fracture orientation as well as *in situ* stress. Inversion is required to transform reflection data into quantitative rock properties, and this is where current methods fall short.

Current inversion technologies provide a useful approximation of rock properties only where there are no fractures. They can't account for subsurface anisotropy, which is needed to optimize fracking and understand fracture propagation. To address this, Schlumberger has developed a high-resolution orthotropic inversion technique for WAZ data.

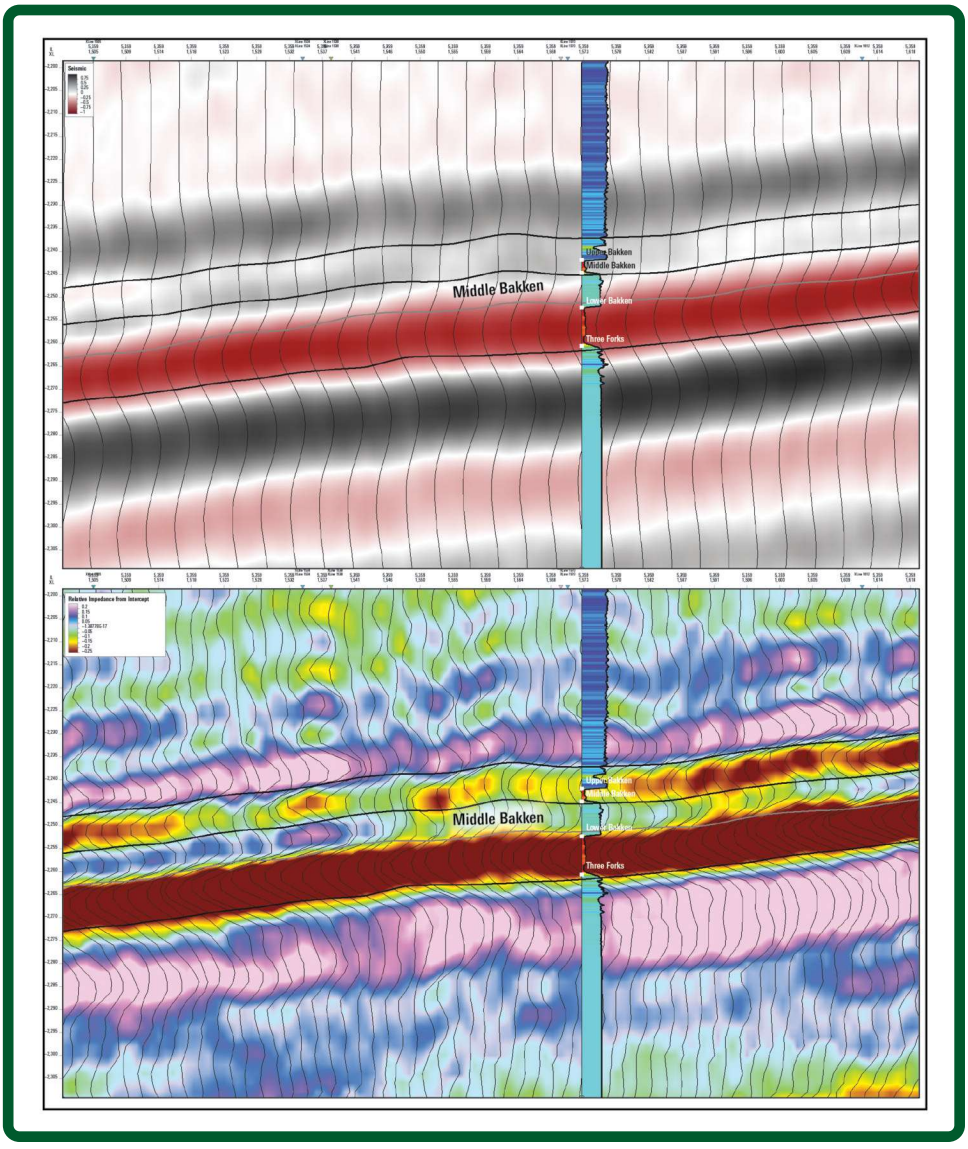
"It correctly estimates complex rock properties in strongly layered unconventional shales with natural fractures and azimuthal stress anisotropy," the authors wrote, adding that operators will be able to resolve thin layers with better resolution and determine each interval's azimuthally dependent properties, providing the ability to identify shale heterogeneities prior to drilling and place laterals and completions in the right places.

In a white paper titled "Bringing Seismic Ideas to Acoustic Logging," Partha Biswas and Shreya Ley of GeoBiz Technology Inc. proposed a method



SIGNS OF A NEW OIL BOOM sprout among the scenic scrub around Midland, Texas.

(Photo by Tom Fox, courtesy of Hart Energy's Oil and Gas Investor*)*



Top: Conventional seismic cannot distinguish the 60-ft Middle Bakken Shale from the upper and lower layers. Bottom: Orthotropic seismic inversion successfully resolves the target reservoir vertically and reveals heterogeneities laterally. *(Image courtesy of Schlumberger)*

adopted from seismic and microseismic to create a new processing technique for acoustic logging.

The authors said that acoustic logs often don't work well in unconventional shales because of the use of oil-based mud and high-angle wells. And shear wave splitting indicates anisotropic formations, not necessarily fractures.

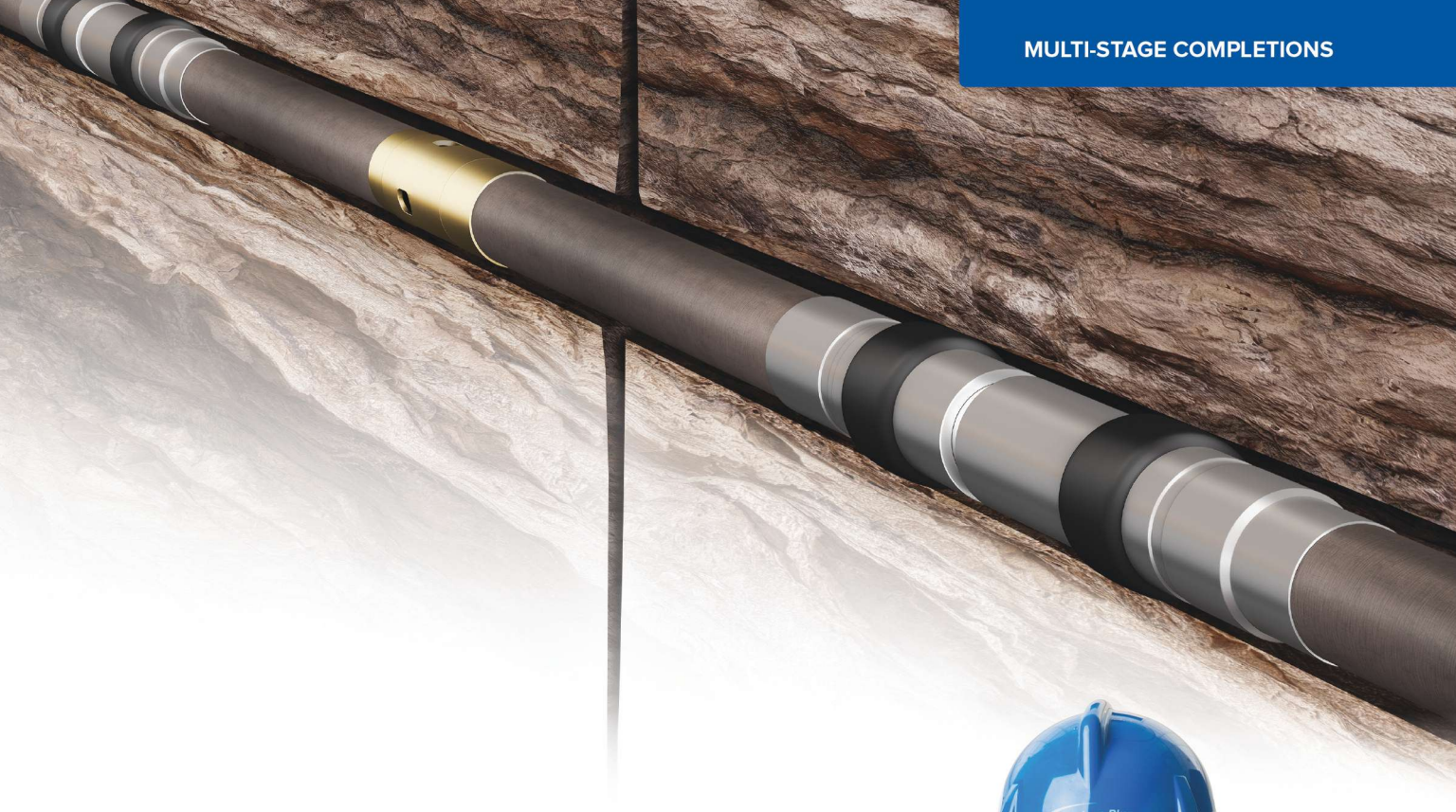
The GeoBiz technique uses the compressional wave, or P wave, to detect fractures. The theory is that across an open fracture the P waves show a significant drop in energy. "By mapping this drop in energy, fracture location and azimuth can be calculated," they wrote, adding that the technique has been tested in a number of wells and against core results. These results show about a 90% match between core data and log data in both fractured and unfractured intervals, according to the white paper.

Using sectored P waves is essential, as is root mean square normalization and a modified stacking technique, which is not usually applied to acoustic logs.

Rock physics

It might seem unjustified to study a field at the pore scale rather than the acre scale, but many of the formations in the Permian Basin, notably the Wolfcamp, are highly variable in mineralogy. "You can have a lot of changes just within a few inches vertically," said Joel Walls, director of technical resources for unconventional reservoirs for Ingrain Inc. The company recently conducted a study on core samples loaned by the Bureau of Economic Geology at the University of Texas at Austin to see if its digital rock physics (DRP) approach could help target the sweet spots. Using its CoreHD dual-energy X-ray computerized tomography imaging technology to scan the core, it then computed a high-resolution vertical profile of rock bulk density, an indicator of porosity and organic content matter, and photoelectric factor, an indicator of mineralogy. Combining these two measurements can define shale facies.

