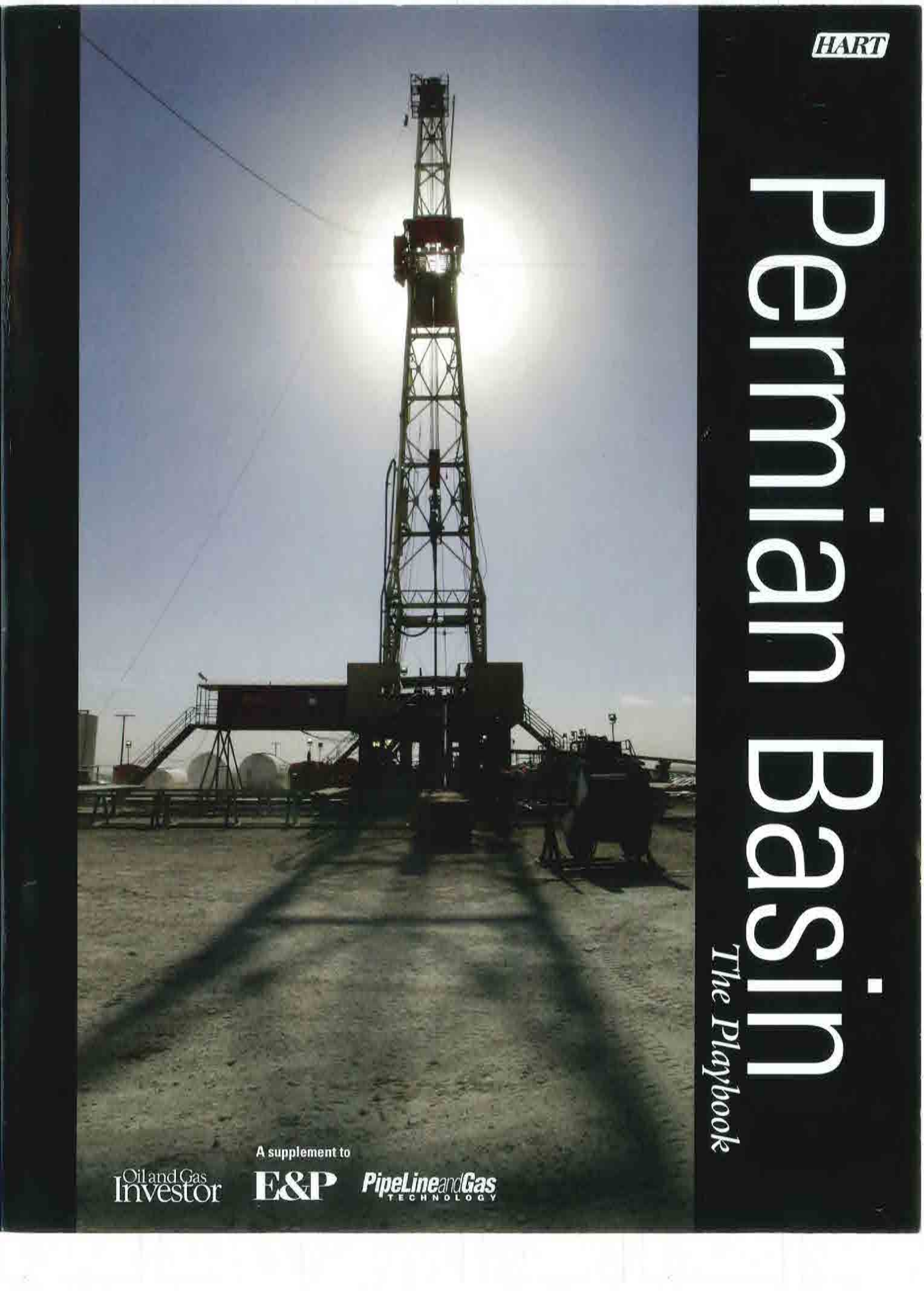


HART

Permian Basin

The Playbook

A supplement to

Oil and Gas Investor | E&P | PipeLine and Gas TECHNOLOGY

UGcenter.com
Permian Basin:
The Playbook

A supplement to *Oil and Gas Investor*, *E&P*, and *PipeLine and Gas Technology*

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

Editors **JUDY MAKSOUD**, *E&P*
LESLIE HAINES, *Oil and Gas Investor*
JEANNIE STELL, *PipeLine and Gas Technology*
Director Unconventional Resources **PEGGY WILLIAMS**
Manager, Special Projects **JO ANN DAVY**
Contributing Editors **STEVE BERMAN**, **LOUISE S. DURHAM**, **DICK GHISELIN**, **KELLY GILLELAND**, **DON LYLE**, **AL PICKETT**
Assistant Editor **ASHLEY ORGAN**
Editor, *Unconventional Gas Center* **ANN PRIESTMAN**

Corporate Art Director **ALEXA SANDERS**
Assistant Art Director **MELISSA RITCHIE**
Graphic Artist **ROBERT AVILA**
Art Director *Oil and Gas Investor* **MARC CONLY**
Production Director **JO LYNNE POOL**
Marketing Director **GREG SALERNO**
For additional copies of this publication, contact Customer Service +1 (713) 260-6442.

Group Publisher, *E&P* **RUSSELL LAAS**
Group Publisher *Oil and Gas Investor* **SHELLEY LAMB**
Group Publisher *PipeLine and Gas Technology* **JIM HART**
Director of Business Development **ERIC ROTH**

Hart Energy Publishing, LP
Vice President, Consulting **E. KRISTINE KLAVERS**
Executive Vice President & Chief Financial Officer **KEVIN F. HIGGINS**
Executive Vice President **FREDERICK L. POTTER**
President and Chief Executive Officer **RICHARD A. EICHLER**

Table of Contents

On the cover: Robinson Rig #3 was drilled in Midland County for Summit Petroleum, based in Midland. *(Photo courtesy of Lowell Georgia)*

WEB EXCLUSIVES

INDUSTRY MUST EMBRACE TRANSPARENCY, SAYS SALAZAR

Unconventional resources have dramatically expanded US gas potential, but continued development will require strong industry answers to public concerns.

UGcenter.com

COMPLEXITY RULES THE DAY IN THE EAGLE FORD SHALE

The South Texas Eagle Ford, like other shale-resource plays, is complex, perplexing and highly variable. New tools and approaches aid explorers in unraveling its secrets.

UGcenter.com

GAS PRICES TO REMAIN MIRED AT $4 FOR 'A VERY LONG TIME'

Pioneer Natural CEO Scott Sheffield forecasts that drilling spurred on by JV drilling carries and lease expiration is going to keep gas prices suppressed for "a very, very long time."

UGcenter.com

MOST READ ON THE WEB

1. Niobrara Shale Overview
2. Approach Resources Discusses Highlights of the Wolffork Play
3. Australian CBM Bonanza
4. Newfield Updates Rocky Mountain Production
5. Nanoscale Imaging Visualizes Shale Gas Plays

WEBINARS

The Power of Seismic - Unlocking Unconventional Reservoirs

Successful E&P operators in shales are increasingly using seismic to maximize production. Learn from leading experts how seismic can help you understand the geology of shale plays to optimize your wellbore placement and improve overall well productivity.

UGcenter.com/events/webinars

The Emerging Niobrara: Development Strategies and Future Potential

As many E&P companies shift more of their focus to oily unconventional projects, the Niobrara play is gaining even more attention from operators and investors. Among both groups, there is keen interest in the play's economics, drilling/completion time frames, drilling problems/solutions and insider viewpoints about successfully navigating the play. Several E&P companies are excited about the play's potential and they're looking for insight as they shape their development strategies.

UGcenter.com/events/webinars

Marcellus – Enhancing ROI through the Use of 3-D Seismic Data

The Marcellus Shale is a resource play of great potential; however, it is not uniform, and structural variations affect reservoir quality and prospectivity. Operators have found large variations in well performance and, therefore, the return on investment from individual wells. Seismic data can provide cost-effective information regarding the variations in reservoir properties, and it can be used to enhance the success of drilling programs.

UGcenter.com/events/webinars

(Photo courtesy of Devon Energy Corp.)

An Aging Giant Keeps Going

Expert leaders predict the legendary Permian Basin will be a hydrocarbon production leader in the US for years.

By Louise S. Durham
Petroleum Geologist

Viewed from the seat of an airplane high in the sky, the cities of Midland and Odessa in the West Texas portion of the petroleum-rich Permian Basin appear seemingly from nowhere.

The scene suggests a mirage in the midst of miles of desolate land dotted with gnarled mesquite trees, tumbleweeds, and varied species of cacti.

In fact, the locals have been known to tell the story that God felt bad about what he did to the land there, so he gave it oil.

The two cities, whose boundaries seem to overlap, often are referred to as the oil and gas industry's headquarters for the Permian Basin of southeastern New Mexico and West Texas.

Urban isolation is a fact of life across much of the basin. Even so, there's bustling activity in this locale. The busy scene today is considerably mundane from a spectator point-of-view.

Now, geologists, geophysicists, seismic crews, and engineers often roam the land, given the plethora of hydrocarbons already discovered and awaiting discovery.