Those facies were analyzed using a focused ion beam scanning electron microscope (FIB-SEM) to quantify how much porosity was inside organic



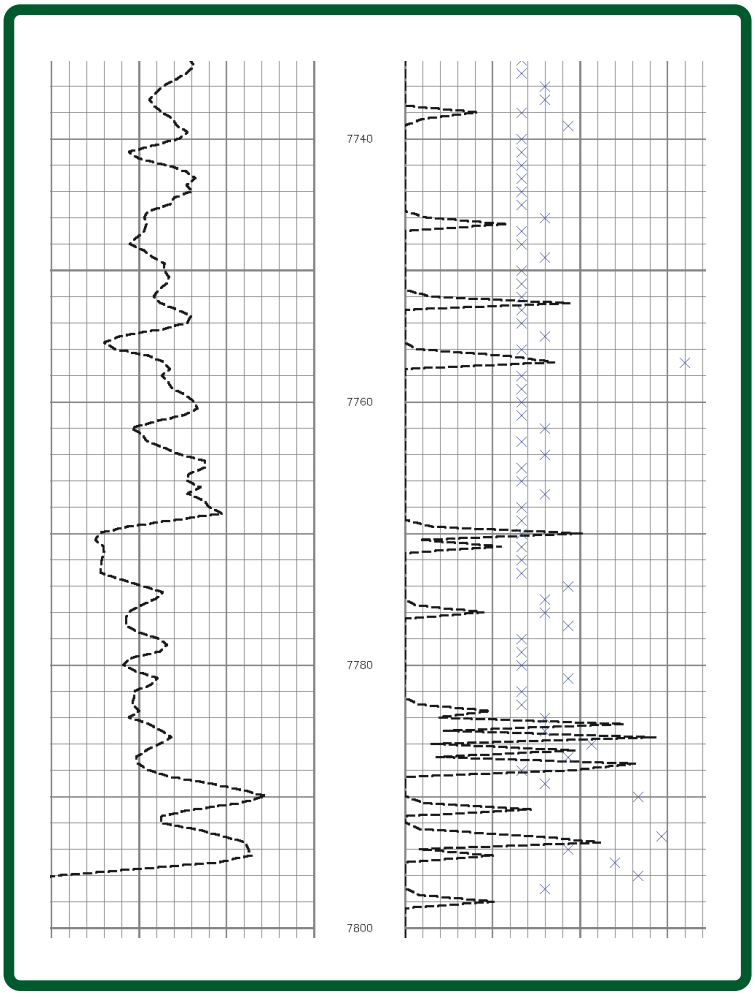
Maximize Your Permian Assets

Only Packers Plus delivers proven, reliable and repeatable results. We have extensive experience to run your jobs efficiently and effectively. Our track record includes running over 14,000 open hole ball-drop systems accounting for over 194,000 fracture stages. Contact us today and let us help you maximize your assets.

DO IT ONCE. DO IT RIGHT.

Packers Plus®

www.packersplus.com



This figure demonstrates performance of GeoBiz Technology's Fracture Identification against core results with high correlation between fractured zones in the core, shown by offset X's and in the log shown by peaks. Pictured on the left are gamma-ray results, and pictured on the right is the fracture identification log (dotted line) and core results (blue X's). *(Image courtesy of GeoBiz Technology Inc.)*

material and how much was between mineral grains (inter-granular). The study concluded that if the assumptions that water resides mostly in the inter-granular pores and hydrocarbons are more likely to be in the organic pores are correct, completions can be targeted to reduce water cut and improve production.

"Using this information, what you would do is look for thicker zones, in the hundreds of feet, where the organic porosity predominates," Walls said. "It wouldn't be the only type of porosity you would see because there is still a lot of fine-scale variation, but you might be able to locate zones in which the organic porosity is more common than the inter-granular porosity. That might steer you toward a better completion."

Logging

Service companies can throw a host of logging tools at the sweet spot problem. Logging tools provide the most intimate view of the formation, although their depth of investigation is limited. But they allow operators to see fracture azimuths quite clearly.

A variety of tools is needed in unconventional plays like the Permian Basin. According to Dan Buller, global adviser for unconventional optimization for Halliburton's formation reservoir solutions group, cross-dipole logs are needed to get the stress azimuth, which is compared with the borehole image logs. Halliburton's WaveSonic dipole wireline tool helps orient a stress matrix in 3-D, and from these data, separate vertical and horizontal components of Poisson's ratio and Young's modulus can be resolved. Buller added that this information is made even more useful when viewed in a 3-D fracture modeling or design software.

"This type of anisotropic stress calculation has been available and used in other North American source rock plays for the past four to five years, but it has been underutilized in the Permian because there have not been a lot of new, completely stress-characterized vertical wells," Buller said. "Also, since the Permian has such a long column of both source rocks and more conventional low-perm reservoirs, there are many under-resolved stress boundaries that are just now beginning to be understood using this type of acoustic stress imaging."

Halliburton also offers the Reservoir Monitor Tool, a pulsed-neutron tool that is pumped down or wireline tractor-conveyed after casing is set on a horizontal well. The tool provides a calibrated through-casing triple combo of resistivity, bulk density and neutron porosity. It also measures direct elemental yields of calcite, silica and potassium. This allows a basic lithology interpretation that leads to a geomechanical stress profile that is calibrated to vertical well acoustic stress and fracture injection closure stress analysis.

Smokeless, Reliable Flaring Solutions by Design.

Zeeco engineers a complete line of smokeless flares that raise the bar on lowering emissions for process industries around the world. But then, we do that **literally by design.**

For more than three decades, Zeeco has gained an enviable reputation for going the extra mile when it comes to designing flares that meet or exceed EPA Quad O standards – and that suits our clients just fine.

So whether you operate in the Eagle Ford or the Permian Basin, trust Zeeco for reliable performance, efficient operation, and extra-long equipment life.

Global experience. Local expertise.

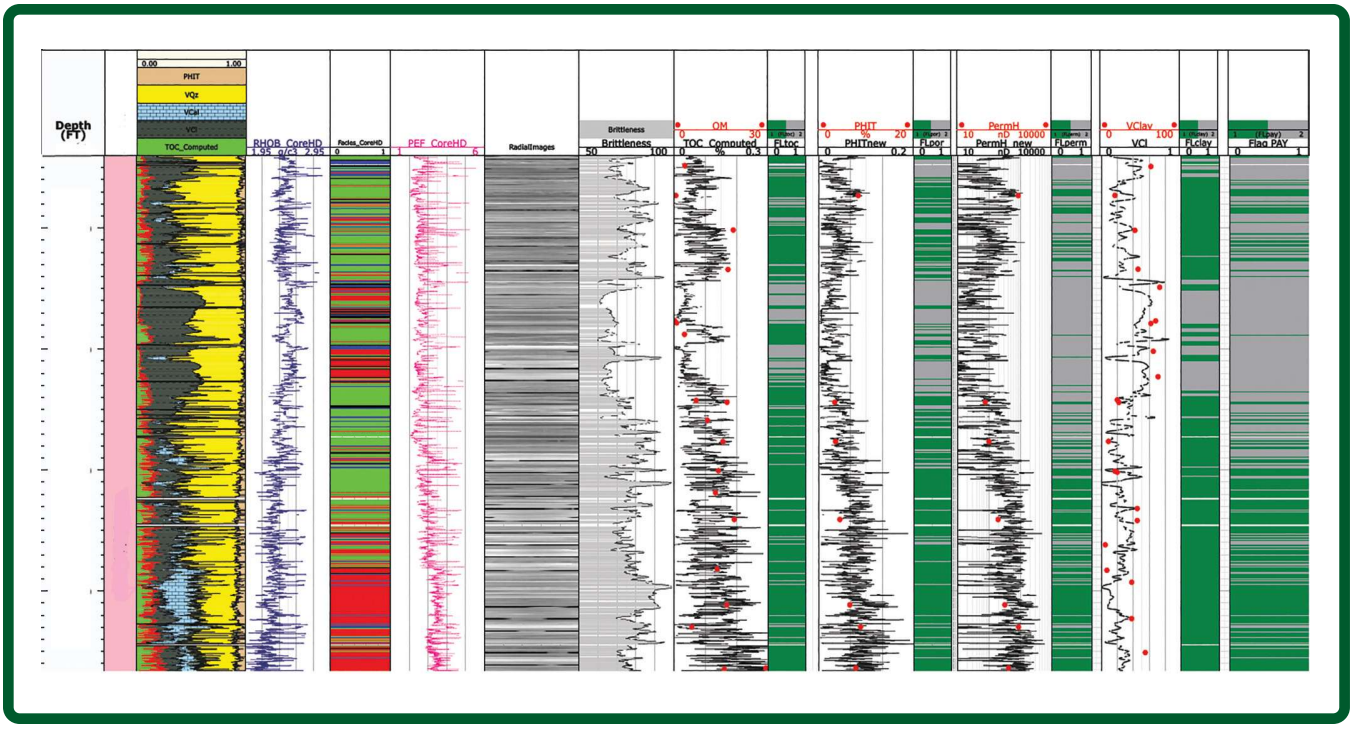
ZEECO® Engineered Enclosed Flare System

Experience the Power of Zeeco.

Open • Enclosed • High / Low Pressure
Rentals • Trailer-Mounted

Explore our global locations at zeeco.com

Zeeco, Inc.
22151 E 91st St.
Broken Arrow, OK 74014 USA
+1-918-258-8551
sales@zeeco.com



Ingrain's CoreHD Suite is used for lithology and facies discrimination and to aid in upscaling. *(Image courtesy of Ingrain)*

According to Dean Prather, technology manager for the Permian Basin at Halliburton, these types of characterizations seem to come in waves. "Logging of the horizontal section seems to have peaked in the last six months," he said. "Now customers are getting an idea of what they're seeing in the laterals and getting their programs lined out. They'll log for a while and then go away, and then they go to another area and pick up the tools to better understand the reservoirs."

Buller continued, "One or two horizontal wells per section that are evaluated with some sort of petrophysical interpretation are probably adequate. You don't need to have every single horizontal well evaluated in the section once you have a pretty good model built and correlated back to the vertical well."

Over the past two years Halliburton has moved from individual services to more of an integrated services approach, according to Doug Walser, technology manager for Pinnacle Technologies, a Halliburton company. "We do the whole thing and look at it from a holistic perspective and put it all together as opposed to looking at the individual pieces alone," Walser said.

Halliburton has helped Laredo Petroleum pinpoint its landing spots within each horizontal target, stay in zone while drilling in the laterals and provide useful information to its completion engineers, according to Pat Curth, senior vice president of exploration and land for Laredo. "The specific parameters we have homed in on to assist us in developing an earth model for the whole property set are proprietary, but a key element was obtaining data of high quality," he said. "The results to date bear out that our efforts continue to be worthwhile when you look at the top 25 to 50 completions in the Midland Basin, with Laredo being one of the top leaders."