The basin once was covered by the Permian Sea, which was hindered by a restricted outlet when it began to recede. The resulting inland sea evaporated over time in the hot dry locale. This ultimately led to formation of thick deposits of mineral-rich sediment, creating one of the world's most productive oil regions.

The Permian Basin has accounted for 17%, or 327 MMbbl, of US oil production as recently as 2002, principally from formations ranging in age from the Ordovician through Permian. This production volume is remarkable considering the cycle of oil booms and busts the region has endured over the years.

The total 30.4 Bbbl of oil produced in the entire basin through 2000 can be broken down to 25.6 Bbbl from reservoirs in the Texas part of the basin and 4.8 Bbbl from the New Mexico portion.

The original commercial oil well in this region reportedly was completed in 1921. This marked the discovery of Westbrook, the first large oil field in the Permian Basin, and operators soon tapped into a succession of major discoveries, such as the well-known Yates Field (1926) and the Wasson and Slaughter fields (1937).

The number of major oil finds declined after the late 1950s when the cumulative reserves that were discovered began leveling off.

As of 2000, annual oil production from significant-sized reservoirs (cumulative production greater than 1 MMbbl through the year 2000) was 301.9 MMbbl, or less than half the peak production that was attained in the early 1970s.

Some of the largest plays in the Permian Basin – the Northwest Shelf San Andres platform carbonate and the Pennsylvanian and Lower Permian Horseshoe atoll carbonate plays – have experienced significant decline.

Despite the number of cyclical downturns and dwindling production over its productive lifetime, the region appears to have the makings of the kind of hydrocarbon province where production essentially will go on forever.

Today, pumpjacks, or "nodding donkeys," are a common sight as they pump oil from beneath the

surface in myriad old fields, along with the not-so-old. Drilling rigs also dot the landscape in various locales, making vertical as well as horizontal boreholes to wrest newer production from the subsurface. Gas processing facilities and a raft of pipelines are integral to the scene.

There are waterfloods aplenty throughout this basin, some dating back many years. CO_2 injection programs to improve recovery also have long been relatively commonplace.

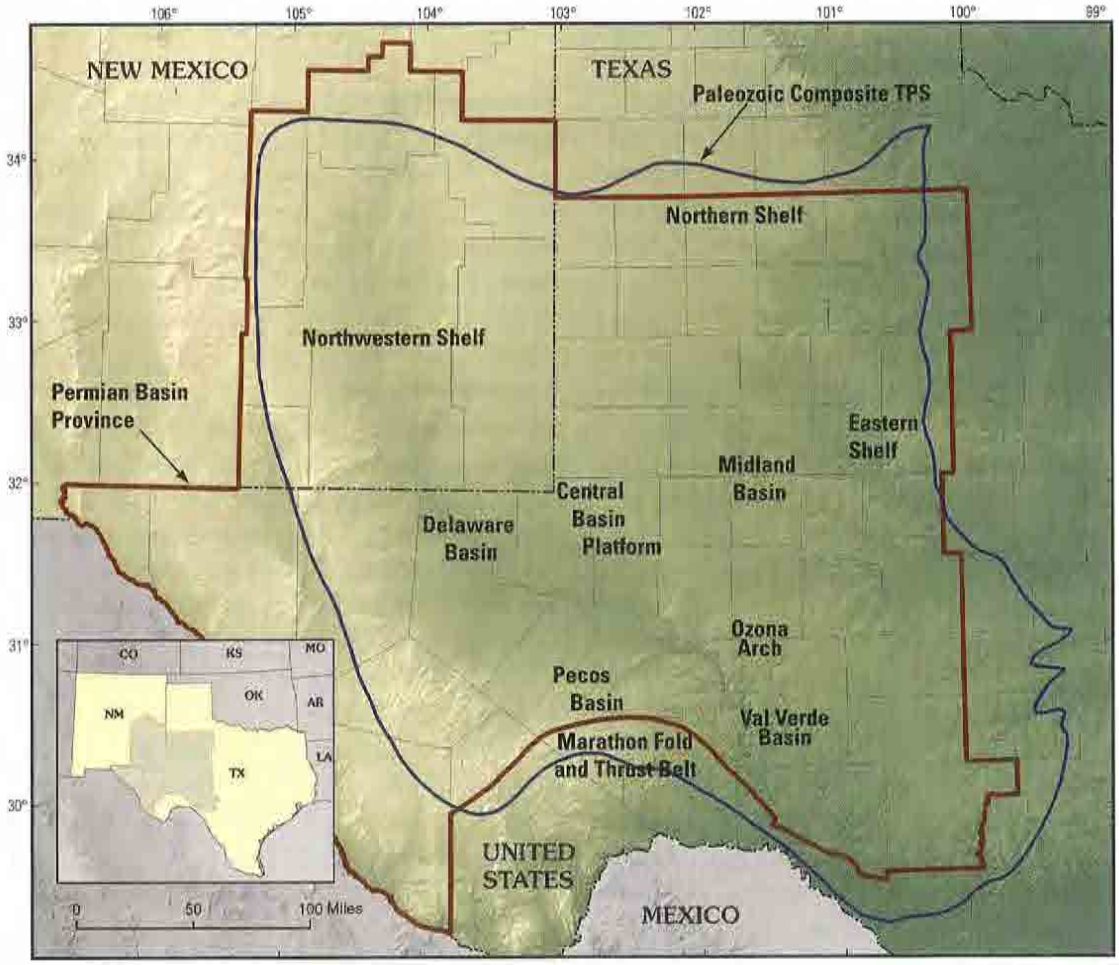
It is significant that this still-productive basin is not just holding its own, so to speak, but staying current with the times. For instance, it now boasts activity in the relatively new hot phenomenon in the oil patch: unconventional resource plays. For example, there's the high-profile Wolfberry (Wolfcamp-Spraberry) play surrounding Midland and the emerging Bone Spring play in southeastern New Mexico, which are attracting a number of oil finders.

The ongoing high interest in the Permian Basin recently was aptly demonstrated when mature-field-turnaround guru Apache Corp. ponied up US $3.1 billion to acquire West Texas and New Mexico Permian Basin oil and gas properties from BP. The acquisition includes 10 oil and gas fields, and the area holds an estimated 141 MMboe in proved reserves, with liquids making up 65%. The properties reportedly produced an average 15,110 b/d of liquids and 81 MMcf/d of natural gas in the first half of 2010.

There's added spice in the Apache deal as the acquired assets include 1.7 million gross acres with numerous drilling prospects anticipated to yield future production.

Structure highlights

The Permian Basin has been characterized as a large structural depression formed as a result of downwarp in the Precambrian basement surface



The Permian Basin Province in West Texas and southeastern New Mexico contains the Midland Basin, Delaware Basin, Pecos Basin, Central Basin Platform, Val Verde Basin, Ozona Arch, and the northwestern, northern, and eastern shelves. (*Source: US Geological Survey*)

Undiscovered Resources* of the Permian Basin

	Oil (MMbbl)	Gas (Bcfg)	NGL (MMbbl)
Total Conventional Resources	747	5,196	236
Total Continuous Resources	510	35,388	785
Total Undiscovered Oil and Gas Resources	1,257	40,584	1,021

*Mean Values
(Source: US Geological Survey)

at the southern margin on the North American craton. It was filled with Paleozoic sediments along with younger sediments to a lesser extent, according to Mahlon M. Ball in the "National Oil and Gas Assessment" report by the US Geological Survey (USGS) in 1995. Its current structural form was developed by Early Permian time.

This massive feature is one of the largest structural basins in North America. Ball reported it has an aerial extent of approximately 260 miles by 300 miles and encompasses a surface area that exceeds 86,000 sq miles. It includes the Texas counties of Andrews, Borden, Crane, Dawson, Ector, Gaines, Glasscock, Howard, Loving, Martin, Midland, Pecos, Reeves, Terrell, Upton, Ward, and Winkler.

Major subdivisions in the basin are identified as the Northwest Shelf Delaware Basin, Central Basin Platform, Midland Basin, Val Verde Basin, and Eastern Shelf.

Although the Permian Basin, in the structural sense, lies beneath the surface, a large part of it occurs beneath two topographical highs:

- The northwest part of the Edwards Plateau in south central Texas; and
- The Llano Estacado (Staked Plains: named by early Texas explorers who placed marker stakes to avoid losing their way on the flat land).

Overall, the Permian Basin is separated into eastern and western halves by the north-south trending Central Basin Platform, according to Ball. He noted that in cross section, the basin appears as an asymmetrical feature, with the western half harboring a thicker and more structurally deformed sequence of sedimentary rock.

In the structural sense, Ball noted the Permian Basin is bounded by:

- Marathon-Ouachita Fold Belt on the south;
- Diablo Platform and Pedernal Uplift on the west;
- Matador Arch on the north; and
- Eastern Shelf of the Permian Basin and west flank of the Bend Arch on the east.

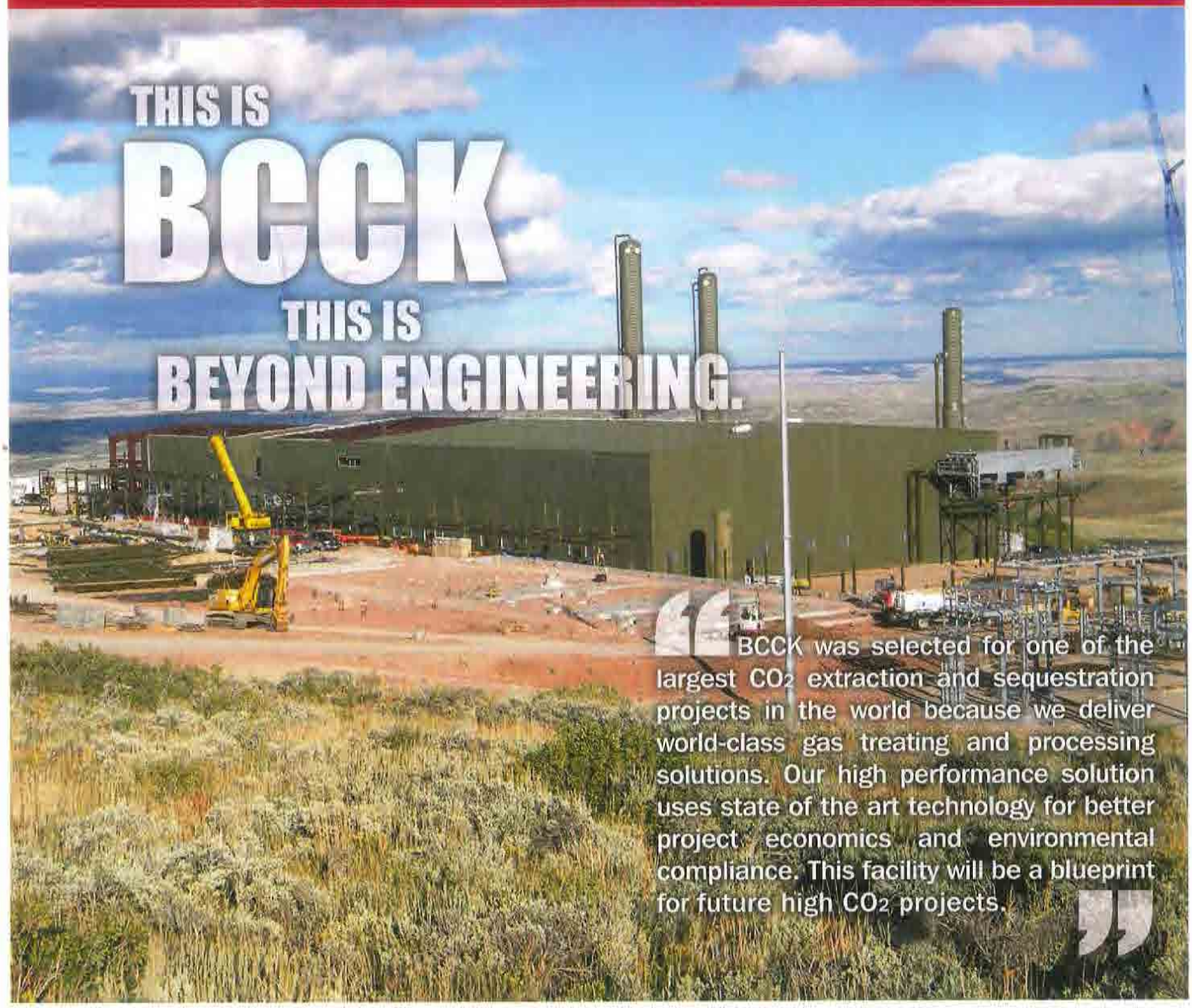
Reservoirs group naturally into plays

The Permian Basin mainly is a carbonate province where carbonate reservoirs account for 75% of total oil production; clastics, 14%; mixed clastics and carbonates, 8%; and chert, 3%, according to a study funded by the Department of Energy (DOE). The 2004 study, "Play analysis and leading-edge oil-reservoir developments in the Permian Basin: Increased recovery through advanced technologies," was a collaboration between scientists at the Bureau of Economic Geology (BEG), Jackson School of Geosciences, University of Texas at Austin, and the New Mexico Bureau of Geology and Mineral Resources. Shirley Dutton, senior research scientist at the BEG, was principal investigator for the project.

Original oil-in-place in the basin was estimated to be 106 Bbbl, and an estimated 30 Bbbl of unrecovered mobile oil remained as of 2002, according to the study's findings. About 80% of significant-sized oil reservoirs in the Permian Basin produce from depths less than 10,000 ft.

Because so much oil likely remains, a new oil-play portfolio of the Permian Basin was devel-

BCCK'S CO_2 TECHNOLOGIES GO BEYOND ENGINEERING.



GAS TREATING AND PROCESSING. SOLUTIONS. NITROGEN, HELIUM, COAL MINE METHANE, CO_2 TECHNOLOGY. BEYOND ENGINEERING.

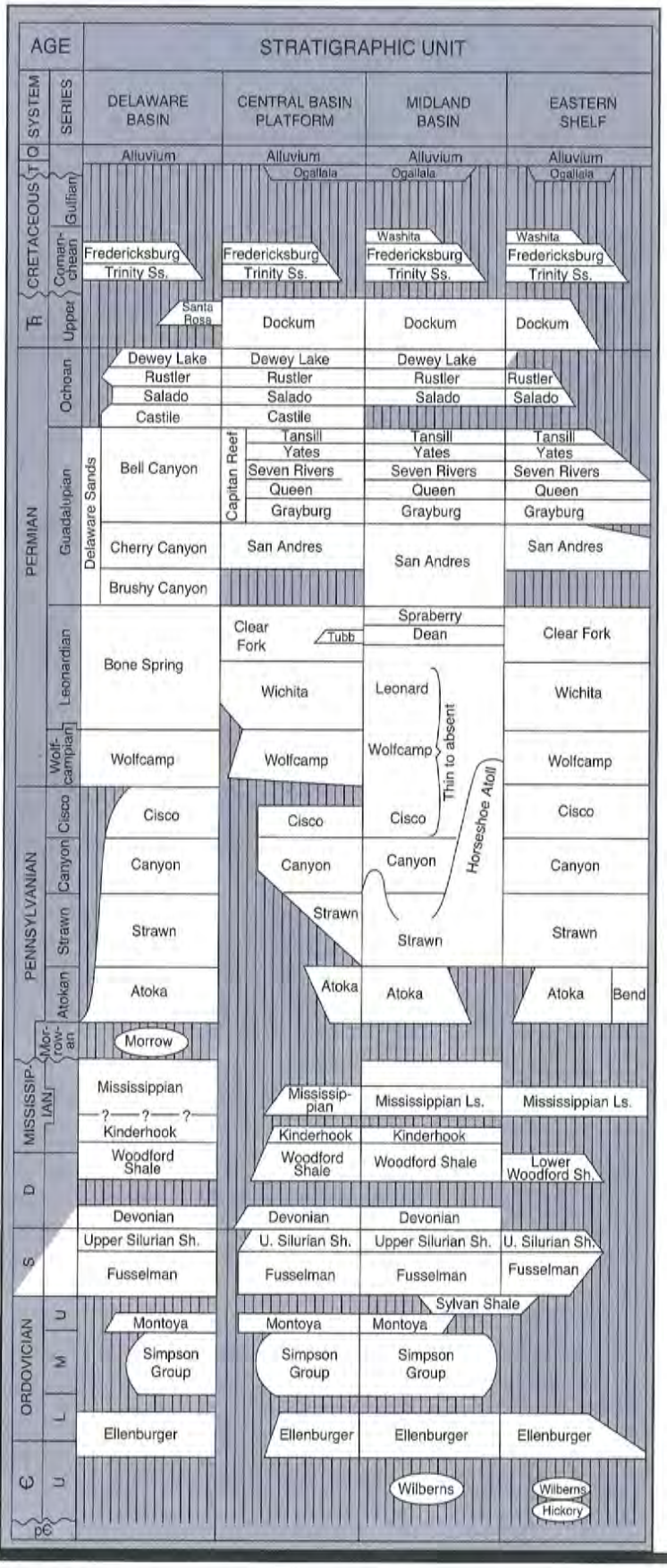
BCCK Engineering, Inc. was chosen to design and build one of the world's largest CO_2 extraction and sequestration plants for processing and treating this high CO_2 natural gas stream. The facility, which overlooks Big Piney, Wyoming, is designed for an inlet flow rate of 200 MMSCFD and uses process technology developed by BCCK engineers. Along with CO_2 removal and sequestration, the facility includes nitrogen rejection/helium extraction using BCCK's patented Nitech™ NRU process.

The facility will produce two revenue streams, crude grade helium and natural gas. Helium, which is a high value commodity, will be transported to a nearby purification and liquefaction plant.

Big Piney will be one of the largest plants of its type in the world and will rely on BCCK developed technologies, including the patented Nitech™ NRU technology. BCCK was selected for the project based on the ability of the company to provide an overall process solution that cleared the economic hurdles of the project while also meeting the environmental requirements.

BCCK ENGINEERING, INC.