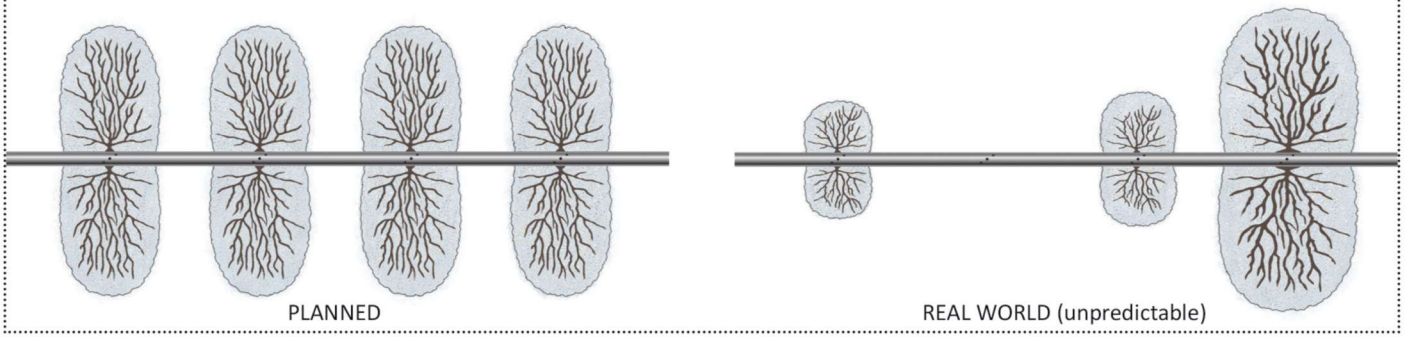
Laredo's data collection includes 3,400 ft of cores, 48 single-zone tests from the objective section (Spraberry to Ellenberger), 8,000 conventional openhole logs, 100% gravity and magnetics data coverage and interpretation, 838 sq miles of 3-D seismic, 13 microseismic surveys and 29 production logs. This attention to detail has its Halliburton colleagues impressed.

"We've been working with them for two or three years now, and they are a very good company," Prather said. "They have a lot of things going for them, and we're working very closely to help them better understand that reservoir so they can be more successful."

The moment of truth:

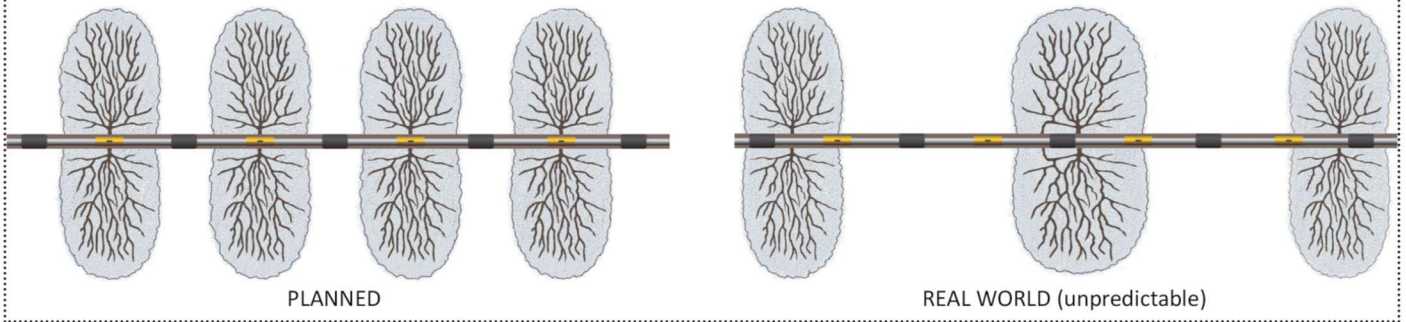
Where do your fracs (and your well investment) go?

Plug-and-perf



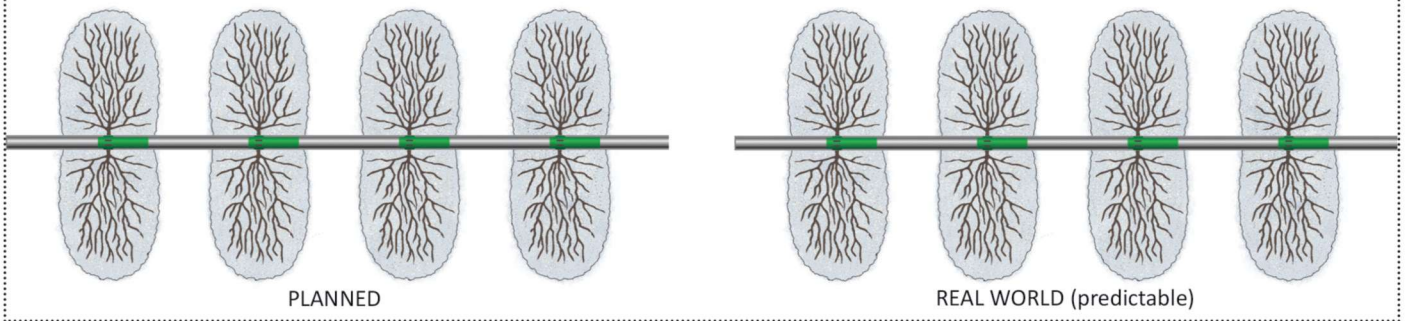
PLANNED | REAL WORLD (unpredictable)

Open-hole packers and sleeves



PLANNED | REAL WORLD (unpredictable)

Multistage Unlimited cemented casing sleeves



PLANNED | REAL WORLD (predictable)

Plug-and-perf simply cannot deliver predictable frac results, and neither can open-hole packers and ball-drop sleeves. But, Multistage Unlimited single-point injection ensures that fracs initiate right where you plan them and proppant volume in every frac is exactly what you want. Cemented, full-drift casing sleeves deliver precise frac location, and frac isolation on coiled tubing provides real-time frac-zone pressure to help you control proppant placement and frac growth on every stage, as well as detect communication between stages. Learn more about achieving the most efficient field frac network at ncsfrac.com.

Drilling-friendly | Completion-friendly | Production-friendly | Remediation-friendly | HSE-friendly

MULTISTAGE UNLIMITED™

Leave nothing behind.

+1 281.453.2222
ncsfrac.com
info@ncsfrac.com

NCS energy services

At Weatherford there is the sense that information is good and more information is better, but not all clients are operating in this mode. Partially it's simply the complexity of the geology. "There's not a thorough understanding of the fracture network and stress orientation in the Permian," said Islam "Sam" Mitwally, business development manager, petroleum consulting for Weatherford. "There is a lot of unconformity."

Weatherford also uses a suite of tools to log these wells, including density neutron, resistivity, cross-dipole or multisonic, borehole imaging, nuclear magnetic resonance, gas chromatograph tracers, and cores and sidewall cores. One of the goals is to identify anisotropy.

"Anisotropy can have an effect on increasing or decreasing the frackability and friability of the rock," said Jim Rangel, manager of petroleum consulting at Weatherford. "So we want to have that in our evaluations."

Of the vast suite of tools available, Rangel finds that the spectral gamma ray, the density, the velocity and the image logs are the most useful for providing attributes. These attributes are put into FracAdvisor, an integrated solution that provides an optimized fracture design that calculates frackability along a horizontal or vertical wellbore, field or basin for enhanced telemetry perspectives and a more profitable fracture operation.

The new service analyzes the different attributes gleaned from the logging tools and places them side by side (or above and below, in the case of a horizontal section). At the bottom of the screen, the tool shows the typical geometric perf design compared to what it considers to be the optimal design based on the attributes that have been identified.

"We can move where and how long the stages are to maximize the completion using the information to improve fracking like rock with like rock within a stage," Rangel said. "That's what this tool recommends." ■


when others call it a day, we are still giving you more.
24/7 WORKOVER OPERATIONS
More. It's what drives the oilfield to push harder, work faster and think bigger. When you work with Key, you always get more. The best trained people. The best equipment. The best technology. From drilling and completion, to production, to abandonment, it's how Key is bringing more efficiency to the field.
844.300.0700
keyenergy.com
Key®

Greater Efficiencies, Cost-Effective Solutions Realized

New technology advances bring challenging Permian Basin shales within reach.

By MJ Selle
Contributing Editor

The Permian Basin offers a variety of challenges, yet with advanced technology the secrets of the basin are slowly being unlocked.

The rig count in the region has increased dramatically, according to the U.S. Energy Information Administration (EIA). In its May 15, 2014, report, "Permian Basin Drives First-quarter Growth in Oil-directed Horizontal Drilling Rigs," authors Philip Budzik and Michael Ford said, "The Permian Basin, a longtime oil- and natural gas-producing region in West Texas and southeastern New Mexico, has seen a significant increase in horizontal oil-directed drilling activity over the past five months." They said this trend began at the start of 2013 and accelerated from the week ending on Dec. 27, 2013, to the week ending on May 9, 2014. During this time, the number of horizontal, oil-directed rigs in the Permian Basin rose by 63 rigs—50% of the total increase in the U.S.—and this growth was heavily concentrated in counties in the Permian Basin containing formations with high production potential, according to the report.

The EIA said producers have been drawn to the potential for new production from the Permian Basin's tight oil formations, which are stacked in multiple layers. During first-quarter 2014, almost 80% of all new horizontal, oil-directed drilling in the Permian took place in five counties: a 14-rig increase in Reeves County, Texas; a nine-rig increase in Ward County, Texas; an eight-rig increase in Martin and Midland counties in Texas; and a six-rig increase in Eddy County, New Mexico. These counties hold the Spraberry, Wolfcamp and Bone Spring formations.

The EIA authors said, "Changes to a formation's rig count are not a perfect indicator of its future production growth because of factors, including:

- Changes in rig efficiency, which can include longer horizontal lateral lengths, greater proppant injection, and reduced drilling and completion time;
- The decline rate of production from legacy wells, which is particularly relevant in the Permian Basin, where development began in the early 1940s; and
- The fact that in recent years, oil production has increasingly come from wells that also produce natural gas and vice versa."

However, the Permian tight oil play rig count seems to be outdistancing other major production areas. "At the beginning of 2013, both the Eagle Ford Shale in South Texas and the Williston Basin in North Dakota and Montana, which con-

A Halliburton frack fleet finishes 37 stages with 10.5 MMlb of sand pumped on Tall City Exploration's Turner AR1H. *(Photo by Tom Fox, courtesy of Hart Energy's* Oil and Gas Investor*)*

tains the Bakken Shale, exceeded the Permian Basin in the number of oil-directed horizontal drilling rigs," according to the EIA report. By year-end 2013, "the Permian Basin's 215 rigs surpassed both the Eagle Ford and Williston Basin, which had 173 and 164 rigs, respectively," and during first-quarter 2014, "the increase in oil-directed horizontal rigs in the Permian Basin was more than four times the combined increase in the Eagle Ford and Williston Basin."

Operators also are adjusting their estimates of recoverable oil and gas in the region. In a May 2014 press release, Pioneer Natural Resources said it now estimates that the Spraberry/Wolfcamp shale formation in the Permian Basin contains 75 Bbbl, an increase from its estimate last year of 50 Bbbl of recoverable oil and gas.

Technology is playing a greater part in these Permian Basin changes. Companies are expanding their resources by using new evaluation methods for the challenging stacked formations of the basin. A new technology center of collaboration has opened in Midland, Texas—the command center for Permian activity. New horizontal drilling tools are bringing greater efficiencies while innovative solutions are in place for recycling freshwater and using produced water, which is one of the region's most challenging problems. With these advances, the vast quantities of shale in the Permian Basin are becoming more economically attractive for operators to explore.

Formation evaluation brings improved production

Formation evaluation in unconventional reservoirs, particularly in the lateral section of horizontal wells, is a key focus for Weatherford in the Permian Basin.