2500 North Big Spring, Suite 230 • Midland, Texas 79705 • 432.685.6095 • 888.518.6459 • www.bcck.com



Stratigraphy of the Permian Basin. *(Source: US Geological Survey, by M.M. Bell)*

oped as part of the DOE Preferred Upstream Management Practices Program. The portfolio includes the entire basin and geologically defines 32 distinct oil plays ranging in age from the Ordovician through the Upper Permian Guadalupian epoch. The variance in number of plays per geologic age group is considerable, ranging from one Mississippian-age play to 13 plays in the Upper Permian (Guadalupian).

Over the course of the study, researchers identified 1,330 significant-sized oil reservoirs and assigned each to a play.

The underlying factor is that a hydrocarbon reservoir is not an isolated occurrence. The 2004 study noted that reservoirs group together naturally into larger assemblages or plays where individual yet similar reservoirs are related geologically, demonstrating same source and trap characteristics and, in turn, similar production characteristics.

As a result, reservoir development methods that have proved to work successfully in one reservoir should be applicable to other similar reservoirs in the play.

It is anticipated that the bulk of future production in the basin will occur by improved recovery from existing fields. The ability to extrapolate characteristics of better known reservoirs to other reservoirs in the same play likely will go far to make the oil players' jobs more straightforward.

The 2004 study determined that the largest plays relative to cumulative production are the Northwest Shelf San Andres platform carbonate play of Guadalupian age (4 Bbbl), the Lower

Premium Grade Sucker Rods

API Grade D

- **CD – Carbon D**
  Average: Tensile 121,937 psi, Yield 88,920 psi
- **AD – Alloy D**
  Average: Tensile 132,025 psi, Yield 106,954 psi
- **KD – Special D**
  Average: Tensile 124,979 psi, Yield 91,580 psi

High Strength

- **SD – Super D**
  Average: Tensile 139,966 psi, Yield 108,058 psi
- **HS – High Strength**
  Average: Tensile 146,030 psi, Yield 119,858 psi
- **HX – Extra High Strength**
  Tensile 140/160,000 psi, Yield 115,000 psi Min.

UPCO, Inc.
PO Box 725
Claremore, OK 74018
888-364-UPCO (8726)
www.upcoinc.com
dbugg@upcoinc.com

UPCO

UPCO Permian Basin
Distribution Center
12506 W Hwy 80 East
Odessa, TX 79765
432-617-0408

Permian Leonardian-age Leonard restricted platform carbonate play (3.3 Bbbl), the Pennsylvanian-age Pennsylvanian and Lower Permian Horseshoe atoll carbonate play (2.7 Bbbl), and the Guadalupian-age San Andres platform carbonate play (2.2 Bbbl).

Percentage-wise, Upper Permian Guadalupian-age reservoirs are the winners when it comes to cumulative oil production in the basin (54%), followed by Lower Permian Leonardian (18%) and Pennsylvanian-age reservoirs (13%).

Reservoir development methods can be esoteric

The Permian Basin is reported to contain 29% of estimated future oil reserve growth in the US. Most of this is expected to come via application of improved reservoir techniques. There are many newly implemented techniques currently being used across the basin.

Harking back to the definition of a play, recovery methods that work well in one reservoir in a play should be applicable to the other reservoirs.

Many reservoirs in the Permian Basin produce by solution gas drive yielding typically low primary recovery efficiencies. Average primary recovery in certain of the basin's reservoirs characterized by solution gas drive was 14.8%.

Secondary recovery via waterflooding has long been used in this region and heads the list of most common reservoir development methods. Where used to supplement solution gas drives, these floods increase recovery efficiencies considerably.

CO_2 flooding (currently via horizontal injection wells in many cases) also has been applied successfully for some time in the basin.

The basin is a longtime industry leader in the use of secondary and tertiary CO_2 flooding operations, with the process accounting for 750 MMbbl cumulative production and growing by more than 60 MMbbl of oil annually, according to Ball.

He also noted that technology for transporting, injecting, and processing CO_2 provides 450 Bcf, or 25 million tons, per year of "new" CO_2 as well as processing and reinjecting 550 Bcf, or 31 million tons, annually.

CO_2 has proven to work efficiently in many plays, including the Pennsylvanian and Lower Permian Horseshoe atoll carbonate, San Andres platform carbonate, Grayburg platform carbonate, Devonian Thirtyone deepwater chert, and Delaware Mountain Group basinal sandstone. Reservoirs in these plays harbor clear target intervals with adequate seals.

CO_2 floods tend to be less effective in plays with highly fractured, bottom-water-drive reservoirs; e.g., the San Andres karst-modified platform carbonate and the Ellenburger limestones.

Sometimes operators throw the proverbial book of enhanced methods at a field. This was the case at the Yates Field, which was subjected to gravity drainage assisted by nitrogen and CO_2 injection, water coproduction, and steam injection.

There are plenty more tools in the enhanced recovery kit.

High-pressure air injection used in low-permeability reservoirs has been tested in Barnhart Field in the Ellenburger selectively dolomitized ramp carbonate play. Artificially created, downhole high-energy, low-frequency shockwaves designed to coalesce and allow bypassed oil to be swept to producers have been tested in the Wasson South Clearfork unit (Wasson 72 Field, Leonard restricted platform carbonate play).

There's also activity in the basin targeting bypassed pay identified by 3-D seismic attribute analysis.

Permian Basin still attracting experts

The Permian Basin is a big petroleum-rich region boasting still-sizeable volumes of hydrocarbon production, but can it really go on forever?

This behemoth play clearly keeps chugging along. The still-undiscovered oil and gas is estimated to be considerable.

The "USGS Assessment of Undiscovered Oil and Gas Resources of the Permian Basin Province of West Texas and Southeast New Mexico 2007" report estimated a mean of 41 Tcf of undiscovered natural gas and a mean of 1.3 Bbbl of undiscovered oil in the Permian Basin province.

Oil Plays of the Permian Basin

Play	State	2000 Prod (bbl)	Cu m Prod (bbl)
Permian			
Guadalupian			
Artesia platform ss	TX, NM	6,526,676	1,855,409,025
Queen tidal-flat ss	TX	1,517,501	179,600,165
Delaware Mtn Group, basinal ss	TX, NM	9,208,247	351,912,395
Grayburg high-energy platform carbonate, Ozona Arch	TX	1,968,685	298,378,769
Grayburg platform carbonate	TX	10,104,204	1,271,232,325
Grayburg platform mixed clastic-carbonate	TX	7,806,840	669,727,337
San Andres–Grayburg lowstand carbonate	TX	9,357,241	681,131,877
U San Andres and Grayburg platform mixed, Artesia-Vacuum	NM	11,392,997	796,416,386
U San Andres and Grayburg platform mixed, Central Basin Platform	NM	5,790,360	808,957,693
San Andres platform carbonate	TX	26,420,818	2,151,296,650
San Andres karst-modified platform carbonate	TX	11,460,129	1,567,103,814
E Shelf San Andres platform carbonate	TX	6,613,837	706,897,011
NW Shelf San Andres platform carbonate	TX, NM	50,666,870	3,969,256,500
Leonardian			
Spraberry–Dean submarine-fan ss	TX	27,576,283	1,287,098,237
Bone Spring basinal ss and carbonate	NM	2,455,154	70,703,460
Leonard restricted platform carbonate	NM	49,928,957	3,297,197,998
Abo platform carbonate	TX, NM	6,105,583	541,459,683
Wolfcampian			
Wolfcamp–Leonard slope and basinal carbonate	TX, NM	9,093,948	195,077,551
Wolfcamp platform carbonate	TX, NM	4,012,646	457,405,339
Pennsylvanian			
U Penn and Lower Permian slope and basinal ss	TX	1,802,373	271,448,389
Penn and L Permian Horseshoe atoll carbonate	TX	13,686,639	2,699,242,936
Penn platform carbonate	TX	2,076,281	340,469,274
NW Shelf upper Penn carbonate	NM	4,883,971	353,848,173
NW Shelf Strawn patch reef	NM	1,539,376	70,337,831
Penn and L Permian reef and bank	TX	315,183	92,104,283
Upper Penn shelf ss	TX	426,556	7,264,141
Mississippian			
Miss platform carbonate	TX	91,765	15,110,822
Devonian			
Devonian Thirtyone ramp carbonate	TX	1,747,319	110,249,504
Devonian Thirtyone deepwater chert	TX, NM	6,786,521	785,929,988
Silurian			
Wristen buildups and platform carbonate	TX, NM	4,773,912	888,757,885
Fusselman shallow-platform carbonate	TX, NM	2,046,889	356,268,389
Ordovician			
Simpson cratonic ss	TX, NM	420,651	103,228,356
Ellenburger karst-modified restricted ramp carbonate	TX, NM	2,802,096	1,487,309,287
Ellenburger selectively dolomitized ramp carbonate	TX	537,120	163,734,910
		301,943,628	**28,901,566,384**

(Source: Modified from Dutton et al, 2004)

Oil Recovery Techniques Applied to Permian Basin Plays

Play	Reservoir Techniques
Permian	
Abo platform carbonate	Selective perforation to prevent coning of gas
Artesia platform ss	Improved waterflooding; CO_2 flooding
Bone Spring basinal ss and carbonate	Limited entry, two-stage stimulation
Delaware Mtn Group, basinal ss	CO_2 flooding; Hz and vertical wells drilled on 3-D siesmic attributes
E Shelf San Andres platform carbonate	Tiltmeter fracture mapping to establish waterflood pattern orientation, spacing, injection rates
Grayburg high-energy platform carbonate, Ozona Arch	Infill drilling; CO_2 flooding; Hz CO_2 injection wells; Drilling by-passed pay
Grayburg platform carbonate	Infill drilling; CO_2 flooding, Hz CO_2 injection wells; Drilling by-passed pay
Grayburg platform mixed clastic-carbonate	Strategic plugbacks; Infill drilling; Hz drilling
Leonard restricted platform carbonate	Targeted infill development; Drilling lateral waterflood wells; Sinusoidal hz drilling, Shockwaves
NW Shelf San Andres platform carbonate	CO_2 flooding
Queen tidal-flat ss	Drilling by-passed pay on 3-D seismic attributes
San Andres karst-modified platform carbonate	Gravity drainage assisted by nitrogen injection; Water coproduction; Steam injection
San Andres platform carbonate	CO_2 flooding
San Andres–Grayburg lowstand carbonate	CO_2 flooding
Spraberry–Dean submarine-fan ss	Waterflooding using low-rate water injection
U San Andres and Grayburg platform mixed, Artesia-Vacuum	CO_2 flooding; Multilateral serpentine hz wells
Wolfcamp platform carbonate	Hz drilling
Wolfcamp–Leonard slope and basinal carbonate	Drilling channel facies on 3-D seismic data
Pennsylvanian	
Penn and L Permian Horseshoe atoll carbonate	CO_2 flooding
Devonian	
Devonian Thirtyone ramp carbonate	Hz drilling
Devonian Thirtyone deepwater chert	CO_2 flooding; Tertiary infill drilling and CO_2 injection; High-pressure, lean gas injection
Silurian	
Fusselman shallow-platform carbonate	Recompletions and infill drilling
Ordovician	
Ellenburger karst-modified restricted ramp carbonate	Selective recompletions
Ellenburger selectively dolomitized ramp carbonate	High-pressure air injection

(Source: Modified from Dutton et al, 2004)

MITIGATION SOLUTIONS USA

A Turnkey Approach To Environmental Credits

We move you *forward*, because slowing down is not an option.

Our mitigation banks in Texas and Arkansas offer stream and wetland mitigation credits to help offset environmental impacts, allowing companies to quickly move forward with projects.

We partner with your company to help you comply with state and federal regulations efficiently and effectively – so you can get back to doing what you do best – supplying the energy to fuel the world.

Mitigation Banks Currently Being Permitted

TEXAS

Daisetta Swamp, Liberty County
Wetland Credits: 1,170 FCUs

Fall Off Creek, Coryell County
Wetland Credits: 500 FCUs
Stream Credits: Phase I: 170,000;
Phase 2: Approximately 370,000

Keystone, Rains County
Wetland Credits: 5,600 FCUs
Stream Credits: 230,000

ARKANSAS

Davis Creek, Searcy County
Wetland Credits: 25
Stream Credits: 171,000

Dutch Creek, Yell County
Wetland Credits: 500
Stream Credits: 600,000

Hartsugg Creek, Van Buren County
Stream Credits: 90,000

South Fork, Van Buren County
Stream Credits: 290,000

**Projected credits are approximate.*

For information about our banks, including upcoming ones in Oklahoma and Northwest Louisiana, contact us:

Toll-free
888-838-0881

Houston Headquarters
713-812-9000

Longview Branch
903-754-6139

Web
www.mitigationsolutionsusa.com

Email
terry@mitigationsolutionsusa.com
troy@mitigationsolutionsusa.com

Social Media
Facebook: mitigationsolutions
LinkedIn: msusa
Twitter: MitigationUSA

Undiscovered natural gas liquids (NGLs) tallied a mean of 1 Bbbl.

The agency outlines the province as being comprised of the Midland Basin, Delaware Basin, Pecos Basin, Central Basin Platform, Val Verde Basin, Ozona Arch, and the Northwestern Shelf, Northern Shelf, and Eastern Shelf.

The USGS is mandated by law from the Energy Policy Conservation Act of 2000 to provide these types of assessments of 32 priority basins in the US, according to USGS geologist Rich Pollastro. He noted that these priority basins hold about 96% to 98% of the known oil and gas resources for the US. They are prioritized based on resource potential and federal land percentage.

The assessments use a geology-based assessment methodology based on geologic elements of a total petroleum system (TPS) that includes:

- Petroleum source rocks (quality, source rock maturation, generation, and migration);
- Reservoir rocks (sequence stratigraphy and petrophysical properties); and
- Traps (trap formation and timing).

For the Permian Basin, this assessment methodology resulted in identification of a Paleozoic composite TPS encompassing 31 assessment units (AU). A quantitative estimate was made of the undiscovered oil and gas resources within 30 of the AUs.

The USGS study assessed the potential for technically recoverable resources in new field discoveries only. Field growth, or reserve growth, of conventional oil and gas fields was not addressed.

For the first time, the agency defined continuous (unconventional) AUs in the Permian Basin province:

- Spraberry Continuous Oil AU;
- Woodford-Barnett Continuous Gas AU;
- Delaware-Pecos Basins Woodford Continuous Shale Gas AU;
- Delaware-Pecos Basins Barnett Continuous Gas Shale AU; and
- Delaware Basin Wolfcamp Shale AU.

The assessment noted that the major portion of undiscovered natural gas in the province is estimated to be in three continuous AUs of the Delaware and Midland basins. Approximately 35 Tcf of gas of the total mean of 41 Tcf of gas in the province is estimated to be in these three AUs. Given that few wells have produced from these AUs, there is geologic uncertainty in the estimates, the USGS noted.

Regarding unconventional oil resources, the estimated mean was 510 MMbbl of oil in the Spraberry Continuous Oil AU in the Midland Basin.

Chris Schenk, project chief with the USGS, commented that the greatest potential for the Permian is located in unconventional reservoirs, emphasizing that the current active Wolfberry play surrounding Midland would qualify as an unconventional resource.

This new play uses specially designed slickwater fracs to coax oil from the mostly packed-limestone Wolfcamp Formation and commingling it with that from the overlying Spraberry sandstone. The Spraberry overall is a tight sand with isolated sandstone zones that are conventional pays. It has long been looked on as a formation where one can punch a well in almost any locale and essentially be guaranteed to tap into what can be middling production volumes, at the least, that have the potential to keep going for innumerable years.

Regarding conventional resources, the estimated means were reported by the USGS to be 747 MMbbl of oil, 5.2 Tcf of gas, and 236 MMbbl of NGLs in 26 AUs.

Schenk emphasized that although conventional reserves have declined in the Permian Basin, there is growth potential for reserves within existing fields.

He noted that the Permian Basin probably is the leading basin in the world in field growth, owing to new technologies such as horizontal drilling and improved fracturing techniques along with growth produced by secondary and tertiary recovery efforts.

Although the USGS study on new field discoveries doesn't report on reserve growth, Schenk noted such growth is "key to the Permian Basin." A combination of potential reserve growth and unconventional resources leaves little doubt this region will continue to be a hydrocarbon production leader in the US for many more years. ■

Unconventional Plays Pep Up the Permian

Wolfberry, Avalon Shale/Bone Spring plays spur increased activity.

By Al Pickett
Contributing Editor

Poke a hole and "out through the ground comes bubbling crude."

Obviously, drilling for oil and gas never has been quite that easy, but it must look that way to outsiders observing the industry in the sprawling Permian Basin.

This semiarid region, the nation's largest and most prolific basin that has been producing billions of barrels of oil for nearly 90 years with vertical wells in traditional reservoirs, stretches across 102,000 sq miles over much of West Texas and four counties in southeastern New Mexico. But the current explosion of unconventional drilling activity in the country now has reached the Permian Basin, which still has more than 150,000 active producing wells and provides 72% of the oil production in Texas and 13% of US domestic oil production as well as 67% of casinghead gas, 13% of well gas, and 8% of the condensate produced in Texas annually, according to statistics compiled by the Railroad Commission of Texas.

Unconventional resource plays usually mean horizontal drilling, but not in the hottest "new" play in the Permian Basin, which is known as the "Wolfberry" for its commingling of the more traditional Spraberry and Wolfcamp formations. The Permian Basin also is home to a new horizontal play known by several names, including the Avalon Shale, the Bone Spring, or the Leonard Shale in southeastern New Mexico. The Permian Basin has received a remarkable rejuvenated boost from these latest unconventional plays.

The name of the game in today's unconventional wells is "contacting more pay," according to Jeff Fisher, senior vice president of production for Chesapeake Energy Corp.

"Stimulating more rock area to be able to contact more of the reservoir is really the key," he said, citing the role that hydraulic fracturing has played in the enormous increase in unconventional drilling activity across the country. "Bust more rock and that means bigger drainage capacity," Fisher said. "Bigger frac jobs mean bigger pay zones. The Barnett Shale (in the Fort Worth Basin of Texas, which is considered the granddaddy of today's shale gas plays) gets credit for developing horizontal drilling and multistage completions. Now, that technique has gone nationwide, and maybe worldwide."