"Until recently, operators focused on improving operational efficiencies of horizontal drilling, multistage hydraulic fracturing and other enabling technologies for unconventional reservoirs," said Sandra Denson, Permian area sales manager for Weatherford Wireline. "They have made great strides, too—drilling to total depth in fewer days, fracturing more stages per day and moving quickly to the next location—by using best practices and applying the 'well factory' approach to drilling and completions."

1. Compact tools are protected inside the drillpipe while being tripped into the wellbore.

2. Tools are "pumped" out of the drillpipe into an open hole by a messenger dart or impulse system.

3. Tools are latched into position, and drillpipe is free to rotate and reciprocate.

4. Drillpipe is tripped out of the well, and compact tools acquire data in memory mode.

This graphic explains the operations of the Weatherford CWS. *(Image courtesy of Weatherford)*

Denson said the completions designs were generally standardized, too. "A fixed number of equally spaced stages were laid out, with perforation clusters spaced within the stages. Unfortunately, although the wells may have been completed with the same approach, the production varied widely," Denson said. "Operators learned that the simple geometric approach might result in an excellent well on one occasion and a very disappointing, marginal producer on the next. This led to recognition of the need for an engineered design, using measured data and reservoir properties acquired along the lateral section for better, more consistent production."

Medium-sized operators are investing in this reservoir-driven approach by using Weatherford Frac-Advisor, according to Islam Mitwally, business development manager of Petroleum Consulting. These operators are investing in formation evaluation to understand the variations in reservoir qualities and rock properties and to learn how those change along the lateral section and across the field, Mitwally said. "The return on investment is huge since operators start to see improved, consistent production from well to well in the same field. At the same time, having the reservoir data available can point the way toward opportunities to achieve greater efficiencies, too. If you can use the money that might have gone toward an ineffective treatment and spend it where it will impact your production, you will be miles ahead and have more capital at the end of the year to drill another well."

Safe and effective conveyance of tools downhole also is an important part of the evaluation process. While wireline is the long-time standard for acquiring logging data, it might not always be efficient or even possible, according to Gregory Gonzalez, Permian Basin area compact memory logging (CML) manager for openhole operations.

"The Weatherford Compact family of tools and services brings the ability to acquire the full spectrum of evaluation data, including imaging, with or without wireline," he said.

With a short rigid tool length coupled with a 2¼-in. diameter, the Compact tools can negotiate doglegs and wellbores with high angular build rates, thereby increasing the chances of bypassing restrictions. The design also enables the tools to pass through 3½-in. drillpipe.


Doing whatever it takes to help get the job done.
Now offering complete pump solutions.
Following our recent acquisition of the second largest pump rental company in North America, United Rentals has further expanded its specialty offerings to meet customers' diverse business needs. Our team is proud to provide the best equipment, tools and solutions in the industry.
You're building the future. We're here to help.™
United Rentals®
UnitedRentals.com/Pumps | 800.UR.RENTS
Aerial | Earthmoving | Material Handling | Pumps
Power & HVAC | Trench Safety | Tools | Technology
#URPumpSolutions
© 2014 United Rentals, Inc.

The CML techniques have helped operators avoid millions of dollars in drilling and logging costs as well as bring completion and production optimization to about 360 wells, Gonzalez said.

According to Weatherford, two specific technologies have proven effective in dealing with Permian Basin wells that have extremely complex trajectories, poor hole conditions and/or impassable zones—the Compact Well Shuttle (CWS) and Compact Drop-Off (CDO) techniques.

During tripping, the drillpipe protects the tools while logging with the CWS, according to the company. Once total depth is reached in the open hole, the tools are deployed. As a result, the drillpipe can be rotated for specific well conditions. Reciprocation and circulation also are enabled. The technique is especially useful for extended-reach wells, since data can be acquired in a single pass instead of the multiple passes often needed during conventional pipe-conveyed logging.

threats that need to be monitored and assessed to prevent loss of future wells and asset integrity," said Randall Smith, U.S. specialty service manager, Weatherford Wirelines Services. "The same is true before the plug and abandonment phase."

Smith said these downhole threats could be classified into two categories:

- Failure of the cement barrier between to support and protect the casing as well as to provide hydraulic isolation between zones or to prevent migration of formation fluids to surface; and
- Failure of the casing, completion elements or production tubing to provide an unobstructed conduit from surface to total depth, i.e., no leaks.

"The Weatherford suite of well integrity tools is combinable and includes technology to ensure safe and efficient diagnosis of well integrity issues all while reducing logging time," Smith said.

"IF YOU CAN USE THE MONEY that might have gone toward an ineffective treatment and spend it where it will impact your production, you will be miles ahead and have more capital at the end of the year to drill another well."

—Islam Mitwally, business development manager of Petroleum Consulting, Weatherford

The CDO technique can be applied to challenging boreholes. An open-ended drillpipe with a special bottomhole assembly (BHA) is lowered to the bottom of the well. The wireline conveys Compact tools through the pipe, releasing onto the BHA's landing sub. The tools then obtain data in memory mode when the drillpipe is tripped to the surface. One advantage is that the tools can be retrieved with the wireline at any time during this operation.

As operators' focus on unconventional markets and aging reservoirs has increased, so has the focus on well integrity. "Every phase on the well life cycle has its own challenges to maintain well integrity, and as such when the well is on its drilling and production/intervention phases, there are downhole

Weatherford well integrity products include the Ultrasonic Radial Scanner for cement and casing evaluation, the Multisensor Caliper for internal casing defects, the Cement Bond Tool for cement bond evaluation and the magnetic Casing Inspection Tool for internal and external casing defects.

The company acquired critical formation evaluation data in the lateral section for a major Permian Basin operator using its CWS deployment system consisting of Compact Cross Dipole Sonic, Compact Borehole Micro Imaging and Compact Spectral Gamma Ray. The integration of the formation evaluation data gave the operator a solid understanding of the rock geomechanics, formation anisotropy, natural fracture network, total organic-carbonate and clay typing. Weatherford provided

Our customers expect our world class PDC Bits, Downhole Tools, and dedicated Field Support to

Go the Distance.

Call your Drilformance representative to exceed expectations in your next well.

DRILFORMANCE.COM
1 . 877 . PDC . DRIL

Drilformance
YOUR DRILLING EDGE

recommendations on completion design to reduce the uncertainty in the decision making, to maximize the hydrocarbon recovery and ultimately to help in reducing the variation in field production.

New facility brings services closer to Permian operators

Schlumberger's presence in the Permian Basin has expanded with the recent inauguration of a new $19 million regional headquarters in Midland, Texas. "Schlumberger conducted the first evaluation services in the basin in June 1934 and now, 80 years later, we continue investing for the future with this 80,000-sq-ft facility," said Charles Harding, Schlumberger's vice president, Permian Basin. "It is a great time to be in the Permian."

The new 80,000-sq-ft facility of Schlumberger's regional headquarters offers an integrated suite of services to support expanding activities in the Permian Basin. *(Image courtesy of Schlumberger)*

The facility will house 300 employees from 16 of Schlumberger's product lines. At the heart of the new Midland center will be a collaboration area where Schlumberger's drilling and completion engineers will be supported by its Petro Technical Services and Technical Integration Group. Permian operators face complex challenges, Harding said, and "we need to have the ability to draw effectively from our own local group of experts across all domains to find the best fit-for-purpose solutions."

Schlumberger currently employs about 3,000 people in the Permian Basin. "There are about 550 drilling rigs working here. It is an immense and fulfilling challenge to take on," Harding said. Since the first Permian discovery wells drilled in the 1920s, the focus, until recently, has been on vertical wells. "More than half of the wells completed in the basin are still drilled vertical, and a significant portion of the Permian's production comes from vertical wells," Harding said. "However, development of the deeper horizons from the Delaware and Midland basins is driving an increase in horizontal drilling and unconventional completion activities."

Harding said that the biggest challenge is the complexity of the plays. "The Permian has a little bit of everything," he noted. "We are not talking about a single play but dozens of stacked zones, each having unique drilling and completion challenges spread across the Delaware, Midland and Central Platform sub-basins. Reservoir intervals measure in thousands of feet compared to hundreds in other unconventional basins. Geographically, large variations in reservoir properties appear within each sub-basin. These variations are the source of the complexities that challenge Permian [operators]."

Schlumberger focuses on achieving greater efficiencies by integrating its workflows from well placement and formation evaluation through completion optimization and reservoir management. Technological advancements have been designed to help operators make better decisions and improve their return on investments.

"You have to be able to take accurate measurements to understand these reservoirs and properly evaluate the production results," Harding said.

Horizontal drilling and completions continue to increase. Accurately measuring both reservoir quality and completion quality are key to maximizing production. Schlumberger recognizes the importance of measurements and provides Permian operators with multiple horizontal conveyance options. According to the company, the advantage of its ThruBit logging services is that it delivers a quad-combo logging suite through the drillstring and the company's Portal proprietary bit designed for ThruBit services to log the open borehole as the drillpipe is tripped out of the hole. Additionally, the company's TuffTrac cased hole tractor enables operators to obtain vital reservoir data via the Schlumberger Scanner family of tools.

"We are seeing a big uptake on these types of operations," Harding said. "Everything is centered on measurements in the lateral. Logging the lateral gives us the ability to improve the drilling process and is almost irreplaceable with respect to the workflows that the production group and stimulation domain are applying on the completion side to improve productivity."

Michael Skibicki, Schlumberger's vice president of the Drilling Group, North America Land, concurs. He said operators are always looking for ways to increase their drilling efficiencies and reduce the variability on the time from spud to total depth as they drill more and more horizontal wells in the basin. "We need to make sure that we are placing wells optimally both geometrically and geologically every time, so the completion effectiveness and the production can be maximized." The company is working to engineer a drilling system that will reduce the authorization for expenditure cost through faster shoe-to-shoe drilling, he said.

"WE NEED TO MAKE SURE that we are placing wells optimally both geometrically and geologically every time, so the completion effectiveness and the production can be maximized."

—Michael Skibicki, Schlumberger's vice president of the Drilling Group, North America Land

Schlumberger has made continual advancements in both motor and rotary steerable technologies, most recently with the introductions of its DynaForce Flex shale drilling motors and PowerDrive Orbit Rotary Steerable Systems. "We have invested $65 million in a Motor Center of Excellence in Houston," Skibicki said. "Our new fit-for-purpose motors are designed specifically for improving delivery for unconventional wells. By matching the optimum bottomhole assembly, including the bit, with the right drilling fluid properties and the right fluid cleaning capabilities, we can eliminate nonproductive time and bring those wells in efficiently and ahead of plan. If the bit, BHA and fluid system are not engineered as an interdependent system, the chance of getting the optimum efficiency is very low."

Another Schlumberger technology aiding in drilling efficiency is the iPZIG at-bit inclination, gamma ray and imaging service. Placed at the bit, the iPZIG maximizes in-zone exposure while minimizing tortuosity in the curve and lateral by providing early identification of lithology and wellbore trajectory changes. It enables confident, nonambiguous steering decisions using actual formation dip and inclination data in contrast to traditional steering, which is based on estimated bit projections and geological assumptions.

With the wide variability in the Permian Basin reservoirs, Timothy Pope, stimulation domain manager at Schlumberger, said operators might not be stimulating fields efficiently. "The complex fracture networks present in the Permian make accurate production forecasting a real challenge. The Schlumberger Mangrove engineered stimulation design in the Petrel software platform can grid these networks and conduct a 20-year production forecast," he said. "The widely used trial-and-error technique forces operators to wait six to 12 months to understand if that treatment was effective. Mangrove, on the other hand, has the ability to help [operators] 'right-size' their treatments and get the appropriate level of stimulation, aligned with project economics, while optimizing the proppant and water requirements per well. A 'bigger hammer' mentality is not going to work going forward as the activity continues to ramp up and the strain on the water supply system increases."

The BroadBand Sequence fracturing technique is another new Schlumberger technology designed to increase the efficiency of completion operations.

This fracturing technique sequentially diverts fracture propagation along the wellbore to make sure every cluster in each zone is fractured and contributing to the well's full potential. "The field is a very expensive laboratory," Pope said. "We can use Mangrove to optimize the completion before we get the pumps in gear and shorten the learning curve while allowing BroadBand Sequence to reduce stage count and completion costs." This leads to better returns on their investment, he added.

"The onus is on us to improve integrated workflows," Harding said. "Every day technology plays a bigger role, and going forward it is going to be needed more than ever. Bottom line, optimal development of the Permian requires logging the lateral, ensuring BHAs are engineered as interdependent systems and completions are engineered to optimize production."

New drilling techniques, tools change production outlook

With a great number of legacy vertical wells, operators are looking at new horizontal drilling challenges in the Permian Basin.

"I do not think that we as an industry had a good idea of what really drove the sweet spot in the Permian until the last year or so," said Dan Buller, Halliburton's Formation and Reservoir Solutions global adviser of unconventional optimization. "If you have undrained or still partially pressured or overpressured intervals between areas where we thought we had drainage before, it creates a differential permeability system. Draining that system and/or identifying the best delivery portion of that kind of system with modern technology and modern evaluation are going to be key to the rate of return."

One unusual challenge that the Halliburton experts see occurring in the Permian Basin is a concept they call "thread-the-needle" drilling. "Some operators are going between existing vertical completions for a given lithological horizon," said Doug Walser, technology manager of Pinnacle, a Halliburton service line. "They have discovered the drainage shapes associated with vertical wells are substantially longer and narrower than they thought, so they are able to successfully make wells by threading the needle between existing old vertical wells."

Walser said this has changed the production outlook in a radical way. "It is still a challenge, because it does make a difference in how old a particular well is and how many cumulative barrels the older wells have produced. It is a huge opportunity that we did not understand until just a couple of years ago when people started experimenting with this type of drilling."

Dean Prather, technology manager, Permian Basin, said that Halliburton's CYPHER Seismic-to-Stimulation Service is one technology helping operators make decisions on what is needed to efficiently drain Permian reservoirs. "The CYPHER Service is all about trying to understand the reservoirs, finding the right places to drill and getting the maximum production out of the reservoir," he said. "It takes a lot of work to build up earth models."

Powered by Landmark's DecisionSpace next-generation earth modeling solution, the CYPHER workflow is updated dynamically and iteratively with the seismic and well data required to model the structure, rock and fluid properties. Halliburton's petroleum systems modeling technology defines the distribution of hydrocarbons in the unconventional reservoir to aid well placement, while an integrated formation evaluation module identifies the sweet spots for optimizing the spacing of perforation clusters.

For drilling, the Geo-Pilot Dirigo system is the newest member of Sperry Drilling services' Pilot fleet of automated drilling systems. "We are trying to increase the dogleg up to 10 degrees," Prather said. "This technology is showing good promise. There is a big demand from people doing 8- and 10-degree HDL [horizontal dogleg] Severity over last year. This new tool will help us hit that mark better."

The Geo-Pilot Dirigo system's advantages are achieving consistently higher build rates in large hole sizes and its enhanced dogleg capability for drilling wells where high build rates are required or where soft formations typically limit build rate capability when using other rotary steerable systems. These well trajectories improve drilling efficiency by reducing the sail angle required, reducing torque and drag and facilitating faster and smoother tripping.

Prather also said Halliburton's Baroid Product Service Line has been setting records with its new INTEGRADE oil-based mud system. "We are using this drilling fluid in the Wolfcamp and Cline formations with great success. With this mud system, we drilled a 10,000-ft-plus horizontal well in 3.7 days. That is pretty phenomenal."

Another Halliburton technology, the RapidStart Initiator CT (coiled tubing) Sleeve, is being used in the Permian Basin. "This is a pressure-activated sleeve designed to enable a casing test prior to opening and establishing a fluid flow path to the target formation without having to make a coiled tubing run and perforate the pipe," Prather said. "This allows for a casing pressure test that may be required to meet the obligations of the Texas Railroad Commission or for the operator who wants [to] verify pipe integrity."

For formation evaluation, Buller highlighted a Sperry technology for active geosteering. "The Sperry ALD [azimuthal lithodensity] tool brings the best bang for the buck for looking at different porosity and changing rock properties while drilling. It also gives the drilling team an image to indicate if they are going up structure or down structure."

The ALD sensor combines the existing features of the stabilized lithodensity tool with azimuthal binning of data, an independent acoustic standoff sensor and improved detectors and electronics. These features not only provide density and photoelectric logs with improved accuracy and precision but also formation dip and borehole shape information for geosteering and hole quality applications, according to Halliburton.

Halliburton experts believe that multilateral completions from one parent wellbore might be the next wave of the future in the Permian. "We have done nine of them," Prather said. "There is a team working on it and [there are] still some things to be worked out, but it is an interesting challenge. Operators are asking, 'If I drill down to the Cline, why do I need to put another parent wellbore next to it to get to parts of the Wolfcamp?'"

Halliburton believes that this also would have a positive environmental impact since it would lessen the drilling footprint. "It would be an opportunity to go in other directions and have four to six laterals out of one parent wellbore. There are not too many other places in the world that have the stacked geological columns like the Permian to exploit this situation," Prather said.

One operator drilled its first horizontal Bone Spring sand horizontal well in Lea County, N.M., and had unacceptable production results. The operator was planning on drilling a second horizontal well hoping to improve performance. Halliburton recommended using a vertical well to gain reservoir information via a suite of logs, getting sidewall cores and a FracXpert Log. The FracXpert helps in understanding the formation anisotrophy and reservoir rock mechanics. This improved understanding of the reservoir helped the operator identify the horizontal target to be drilled.

The second horizontal well was drilled with the knowledge gained from the vertical well. While drilling the horizontal, cuttings were captured to apply customized chemistry, including Halliburton's RockPerm service that allowed the fluid chemistry to better match with the reservoir to improve fluid flow along with applying chemistry to minimize fines migration from the formation fracture face.

The second well, which had 115,198 bbl of 12-month cumulative oil production showed a 61% increase in production over the first horizontal well, which had 43,848 bbl of 12-month cumulative oil production.

Water scarcity brings innovative solutions

With a natural scarcity of water and lingering drought conditions in the Permian Basin, the availability of freshwater is one of the primary challenges for development of unconventional resources.

Stephen Monroe, senior technology and applications manager at Baker Hughes, said freshwater has traditionally been used in operations because it has been readily available and inexpensive. "Also, the chemicals developed by the industry to be safely used in fracturing systems were designed for use with freshwater. Those same fluid systems, however, do not react the same way when produced water is used. Today, with the drought situation going back to 2011 in the Permian—primarily West Texas, New Mexico and parts of the Oklahoma Panhandle—water scarcity has become a critical issue," he said. "One of the challenges is the sourcing of

available and effective water for use in these fracturing systems."

Monroe said that the industry has responded by finding ways to treat water for reuse while at the same time developing hydraulic fracturing fluid systems that are more tolerant of brackish and produced water. "We have an overabundance of produced water, especially in the Permian," he said.

Unfortunately, this water contains high levels of salinity, heavy metals and contaminants that will affect performance, according to Sahar Mouallem, product line manager of Surface Water Treatment at Baker Hughes. "On average, nine to 11 barrels of water are generated for each barrel of oil produced. Traditionally, it has been disposed of because that was the most economical way to get rid of it. We did not have the need to address those contaminants in the water, but today we do. We have cost-effective and efficient technology solutions to treat and reuse this water."

Storage of produced water also has been a challenge for Permian operators. "Traditional horizontal hydraulic fracturing jobs in the Permian can use up to 1.1 million gallons of water. Do you store it for reuse or send it to a disposal well?" Monroe said. "There are other things that need to be considered as well, including rules and regulations. For example, in Texas extensive ground work, liners and safety precautions are required to ensure high-chloride water does not leak out of storage and contaminate groundwater."

In the Permian, there are areas where sour wells are a major concern. "In some zones, there is hydrogen sulfide [H_2S] that has to be managed and controlled," Mouallem said. "Conventional practice would dictate disposing of this water, but [operators] are looking for complete solutions to support their water reuse efforts, which include eliminating H_2S, removing heavy metals and solids, and applying safe, effective bacteria-control products."

Baker Hughes' H2prO water management services include several technologies geared for these specific challenges, including H_2S and bacteria remediation, removal of suspended solids and heavy metals, and solids processing. "Our H2prO HD [high-definition] system, which addresses the souring problem, is widely used in the Permian," Mouallem said.

In 2014 alone, Baker Hughes treated close to 20 Mbbl of water in Texas, and Monroe said that volume is growing every month. "We see this as a big trend going forward, and we are going to meet the need with operations in every unconventional shale play in the U.S."

Baker Hughes' H2prO HD system uses chlorine dioxide, an environmentally preferred chemistry, to eliminate bacteria, H_2S, iron sulfide, phenols, mercaptans and polymers. *(Image courtesy of Baker Hughes)*

"The HD service is a green chemistry," Monroe continued. "It does a great job with biocides and can give operators a drop in their iron if they're doing crosslinked fracks. It is a technology that has been used for decades in the water treatment industry but is relatively new to the upstream oil and gas industry."

Safety also is a key element of the Baker Hughes HD system. "This system does not allow production of chlorine dioxide if there is no water flowing through the system," Mouallem said. "One of the reasons why we went with this design is safety. These systems are extremely reliable and safe."

On the regulatory front, Monroe singled out the Texas Railroad Commission for special recognition of its recent action regarding produced water. "Over the last year, the Railroad Commission modified the rules to facilitate recycling and remove unnecessary barriers," he said. "These actions ranged from clarifying the permitting requirements for operators and water treatment service providers. They also defined ownership of water at various stages of the water cycle. All of these have been helpful measures in encouraging the oil companies to develop recycling plans." ■

Experts Chime in on the Thriving Activity in the Permian

The Permian Basin accounted for 18% of total U.S. crude oil production in 2013, according to the EIA.