The large multistage fracs that were developed in the Barnett Shale now are being used in the Permian Basin, but differently in the Wolfberry play.

'Discovering' the Wolfberry

"The beauty of the Permian Basin is you are not looking at one zone," said Ross Craft, president and CEO for Approach Resources.

The ability to use multistage fracs on multiple zones in vertical wells and then commingling those zones is the secret to the Wolfberry, as well as other plays in the Permian Basin.

Dave Feavel, now a partner in ExL Petroleum, received the Hearst Energy Award in 2009 for his role in the development of the Wolfberry play.

"I've been credited with opening it up," Feavel said, who was exploration manager for Henry Petroleum at the time of the "discovery." "That is not

true, but I was in the room when the lights came on," he noted.

The Spraberry Trend has long been a target of Permian Basin operators. But when Feavel and the folks at Henry Petroleum figured out that the Wolfcamp Formation, which lies below the Spraberry, could be commingled with the Spraberry, as well as everything in between the two, including the Dean Formation, it changed the dynamics in the Permian Basin dramatically.

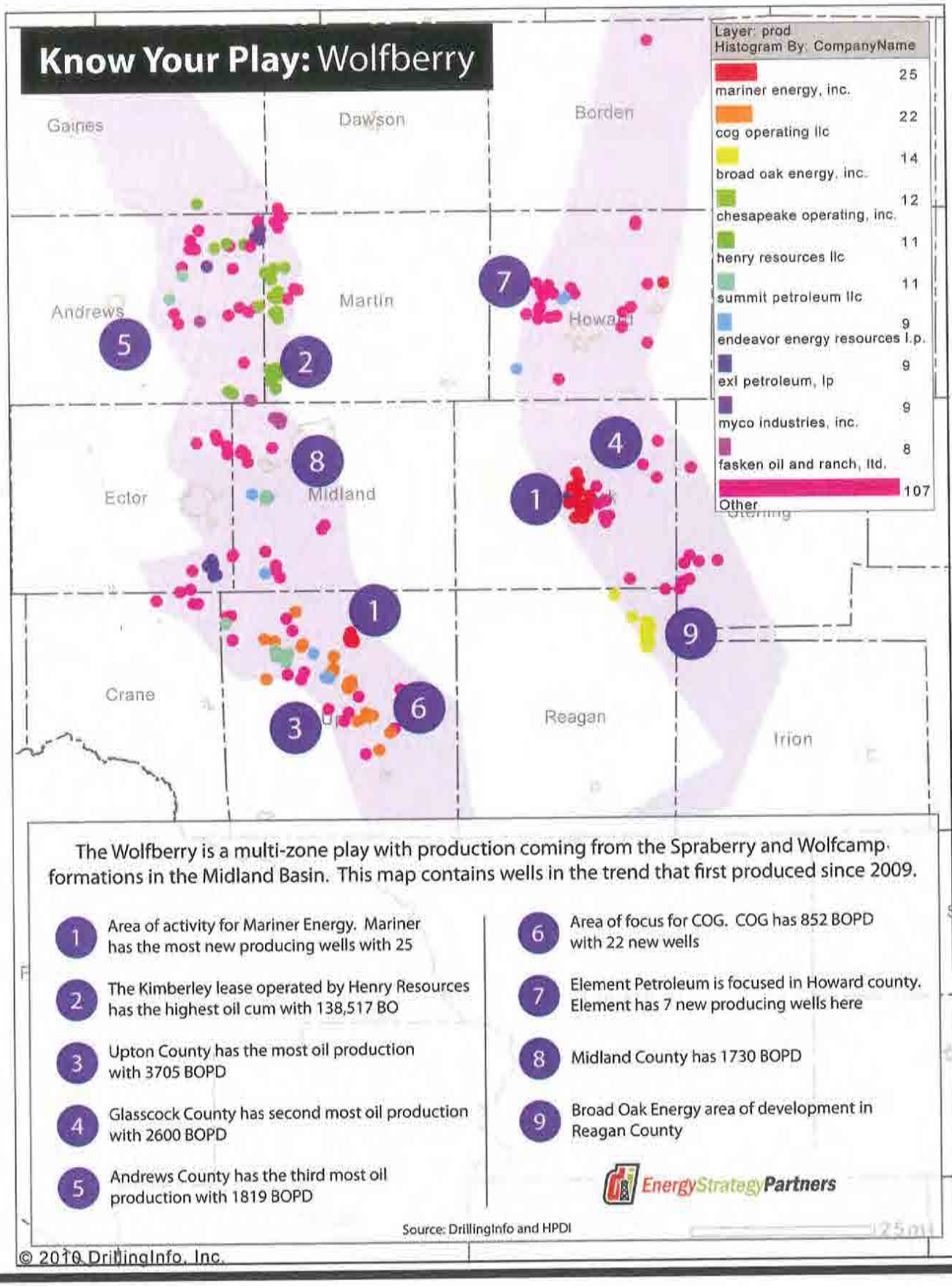
Tim Dove, president and COO for Pioneer Natural Resources Co., the largest operator in the Spraberry Trend with more than 900,000 acres under lease, pointed out that 292 rigs were running in the Permian Basin in August 2010 — a return to numbers equal to the pre-2008 economic downturn — with 145 of those operating in the Spraberry Trend, which reflects the burgeoning Wolfberry expansion.

"This is a very large field," Dove said. "There are 30 Bbbl of oil in play. Every one-percent increase in the recovery rate means 300 MMbbl. That is why you are seeing a dramatic ramp-up."

Feavel emphasized that the Wolfberry is the only oil resource play in the US other than the Bakken Shale in North Dakota and Montana. He said Henry Petroleum flew under the radar as it first began developing the Wolfberry.

"It was in the mid-1990s that Arco Permian got a big chunk of money (US $100 million) from Mother Arco (Atlantic Richfield) and took a big lease of acreage to the east of the Pegasus Field," Feavel said. He considers an understanding of what the logs were

Devon Energy has an active drilling program in the Wolfberry play. *(Photo courtesy of Devon Energy Corp.)*


Know Your Play: Wolfberry
Gaines
Dawson
Borden
Andrews
Martin
Howard
Ector
Midland
Crane
Reagan
Irion
Layer: prod
Histogram By: CompanyName
mariner energy, inc. 25
cog operating llc 22
broad oak energy, inc. 14
chesapeake operating, inc. 12
henry resources llc 11
summit petroleum llc 11
endeavor energy resources l.p. 9
exl petroleum, lp 9
myco industries, inc. 9
fasken oil and ranch, ltd. 8
Other 107
The Wolfberry is a multi-zone play with production coming from the Spraberry and Wolfcamp formations in the Midland Basin. This map contains wells in the trend that first produced since 2009.
1 Area of activity for Mariner Energy. Mariner has the most new producing wells with 25
2 The Kimberley lease operated by Henry Resources has the highest oil cum with 138,517 BO
3 Upton County has the most oil production with 3705 BOPD
4 Glasscock County has second most oil production with 2600 BOPD
5 Andrews County has the third most oil production with 1819 BOPD
6 Area of focus for COG. COG has 852 BOPD with 22 new wells
7 Element Petroleum is focused in Howard county. Element has 7 new producing wells here
8 Midland County has 1730 BOPD
9 Broad Oak Energy area of development in Reagan County
EnergyStrategyPartners
Source: DrillingInfo and HPDI
© 2010 DrillingInfo, Inc.

Horizontal Well Placement in the Permian Basin

In 9 months during 2010, the PowerDrive RSS and Periscope bed boundary mapper were used by teams in the Permian Basin to drill 25 wells with over 90,000 horizontal feet—94% in zone.

For more of the story, visit **www.slb.com/WellPlacement**

Global Expertise | Innovative Technology | **Measurable Impact**

Schlumberger

showing at the time, development of new technology and hydraulic fracturing techniques, and an existing Railroad Commission of Texas regulation as factors in unlocking the Wolfberry potential.

According to Feavel, Arco drilled 300 wells to approximately 10,000 ft, reaching the top 300 to 400 ft of the Wolfcamp. Among Arco's acquisition was what Feavel called the "Boultinghouse leases." He noted that Arco Permian drilled successful wells, but they weren't exceptional because they relied more on the Spraberry than the Wolfcamp.

Arco then sold out to BP, according to Feavel, and lost most of its technical people, including Dennis Phelps, the engineer in charge of the project, who retired and left Midland, Texas.

"Henry Petroleum at that time had taken over operation of the Pegasus and Parks leases in the Woodford (to the top of the Devonian) with Mobil," he added, "and we were always looking to enhance the zones above the Woodford."

About that same time, CMS Energy had bought leases from Arco and drilled several horizontal Devonian wells under Midland. CMS Energy, however, ran into financial troubles and approached Henry Petroleum to take over some of its locations in an effort to maintain the leases despite financial woes, according to Feavel. CMS Energy made a deal with Jim Henry, now president of Henry Resources who was Feavel's boss at Henry Petroleum at the time. Henry chose 14 of CMS's 25 160-acre tracts, and Phelps came back to work as a consultant with Henry to help with the project.

Before the sale to BP, Arco also had purchased 10 sections to the south and west of Pegasus Field, which BP retained. BP drilled five wells with "underwhelming results," according to Feavel.