By Ariana Benavidez
Associate Editor

Oil companies have been flocking to the Permian Basin as activity in the region continues to surge. According to a July report from the U.S. Energy Information Administration (EIA), the Permian is the largest crude oil producing region in the U.S., and crude oil production in the Permian Basin increased from 850,000 bbl/d in 2007 to 1.3 MMbbl/d in 2013.

THE EXPERTS

Matt Cooley, drilling operations manager, *Anadarko Petroleum*

Michael Gerstner, GeoMarket sales director, Permian region, *Baker Hughes*

Timothy Pope, stimulation domain manager, Permian region, *Schlumberger*

Brad M. Robinson, vice president of reservoir engineering and CTO, *Matador Resources Co.*

Scott Sheffield, chairman and CEO, *Pioneer Natural Resources*

Jay Still, president and COO, *Laredo Petroleum*

**Comments presented at Hart Energy's DUG Permian Basin Conference, May 2014.*

The oil field is about 250 miles wide by 300 miles long with a variety of geological formations. One of the charming characteristics of the Permian is its stacked plays, which means that multiple producing zones can be accessed with either a vertical well or multiple horizontal wells. This allows operators to recover oil and natural gas that could be too costly to produce under other circumstances. Furthermore, there is a large move from vertical to horizontal rigs in the Permian with more than 50% of the rigs now being horizontal.

According to the EIA, almost three-quarters of the increase in Permian crude oil production came from the Spraberry, Wolfcamp and Bone Spring formations.

Hart Energy interviewed some of the industry's top experts in the Permian and gained their perspective as the Permian adventure reaches its most exciting time.

What's your perspective on the progress in the Permian, and what do you predict for its future?

SHEFFIELD (Pioneer): It is the most active field in the world to date. With more than 300 rigs in the Spraberry/Wolfcamp alone and the Permian Basin (including Texas and New Mexico) up to 550 rigs, I

Facing page: One of the first horizontal rigs drilling for Pioneer in the Southern Wolfcamp area is shown (February 2012). *(Image by Sands Weems, courtesy of Pioneer Natural Resources)*

see it continuing to grow significantly over the next several years.

What's also interesting is the amount of creation in upstream value. The enterprise value of Permian-weighted companies has increased from $20 billion to $55 billion since 2009 and included several upstream company IPOs.

When you focus on the Midland Basin, it's unique that *Time Magazine* declared the Spraberry/Wolfcamp Field as the most uneconomical oil field in the world in 1953 on a cover page in the issue. Pioneer has 10 billion barrels recoverable and more than 20,000 drilling locations in the horizontal Spraberry/Wolfcamp intervals. There has been a shift from vertical to horizontal wells in the Spraberry/Wolfcamp, now up to 42% horizontal. This number will continue to move on up due to the capital efficiency of horizontal wells. Within the next three to five years, we [Pioneer] expect to be utilizing 100% horizontal rigs. The Spraberry/Wolfcamp has picked up more than 400,000 barrels a day equivalent since 2009—still on a straight upward curve. The first three or four years of the growth were really the development of the Wolfberry play and increased vertical rig activity, so we've only seen about 100,000 barrels a day equivalent coming from the Spraberry/Wolfcamp zones. We're just now starting to see the big increase from the ramp-up in horizontal activity starting about a year ago. The Eagle Ford and Bakken are starting to level off. Most people predict they will reach their peak sometime around 2016 to 2020 unless other or more zones are discovered. That leaves the Spraberry/Wolfcamp.

How many wells does it roughly take to define whether a play is going to take?

POPE (Schlumberger): That really is a measure of how heterogeneous the formation is laterally, and the answer, I believe, is 10 to 15 wells. However, in the end, it depends on heterogeneity. I was working a cross section where I had wells that were 800 ft apart, and then to the south there was a third one that was 700 ft away. There was no correlation whatsoever. You can start with a basin-level map and try to look at large-scale heterogeneity, but at some point you're always going to have to scale down and test and see if your model makes sense.

COOLEY (Anadarko): We currently have eight rigs drilling in the Wolfcamp right now with four of them in the exploitation/delineation mode right now. A lot of it depends on the heterogeneity of the formation. I think this year we have 14 to 16 pilot holes planned over a pretty large acreage position, so that depends on the results of our pilot hole program. Once our target zone is defined, I would hope that we can establish an efficient drilling operation within eight to 10 wells. At this point, we should start the optimization phase.

ROBINSON (Matador): It depends on the formation, [and] it depends on the area you're in. We're primarily in the Delaware Basin of West Texas and southeast New Mexico. It's interesting [that] the eastern side of the basin is a completely different animal than the western side. It's going to take a different amount of wells to figure out the Wolfcamp in the west than it's going to take on the eastern side of the basin, because you're going to have more liquids being produced on the east. You have to be concerned about conductivity of the fracture, multiphase flow and things like [that] vs. a more gaseous environment. So it's going to take cores, logs and fluid tests, fluid analyses and modeling in each of these different areas. The southern part of the basin is a lot deeper and geopressured than the northern part of the basin, so we feel strongly about gathering the right amount of data that we need to evaluate each prospect area. If that's a half dozen or a dozen wells to delineate an area and figure it out, then that's what it will take.

Do you have an estimate on the percentage of horizontal wells that might be drilled on pads in the Permian?

GERSTNER (Baker Hughes): We're at 290 total horizontal wells with a 550 total rig count right now. Out of that 550, we are probably at 5% or 10% of the wells on pad drilling. It's very, very low, but it's constantly increasing. Baker has product lines that are working for just about every company, so we get to see how the customers operate differently. The pad drilling has two different places it is typically being used at present. In New Mexico—which has the potash deposits—if you're going to be drilling underneath these areas, it is much more efficient to utilize pad drilling. There have been several problems between the relationship of the oil companies and the potash companies, making pad drilling essential to tap these resources. In Texas as the delineation phase continues and you get to know what zone(s) you are going to target—the Wolfcamp A, B, etc.—then you start to do more pad drilling, because it's more efficient. You get to where you know what zones you're going to target, and then companies can start a program using pad drilling to increase their efficiencies and lower their costs.

POPE (Schlumberger): We crossed over 50% in 2014, maybe late 2013. We crossed over from having more vertical to having more horizontal rigs in the Permian Basin. My experience [with] the clients I've been working with [and] that my technology integration [team] works with is we tend to see more single-well operations right now, but some people are experimenting with vertical zipper fracks and traditional side-by-side zipper fracks. So the impetus to move toward pad drilling definitely seems to be there. People are trying to figure that out right now.

How much original oil in place is getting out now? Is it 3%? 6%? What theoretically can we get that to?

GERSTNER (Baker Hughes): I'm not really a reservoir engineer, but it is way under 10%. Part of the problem with the poor recovery rates is the inability to treat each set of perforations individually. In a vertical well you shoot four or five sets of perforations, drop ball sealers, open them all up and pump a limited entry job to get all of the zones treated. On a horizontal well, we have four or five sets of perforations, we say a "Hail Mary," and we start to pump. Not all of the perforations get treated, so recovery rates are way under 10%. So we've got a long way to go.

And oil is harder to move in comparison to gas, so if you moved recovery rates up to 20%, you'd recover millions of barrels of oil.

ROBINSON (Matador): If we had 20%, that would be phenomenal. If you think back to recovery efficiency in the conventional world, we are at 15% or 20%. Then with secondary recovery efforts, we'd double it or something like that. So, I don't think 20% would be the high end. We're definitely right now in the 3% to 4% to 5% range. I do think it can go to 10% pretty easily, because I think we're going to get better at completing the wells [and] we're going to do things with stacked laterals and offset stacked laterals, better fracturing technology and picking better intervals to stimulate and designing optimal treatments for those intervals. I think we're certainly going to get about 10% and literally double the potential reserves in the Permian and other shale plays too.

SHEFFIELD (Pioneer): We updated our 50 billion recoverable number in the Spraberry/Wolfcamp to 75 billion barrels of oil equivalent. We think that as downspacing occurs over time and more zones are proven to be productive, this number will continue to go up. You're getting somewhere close to 1 trillion barrels of oil equivalent in place with somewhere between 5% and 10% recovery rates.

How are technologies changing? Do we have the technology we need, or do we need to develop something else?

ROBINSON (Matador): We drilled a well in South Texas not too long ago in eight days. We couldn't even drill vertical wells in eight days 10 years ago much less 15,000-ft to 16,000-ft horizontals, so it's pretty phenomenal what they've been able to do. It's a combination of improved technology on the rigs,

geosteering, bit and mud hydraulics along with everything else.

POPE (Schlumberger): We have a lot of the technology we need right now. However, it's always evolving. We can always use a little more technology as far as I'm concerned. We now have the ability, with microseismic as a boundary condition, to model complex fracture networks. We can model the interaction of the hydraulic fracture with the natural fracture system and the complexity that this interaction creates. We also have tools to measure the natural fracture systems. One of the newer tools is borehole acoustic reflection surveys [and] different things to help us look at the reservoir and determine what is the azimuth and spacing of the natural fracture system.

We have a lot of great technologies. We need to put them to the test and pressure test them, because they're pretty new right now. I'm sure we'll see evolutions in these technologies as well when we put them through the paces and see where the shortcomings are. Right now we can take our complex fracture model and grid the permeability enhancements directly into a reservoir simulator, so we have a full design/execute/evaluate loop that we can run to optimize unconventional stimulations.

GERSTNER (Baker Hughes): We need to start using the technologies that we have. What bugs me about the industry is that we jump to a commodity-based situation too quickly. We need to spend the time and effort to understand the reservoir. Let's perform flow-through studies utilizing the cores to make sure we are pumping the right fluids. We've got to make sure we're getting the right frack lengths instead of just trial and error. We really need to do some more science on these formations, and a lot of the tools are there and can be utilized; they're just not being used as much as they need to be.

SHEFFIELD (Pioneer): The vertical wells used to make 140,000 barrels of oil equivalent in 40 years. Now we can make that out of one zone in six months or less. That's what's amazing with technology changes.

STILL (Laredo): You're getting 90% of your production out of 50% of your [fracked] stages. There are a number of stages [in the Permian] that didn't contribute at all or are contributing very little, and [with technology] we can tie those stages to the seismic deck that we tuned to know in advance what rocks are going to contribute the most. How do we alter our completion to make those rocks that are more challenging [more] efficient, or do we take those completions out altogether and save a tremendous amount of cost in our completion program? That's where we're trying to go in this operation. If you can understand your rocks along the long pathways, 500 ft [or] 10,000 ft, and you can optimize that completion, you're going to lower your cost and increase your EOR. So that's where we're going [in the Permian] as we move into this development phase and move this whole function into a manufactured process.

What has your company done in terms of being able to reduce drilling times and capture efficiencies in the Permian?