"I went into the log files," he said, "and Dennis Phelps went into the completion files. We found BP had massively understimulated the wells on those 10 sections. We created a rating of how badly the wells were stimulated. Henry made a deal with BP and got those 10 sections. They had drilled five wells that made a total of 150 b/d of oil at their peak and then fell off. Our first offset well produced 150 b/d."

Henry, a long-time Permian Basin operator based in Midland, began drilling the locations acquired from CMS in late 2001. About that same time, the logs for the Boultinghouse leases were released.

"When I saw the Boultinghouse logs, I knew what I was looking at and where [the potential Wolfberry combination] was situated on the shelf edge," Feavel said. "I told the geologists, 'I know it's here, we just have to put it on the map.' So we laid out a trend that ran from the South Basin fault around Rankin over to Castle Gap and then up to Odessa. Once the light came on, I knew what we were looking at because I had been here so long."

The Wolfberry play includes a 2,000- to 3,000-ft section from the top of the Spraberry zone to the bottom of the Wolfcamp. The Wolfcamp, which Feavel calls the "key to the Wolfberry," is about 1,500 ft thick.

"Back in the 1960s, the old-time drillers in the Spraberry Trend liked to drill a few hundred feet into the Upper Wolfcamp," he said. "They called it the Wolfcamp Sands and tried to add that to the Spraberry."

Because of that, under existing Railroad Commission of Texas rules, operators are allowed to drill into the Wolfcamp and commingle the Spraberry and Wolfcamp.

"There was another 1,500 ft of the Wolfcamp, but the rules didn't say anything about that," Feavel said. "As a result, no one paid attention to us since we were a well-known Spraberry Trend driller."

That allowed Henry Petroleum to drill and acquire additional acreage without drawing any attention. It amassed 75,000 acres that first year. By the time he left Henry in August 2005 to help found ExL, Feavel said Henry had drilled 200 wells in the Wolfberry play.

Expanding the Wolfberry

Jim Henry has twice sold his company's positions in the Wolfberry as activity in the play has mushroomed since Henry Petroleum's low-profile start nine years ago.

Midland-based Concho Resources Inc. acquired Henry Petroleum's Wolfberry holdings of 163 Bcf of equivalent of proved reserves (70% oil, 62% proved developed) as well as current production of approximately 33 MMcf/d and 282 Bcf of identified unproved reserves for $56 million in cash in 2008.

Henry then formed Henry Resources and continued to drill in the Wolfberry. In May 2010, Linn Energy LLC acquired acreage in the heart of the Wolfberry from Henry Resources for $305 million. The Henry property had 2,800 boe/d midyear 2010 net production. That came on the heels of Linn's $118 million acquisition of Forest Oil Corp. in August 2009 and a $154.5 million acquisition of Permian Basin and Midcontinent properties from Merit Resources that included 9 MMboe of proved reserves and 1,100 boe/d of production in the Permian Basin.

In August, Linn made another acquisition from an undisclosed operator for $90 million that had 950 boe/d average net production from July to September. In September, Linn Energy announced that it had signed three more definitive purchase agreements to acquire oil and natural gas properties located in the Wolfberry trend of the Permian Basin for a combined price of $352.2 million.

"We have acquired a good position in a short period of time," said Mark Ellis, president and CEO for the company. Linn Energy now is producing an estimated 6,000 boe/d in the Permian Basin, but Ellis believes that will grow to 10,000 boe/d by 2011. He said Linn has 76,000 gross acres total in the Permian Basin, prior to its most recent acquisition in September, with 13,000 gross and 11,000 net acres in the Wolfberry play.

Ellis added that Linn Energy's proved reserves are now more than 7 MMboe with a high liquids content of approximately 76%, and are 41% proved developed.

"Since our first Permian acquisition in August 2009, we have built this region into the company's second largest operating area," Ellis said. "An important component of our organic growth will be derived from approximately 400 proved oil-focused Wolfberry drilling opportunities."

COG Operating, a division of Concho Resources, has continued actively drilling in the Wolfberry since acquiring Henry Petroleum's holdings in the play.

"The Henry team had drilled 600 wells in the Wolfberry before the acquisition," said Jack Harper,

A rig drills for Pioneer Natural Resources in the Wolfberry play in the Permian Basin. *(Photo courtesy of Pioneer Natural Resources Co.)*

vice president of capital markets and business development for Concho. "We will have drilled over 1,000 wells by the end of this year. It is good economics. The Wolfberry is like our Yeso play in New Mexico, you can turn it into a manufacturing phase. That is what we like."

According to Harper, Concho has 25 rigs running in the basin, 17 of which are involved in the Wolfberry where it has 50,000 net acres. Concho is drilling on 40-acre spacing in the Wolfberry with typical wells producing 100 boe/d. He said the company has 1,500 identified drilling locations in the Wolfberry.

Now, more than 75 companies are actively drilling in the Wolfberry, which runs through the heart of the Permian Basin. The western flank, which has produced most of the sweet spots, extends about 100 miles long and approximately 15 miles wide from Upton County, Texas, south of Midland, to Andrews County, Texas, which is northwest of Midland. Wolfberry wells are producing in Upton, Midland, Ector, Crane, Andrews, and Martin counties on the western flank. There also is an eastern flank to the play that includes portions of Reagan, Glasscock, Sterling, and Howard counties. It is estimated that oil companies have spent more than $7 billion drilling Wolfberry wells to date.

"The Wolfcamp is certainly a reservoir we have known about," said Don D. DeCarlo, senior vice president of the Western Division for Devon Energy Corp. "But the addition of the Wolfcamp to the Spraberry, improved completion technology, lowered costs, and the improvements in oil prices have all contributed to the development of the Wolfberry. Our acreage tends to be in the western portion, so the Wolfcamp is a substantial portion of our production. The addition of the Wolfcamp and the new frac technology has given us enough reserves to make it worth our while to drill."

Going deeper

Since Henry's first foray into commingling the Spraberry and Wolfcamp formations, other companies are taking the Wolfberry a step further.

For example, Pioneer has discovered that there are additional pay zones, including the Dean Formation that lies between the Spraberry and Wolfcamp, as well as overlapping layers of shale and silt that previously were thought to be unproductive. Pioneer also is drilling as deep as 11,000 ft into the Strawn Formation and fracing and commingling as many as 10 to 12 zones in the vertical wells. Dove said the Strawn is not available in all of Pioneer's leasehold, estimating only 30% to 40% of its acreage will include production from the Strawn zone.

Approach Resources employees discuss the company's unconventional operation in the tight Canyon sands in Ozona Northeast Field in Crockett County, Texas. *(Photo courtesy of Approach Resources)*

FMC Technologies

Boost your performance, savings & safety with our surface wellhead technology.

FMC Technologies has improved surface wellhead reliability by applying advanced sealing technology often used in our subsea applications. We have eliminated steps in drilling and completion, to help you save rig time and maximize crew safety. And our strategically located manufacturing facilities and service bases ensure that you get what you need the minute you need it. So don't settle for average when you can economically boost long-term reliability, time savings and safety with a single call to FMC Technologies.

We put you first.
And keep you ahead.

www.fmctechnologies.com

Chesapeake, which has approximately two-thirds of its 900,000 acres in the Permian Basin in "a nice position in the Wolfberry," according to Fisher, also has started drilling deeper in its most recent Wolfberry wells to include the Strawn and Atoka formations that lie below the Wolfcamp.

"We have been expanding our completion design to open up more pay," Fisher said. "We have identified additional pay zones, so we are deepening our new wells."

He said the company has seven operated rigs in the Permian Basin, which includes three in the Wolfberry.

Multistage fracs

Companies involved in the Wolfberry credit improved stimulation as a critical factor in the success of the play.

"In the 1980s, people started putting on unbelievable frac jobs in the Spaberry that required five or six times as much space," Feavel said. "It became apparent that the desire was to treat wells this way. So pump companies responded with new technology. They developed what they call the 'gorilla pump' that fits everything needed in a standard location at a lower cost. You went from $2 million, inflation adjusted, to less than $0.5 million today. That is a huge benefit. We can do a 10-stage frac now for $50,000/frac or a total of a half-million dollars."

DeCarlo said Devon is doing eight to 10 fracs/well, using smaller intervals. "We are spending a lot of these fracs," he said. "In fact, half the cost of these wells is spent on completion costs. Depending on the situation, there is not a lot of primary porosity in the Wolfcamp."

In those instances in which there is high porosity in the Wolfcamp, Devon has produced some impressive results. For example, Devon's Helen Crump B-11 well in Odessa South came online flowing over 500 boe/d, according to DeCarlo.

Harper agreed that the completion techniques that have evolved into eight to 10 stages per vertical well are the "biggest component of what has made the Wolfberry play successful."

Dove called the Wolfberry play an "application of technology."

Devon drilled to the Wolfberry combination at its Janice well near Midland, Texas. *(Photo courtesy of Devon Energy Corp.)*

"It is the number of fracs – not the size of the fracs – and the depth of the wells," he said when discussing the role that stimulation has had in the Wolfberry success. "We are not completing the wells any differently. The success of these wells is based on more frac stages into deeper well bores."