COOLEY (Anadarko): We've been primarily focused on single-well pads in the Delaware Basin. We have some two-well pads drilling right now, but obviously we'd like to get more in the four to six wells per pad range [like] we have in our Eagle Ford operation. We still have a lot of work to do in the Wolfcamp to match the efficiencies that we see in our Eagle Ford operation. Unfortunately, Mother Nature wasn't quite as kind to us as she was in South Texas, but by no means are we finished with our drilling efficiencies out there. I would imagine a 20% to 25% improvement within the next two years on our spud-to-release numbers. We're still in the learning phase [and] only one year into this Wolfcamp program, but we'll get there.

POPE (Schlumberger): When we're talking about Wolfcamp A, B [and] C, the lateral landing point is hugely important to [completion] efficiency. We have to understand the 3-D geomechanics and how they affect fracture height growth and pick the lat-

eral landing point appropriately. There are situations where we land in zones that were not very conducive to fracturing and that ruins our efficiency from a stimulation standpoint. We have to evaluate the reservoir quality and the completion quality. At this time, there's no one in the Permian interested in tossing part of the lateral out, so what we're trying to do is stimulate the whole lateral as smartly as we can [and] as efficiently as we can. We've had a lot of success so far with our staging and perforating adviser where we look at the stress along the lateral and we place the perforation clusters according to the lowest common stress within a stage. Originally, as a reservoir engineer, I was really happy to hear that we actually had more production. But we actually realized when we looked at [a] 10-well package that the client gained 1.5 days per well, because they were having a more efficient completion operation. We can't go after efficiencies and then lose productivity, because then we're just treading water at best. We need to go after the efficiencies—both operational and technical—while still increasing the reservoir contact and increasing productivity, and then the rate of return goes up. So [in terms of] efficiency gains, if we can actually perform some science and cut down our material requirements and stimulation times, then we're going to gain efficiency [and] we're going to reduce some of the strain on the supply chain.

AT THIS TIME, there's no one in the Permian interested in tossing part of the lateral out, so what we're trying to do is stimulate the whole lateral as smartly as we can [and] as efficiently as we can.

—Timothy Pope, stimulation domain manager, Permian region, Schlumberger

STILL (Laredo): It's all about the rocks. If you know the rocks, [then] the better you can develop the rocks. We're moving into multizone stacked laterals, which really bring in a lot of efficiencies in the development. We've [also] got sales price diversification. If you look at the production increases out of the Permian Basin, and assuming the Gulf Coast can handle it all, it's going to be extremely important that you've got your production where you can get it out of the basin without suffering from severe differentials.

You start looking at that Wal-Mart kind of mentality—where do I get the highest return on the maximum amount of reserves? There's a tremendous amount of efficiency and a way you [can] look at how to develop this from the surface side, not just the subsurface side. But it really makes you rethink how you want to drill these wells.

You can gain a lot of efficiencies by just taking time to mobe out of each well, taking cost out of the equation, rigging up for different pipe sizes, different fluids and whatnot so you can be a lot more efficient in pads. But what it does is it backs up your production, so your spud to first production on a four-well pad moves to about 123 days.

In terms of pressure pumping, it's been an oversupplied market for a long time, not just in the Permian but everywhere. Now it seems like that's beginning to tighten up a little. Are you seeing any changes in pricing?

ROBINSON (Matador): A little bit. Obviously, supply and demand comes into play, but for the most part we've been able to negotiate contracts for services that we're really pleased with and get what we believe is a fair price for the services that offer a reasonable return. We're able to pump treatments that we feel are optimal for a reasonable price and get the type of well performance that we're looking for. It can be tight at times, both in South Texas and the Permian, but we've managed to be able to get reasonable services at a reasonable cost.

COOLEY (Anadarko): It is definitely tightening up, especially from a drilling rig side. Everyone is asking for rigs right now. Availability is becoming more and more scarce not only from the drilling rig and contractor side, but also on the directional drilling services, cementing services and anything that's personnel-based.

If the market does tighten up more, are well costs going to go back up?

GERSTNER (Baker Hughes): Well, on pressure pumping people need to understand that we went from basically eight competitors not that many years ago to [about] 43 currently. What happened is everybody got into the business because there was a lot of margin to be made and the rig count was picking up. Basically when pricing tightened up, people were not able to reinvest back into the equipment, and you didn't see all this new equipment coming out again. So the pressure pumping market has tightened up. Frack days have tightened up a lot. It's supply and demand. Pricing has gone up, but it really needed to because the margins were so poor, so it's definitely gotten better.

What kinds of data essentially come out of a well, and how fast can we access those data?

POPE (Schlumberger): We can get openhole or cased-hole lateral measurements and have those turned around within 48 hrs. So we can keep up with the drilling and completion process even if there's a stimulation waiting for that well as soon as that cement's cured and the well is prepped. It's all a matter of rushing the processing, and then we can turn around the answer product in 24 hrs.

ROBINSON (Matador): You need some rock data, and it's going to involve cutting some core up front, either whole core or rotary sidewalls—something you can [use to] measure the mechanical rock properties. Once you understand the rock then you can correlate that back to the log data and calibrate it to the openhole logs, and you can get a pretty good idea of the mechanical properties and so forth. What you don't want to happen is to have perforation clusters that expand over multiple rock types and multiple fracture gradients, because you're going to get uneven distribution of the fluid and proppant. I think the key in what we're learning is that you want to try to cluster your perforations as close to the same type of rock as possible. You don't necessarily want to skip zones, because you don't know what is 200 ft away from the wellbore. These are very heterogeneous rocks. They do change. We know it's going to change going away from the wellbore, so we tend to stimulate the entire lateral. It does make sense to treat different intervals differently depending on the rock properties.

STILL (Laredo): The challenge is when you drill your vertical well or drill your pilot hole and you study the rocks and find that best landing spot for your 8-in. hole [or] your 8½-in. hole to land in, that's the best data you have about that near-term rock. But we're drilling these wells 7,500 ft to 10,000 ft out. How does that rock change along the way? It becomes absolutely critical that you know the rock and how to most efficiently stimulate that rock to maximize your recovery. So we've got core data [and] we have log data [that] characterize the reservoir. You tie these to 3-D seismic data and you optimize your development plan.

We entered into a program with Halliburton and their Unconventional Resources team about three years ago to start attacking this problem and to help us move farther ahead on the learning curve faster. Halliburton has a tremendous amount of resources available to it to apply to this subject. So we started with our dataset. We drill a lot of vertical wells just to hold the acreage position together. We've got five rigs drilling vertical wells now, [and] we've got seven drilling horizontal wells. We use those vertical wells as our data collection sites, and so we have a tremendous amount of data that we collect all through our field from all of our acreage from log data, core data, full-core data, sidewalk core data [and] single-zone tests.

Is the Permian a slickwater frack or a crosslink gel market? How does this affect conductivity?

POPE (Schlumberger): Well, that's a really big question. If we have 300 ft of pay and we're not properly stimulating that entire 300 ft, [then] this could affect

our EURs, our long-term production [and] our decline rates. We now have the tools [and] the workflows to actually look at our proppant distribution in complex fracture networks, grid those permeability enhancements into reservoir simulators and then play what-if scenarios [by asking], "Is this a slickwater application, or do we need to go slick water followed by crosslink? Do we need to worry about our vertical proppant distribution?" My opinion is yes, we do. We have very laminated large-pay intervals. If we don't prop the entire interval, then as we draw the well down, we run the risk of losing conductivity and connectivity with some of the pay. Since we're trying to produce liquids, conductivity matters. It's not a pure gas play. We now have the tools to look at an optimized treatment. Right now we're kind of just throwing things against the wall and seeing what sticks—slick water on a few wells, hybrid on a few wells, maybe that hybrid is a crosslink, maybe it's just a linear-gel hybrid. In the end, a "bigger hammer" mentality is not sustainable in the Permian. Supply chains already are strained.

GERSTNER (Baker Hughes): This is an oil play. This is not a gas play, so conductivity means everything, but it's also about getting the proppant out there. The issue with slick water is you're taking basically a very low-viscosity fluid and gravity takes over [and] sand falls out in a hurry because you can't keep your velocities up. There are some very good papers out there that illustrate the breakdown pressures for shales. They tested high-viscosity crosslinked fluids down to slick water. The lower viscosity fluids will basically break up the shales and make a more complex fracture. But there is an issue carrying proppant with low-viscosity fluids. We've seen microseismic events out to 1,200 ft, but that doesn't mean we're putting proppant out to this distance. You just can't physically achieve that with a 1 cp fluid, and that's part of the reason we're concerned about those decline curves being so steep. The hybrid treatments that we've pumped seem [to], in some of the areas, kind of flatten out the curves.

ROBINSON (Matador): Getting the right conductivity and getting full coverage of your proppant throughout the whole fracture is so important. In some cases, slick water is going to be just fine. There are going to be areas in the Permian where you have more naturally fractured reservoirs [and] then pumping slick water is going to make a lot of sense. There are certain characteristics about fractured reservoirs where that just works—the Barnett's a great example. In the Wolfcamp, where you have hundreds of feet of thickness that you've got to cover with proppant, you're not going to get good transport with slick water, typically. So everywhere that fluid goes you want the proppant to go. That's generally going to take a more viscous fluid. We generally tend to design our treatments using hybrid-type designs. With some formations, pumping slick water does help create a more intense fracture system. Typically, the more fractures you get, the more complex the geometry. Then you go fill up all the fractures with sand, carried with a more viscous gel. Typically, our results [have shown] double the production and potential reserves on our wells as a result of the hybrid design using a thicker gel, so we think it's important. Is it always going to be the fluid of choice? I don't know. There are different fluids for different applications.

What are some challenges you're facing in the Permian?

GERSTNER (Baker Hughes): There are just not enough qualified people to do everything out here in the Permian, so it's about getting people in the area from other places to go to work. The unemployment rate was two-point-something percent in Midland, Texas—the lowest in the whole country. It's an issue. It's a big issue.

SHEFFIELD (Pioneer): There's really only one item that can derail the growth in the Permian Basin and that's the oil export ban that was enacted in 1975. We all know we've added more than 3 million barrels a day from these four fields [Bakken, Eagle Ford, Niobrara and Permian] over the last four to five years. Part of it is condensate, and part of it is sweet crude. I believe the number will climb up to somewhere between 12 and 14 million barrels a day by 2020 to 2022. We found a 200-year-old supply of natural gas—that's why prices collapsed to $2, settling now around $4.50/Mcf and moving up toward

$5/Mcf as we export LNG. We don't want the rig count to collapse. The relationship with WTI and Brent broke apart in 2011. Today the Brent-WTI spread is about $7 per barrel with WTI at $103 per barrel and Brent at $110 per barrel. Right now the draw in Cushing is helping, but in regard to the storage in the Gulf Coast, we're at all-time highs of crude storage. So what's going to happen in the future? The future's market has the spread at $13 per barrel in the next five years, but there definitely could be some blowouts with WTI and Brent.

We backed out all the light sweet crude being imported into this country. Our refineries were built for heavy crude, not light sweet crude. Certain countries are not sure they're going to back out imports into this country, like Venezuela who owns its own refineries or Saudi Arabia who has its own joint venture at Mativa. So what are those countries going to do? I know Canada is not going to back out, primarily because they have nowhere else to export it because they're having trouble getting it across British Columbia. They're starting to convert gas lines to oil lines in order to export out of the east coast. President Obama is blocking Keystone XL, but Canada is still bringing crude into the U.S. by rail or by trucks at record levels. Meanwhile, the U.S. is exporting more than 4 million barrels a day of products. Since 2004, our exports have increased from 1 million to more than 4 million barrels a day and continue to increase.

The industry has to prove to the administration and to Congress that the relationship between WTI crude and gasoline price is broken. U.S. gasoline prices are tied to Brent, not WTI. If the ban on crude oil exports is removed, it should put more pressure on the world price and soften gasoline prices as most studies show. If the ban is not removed, we'll have too much crude in the U.S., and the country can't afford to have this dislocation happen. Refineries are running at an all-time high of 92% utilization, and most experts say we cannot exceed 92% to 93%.

We do not want to continue to send troops to the Middle East to protect oil; we don't need it.

A lot of the refiners have banded together and are talking to the administration and the commerce department about relaxing the ban on crude. I'm cautiously optimistic that they may start with condensate, but in two or three years we need the ban on crude released to allow this tremendous growth to continue.

STILL (Laredo): Water is a challenge [as wells as] frack impacts. [In regards to] water demands, we just finished one of [the] first four-stack lateral pads, [and] we had to have a million barrels of water on location in two weeks. That's a challenge. Our question now is does water drive our development plan or is our development plan going to drive our water needs? There's a million barrels for a four-stack, four-lateral pad—750,000 barrels of oil for [a] three-stacked lateral [and] 500,000 barrels for a two-stacked lateral. So there's a lot of water that has to be brought to a single spot on a space on the earth in a very short amount of time.

One of the ways we're accomplishing that is along that corridor. We've got all of our frack pits in the area that has about 3.1 million barrels of capacity daisy-chained together. We can collect water from a very large space, aerial extension and then concentrate and focus that water in a very short time to one specific place. We've got water wells that can deliver about 176,000 barrels a day of water. Then our first big recycle plant will be up and running at the end of the third quarter, and that will process about 60,000 barrels a day of recycled water that we can put back in the system. So when you think about this development, how much can you bring on? How much can you pound? How much can you make available for all parts of your operation? That becomes a critical part of your planning.

The other challenge that we face: frack impacts. This is no secret, and it's not unique to the Permian. When you start looking at concentrated resource development, the frack impacts become part of your planning. We've got a lot more work to do about it, but frack impacts are a reality. Frack impacts have to go into your planning and your forecast, because they're going to hit you up to 2,000 ft away. So when we think about drilling side by side and how we complete wells, do we want to impact a well that's producing 700 barrels of oil a day or one that's down in the decline and producing 150 barrels of oil a day? All of that goes into kind of a 3-D planning matrix, and it becomes much more complicated [than] in the oil field of yesterday. ■

HARTENERGY

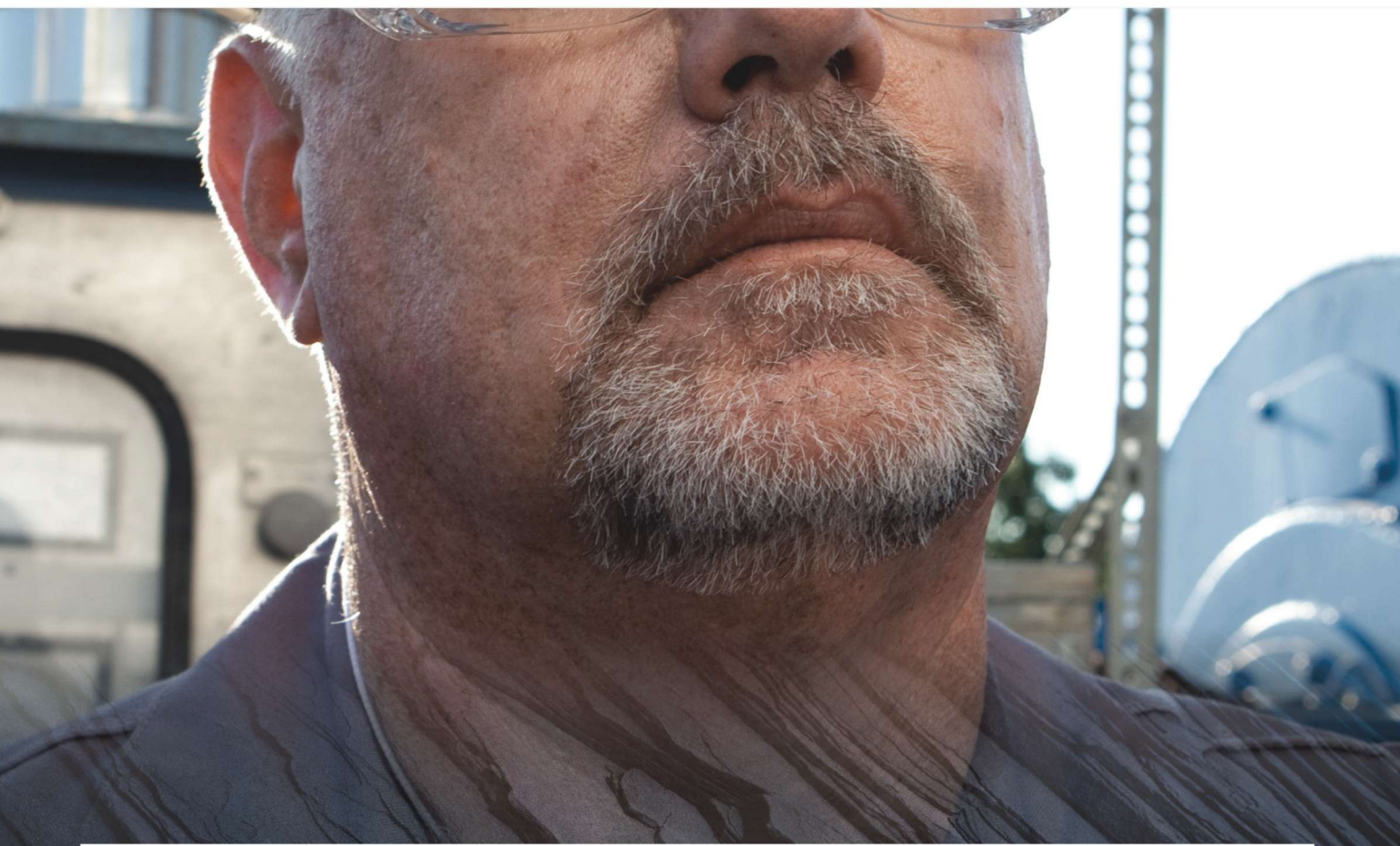
Hart Energy produces informative, impactful and innovative oil and gas conferences that attract the industry's best and brightest. In 2013, Hart Energy organized 12 events covering nearly 600,000 square feet of exhibit space and attracting more than 19,000 attendees, 340+ industry-leading speakers, 450+ sponsors and 1,500+ exhibitors.

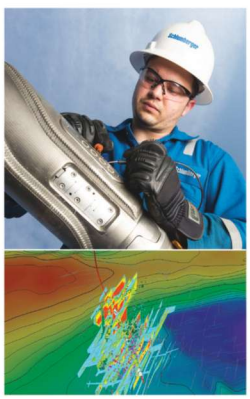
Online registration is now open for all Hart Energy Conferences. Secure your seat early and save!

GULF OF MEXICO Offshore Executive CONFERENCE	**October 16, 2014** OffshoreExecutiveConference.com	**Houston, TX** The Westin Hotel Memorial City	• Offshore Exploration, Drilling & Production • Gulf of Mexico: Shallow Water/Shelf, Deepwater, Ultra-Deepwater
EXECUTIVE OIL CONFERENCE	**November 10-11, 2014** ExecutiveOilConference.com	**Midland, TX** Midland County Horseshoe	• Permian Basin Focus • Business Strategies, Economics, Future Plans
NORTH AMERICAN LNG EXPORTS	**November 20-21, 2014** NorthAmericanLNGExports.com	**Houston, TX** Four Seasons Hotel	• Market Trends, Regulations & Capital Investments • Onshore & Offshore Project Updates; Opportunities & Challenges
MARCELLUS-UTICA MIDSTREAM CONFERENCE & EXHIBITION	**January 27-29, 2015** MarcellusMidstream.com	**Pittsburgh, PA** David L. Lawrence Convention Center	• Pipelines, Gathering, Processing & Storage • Marcellus & Utica Shale Plays
DEVELOPING UNCONVENTIONALS DUG MIDCONTINENT	**February 24-26, 2015** DUGMidcontinent.com	**Oklahoma City, OK** Cox Convention Center	• Exploration, Drilling, Completions, & Production • Woodford, Mississippi Lime & Other Midcontinent Plays
DEVELOPING UNCONVENTIONALS DUG BAKKEN AND NIOBRARA	**March 31 - April 2, 2015** DUGBakken.com	**Denver, CO** Colorado Convention Center	• Unconventional Oil Exploration & Production • Bakken, Niobrara & Other Oil Plays
DEVELOPING UNCONVENTIONALS DUG PERMIAN BASIN	**May 19-21, 2015** DUGPermian.com	**Fort Worth, TX** Fort Worth Convention Center	• Exploration, Drilling, Completions, & Production • Permian Basin & Emerging Shale Plays
DEVELOPING UNCONVENTIONALS DUG EAST	**June 23-25, 2015** DUGEast.com	**Pittsburgh, PA** David L. Lawrence Convention Center	• Exploration, Drilling, Completions, & Production • Marcellus & Utica Shale Plays
A&D STRATEGIES AND OPPORTUNITIES Conference & Workshop	**September 9-10, 2015** ADStrategiesConference.com	**Dallas, TX** The Ritz-Carlton Hotel	• Acquisitions, Divestitures & Mergers • Buyers & Sellers, Deal-Making

For a complete list of events, visit HartEnergyConferences.com

How can we get our factory drilling to deliver factory production?





Start by attacking that 30% rejection rate.

Factory drilling in unconventionals has delivered exceptional results. However, no factory in the world would accept such a high rejection rate. For instance, 36% of zones stimulated on a typical multiwell program in the Eagle Ford did not contribute to production. Getting the production part of the factory on track requires technologies to understand geological variability, optimize well placement, and deliver effective stimulations.

Our technology has led to a 99.9% placement success rate in more than 21,000 unconventional treatments in 20 different countries with a 20% average productivity gain.

Now that's a well-performing factory.

slb.com/shale

Schlumberger