For example, Dove said the "old" Wolfberry wells cost about $1 million, involved five frac stages, made 60 b/d initial production (IP), and declined after that with an estimated reserve of 120,000 boe.

According to Dove, the new deeper Wolfberry wells, which include the Strawn interval, cost $1.3 million, have 10 to 12 frac stages, and produce 20% to 30% more IP than the 60 and 120,000 boe ultimate return.

Pioneer expected to drill 445 wells in 2010, 700 wells in 2011, and 1,000 wells in 2012. Dove said the company is planning two other projects in the Spraberry Trend. It is experimenting by drilling two horizontal wells in the last half of 2010.

"We can isolate certain stages of the horizontal lateral," he said. "We are also reinstituting a water flood in a 7,000-acre project in the Spraberry Trend."

He said Pioneer will use 40-acre spacing in the waterflood with 12 injectors and 156 producing wells, even though Railroad Commission of Texas field rules now have changed to allow 20-acre spacing.

Ellis said Linn Energy, with its most recent acquisitions, now has more than 400 drilling locations identified in the Wolfberry, which he calls a five-year inventory with three rigs currently running in the play.

"We are currently drilling on 40- and 80-acre spacing," he said. "If that goes to 20-acre spacing, those numbers will double. It is very attractive."

Feavel said pump companies now can create 12 different frac planes to cover the 2,000-ft section of the Wolfberry pay zone. "Engineering is always tinkering with ways to cut costs," he said.

Feavel contended that it also is important to realize that the Wolfberry declines quickly after being fraced, but then levels off and offers long-lived production.

"After the initial potential, the Wolfberry wells make a small amount of oil and a lot of water," he explained. "A month later, it will flip-flop and make 90% oil and 10% water."

Feavel said that he and Phelps devised a plan to frac the zone, and Henry's engineering group worked to enhance the technology.

"Part of that was actually training the frac crews," he added. "This play is very interactive and changes have to be made on the fly. The engineer has to know what he is doing, and the company has to know what it is doing."

Avalon/Bone Spring

While the Wolfberry oil resource play is grabbing most of the attention in the Midland/Odessa area in the heart of the Permian Basin, another unconventional play is heating up in Lea and Eddy counties in southeastern New Mexico on the far western edge of the basin.

What to call the play varies according to who is describing it. Companies are drilling horizontal wells in the Avalon Shale, Bone Spring, and Leonard Shale. It doesn't matter what you call it, however, according to DeCarlo. He said they all are Permian-age rocks.

DeCarlo said that Devon began testing in summer 2009 with horizontal drilling in the Avalon Shale. Devon has drilled six wells in the Avalon and has three rigs running in the play, although DeCarlo said that could be up to 20 by the end of the year, indicating the potential Devon believes the play holds.

Like the Wolfberry, large fracs are the key to the success of the play. DeCarlo said Devon is using a "couple million gallons of frac fluid and water and large amounts of sand" with six to eight frac stages per well.

Companies including Devon are drilling horizontal wells in the Avalon Shale as well as the First Bone Spring, Second Bone Spring, and Third Bone Spring formations.

According to DeCarlo, 60% of the rigs are drilling horizontal. "There have been only a couple dozen wells in the Avalon, so you are learning as you go. We are in the early stages of the play, but we are intrigued," he said.

Devon has assembled 235,000 net acres prospective for the Avalon Shale. The shale on the New Mexico side of the play is 125 to 300 ft thick and 7,000 to 10,000 ft deep. DeCarlo said his company still is assessing acreage on the Texas side of the Avalon Shale in Ward and Reeves counties.

Other companies are rushing into the Avalon Shale/Bone Spring play.

Anadarko Petroleum Corp. has more than 500,000 gross acres in West Texas, with much of it prospective for the Avalon Shale. Although the company has been working on deeper formations in the area, it expected to have the results of its first Avalon Shale well by early fall 2010.

EOG Resources has been working for more than a year in what it calls the Leonard Shale on its Red Hills area lease in Lea County, although Mark Papa, chairman of the board and CEO for EOG, acknowledged the Leonard also could be called the Upper Bone Spring or Avalon Shale.

"We now feel we have reserve potential of 65 MMboe net after royalty reserves on 31,000 of the 120,000 net acres we have in the play, which completed seven horizontal and four vertical wells," he said in the company's 2Q 2010 earnings call. "We believe typical reserves for horizontal wells to be about 400,000 boe net after royalty for $6.5 million well costs, which yield a 40% direct after-tax reinvestment rate of return using NYMEX future prices."

EOG reported that two of its wells, Lomas Rojas 26 #1H and #2H, each with 5,000-ft laterals, had initial production of 710 and 800 b/d of oil and 1.7 and 1.5 MMcf/d of liquids-rich gas, respectively, or approximately 1,000 boe/d each.

It is the liquids-rich feature of the Avalon Shale/Bone Spring that companies are finding especially attractive. Papa said EOG's wells each provide roughly one-third mix of oil, dry gas, and gas liquids.

"We are looking at maybe 75% of the reserves on the oil side," Fisher said. Chesapeake has three operated rigs running in the Bone Spring and one in the Avalon Shale. It also is participating in six other non-operated rigs in the play. "We are targeting 200,000 to 250,000 bbl of liquids and maybe a half Bcf of natural gas in the Bone Spring. We are doing data-gathering and analysis now. We have learned that it is best to do the science up front, to learn the characteristics of the reservoir, how long of laterals to use, what works, etc."

FieldPoint Petroleum and Cimarex Energy recently announced that the two companies are partnering to drill two horizontal wells that will target the Bone Spring Formation in Section 15 of the East Lusk Federal Field in Lea County. Drilling of the first of the two wells was scheduled to begin in 4Q 2010. FieldPoint will own a 43.75% working interest, while Cimarex will own a 37.5% working interest, and other partners will own the remaining 18.75% working interest in the two wells.

Concho Resources, which leaped into the Wolfberry race with its acquisition of Henry Petroleum, now has done the same thing in the Bone Spring. In July 2010, the company announced that it was acquiring the oil and gas assets of the Marbob Energy Corp. for $1.65 billion in cash and Concho securities.

"It is the largest acquisition in the history of the company," Harper said. The Marbob acquisition includes 76 MMboe estimated proved reserves (58% oil, 63% proved developed) and 166 MMboe estimated unproved reserves, as well as approximately 2,300 identified drilling locations, including 1,000 in the Bone Spring play.

"It is very early for us in the Bone Spring," Harper added. "The Marbob acquisition gives us over 100,000 net acres. They operate four rigs and we will take it to eight by next year. We are targeting the Avalon Shale on the south part of the play. Move to the north and it is the First and Second Bone Spring. Move to the east, and you are into the Third Bone Spring. It is acreage dependent on what you drill."

Concho's acquisition of Marbob came a couple of weeks before Apache Corp. announced on Aug. 11, 2010, that it had completed a $3.1 billion purchase of BP's oil and gas operations, acreage, and infrastructure in the Permian Basin, both in West Texas and New Mexico.

According to a company news release, Apache picked up 10 field areas with 141 MMboe of esti-

mated proved reserves and net production of 15,100 b/d of oil and 81 MMcf/d of gas. Apache said the transaction also included 1.7 million gross acres in prospective Permian Basin areas, including the Wolfberry and Bone Spring, with "substantial opportunities for new drilling."

Canyon sands

On the other side of the Permian Basin from the new Avalon Shale/Bone Spring play is another unconventional resource play that offers its own features. Fort Worth, Texas-based Approach Resources has 100,000 gross acres in several fields in Crockett and Schleicher counties on the southeastern side of the basin, according to Craft. "Our primary target is the Canyon sands, which is a tight sands formation that requires large stimulation," he said.

Because of the clay in the well bore, Craft said Approach Resources uses CO_2 foam instead of water in its fracs, which he described as "a special recipe of 300,000 lb of foam and sand in 150-ft intervals."

He noted that Amoco first drilled these fields in the late 1960s and early 1970s, looking for deeper conventional horizons as it drilled down to the Ellenburger.

"Amoco drilled through the Canyon sands, but natural gas was less than $2 at the time, so that wouldn't work," he added.

The Ozona Northeast Field was the company's first farm-out. It now has drilled nearly 400 wells in the field. The tight Canyon sands sit between 7,400 and 8,000 ft depth, with the Strawn and Ellenburger sitting below the Canyon sand. Craft described the Strawn and Ellenburger as "typical conventional oil formation." He said the Wolfcamp and Clearfork formations also are horizons in the play.

"We target everything," Craft said. Approach Resources is drilling to total depths of 10,000 to 11,000 ft. "Canyon is the bailout zone. If it will pay off, then anything else is gravy. All the gas has high Btu content. Processing is the key, especially at lower [gas] prices."

He said Approach Resources uses a third party to process its gas. "We evaluated building our own processing plant, but there has not been a lot of drilling here for a while," Craft said, "so there is a good amount of available capacity. We decided we would rather put our capital into developing resources rather than processing."

The economics of producing natural gas liquids (NGLs) and oil in addition to natural gas is one of the reasons why the Ozona Northeast and Cinco Terry fields have been a success for Approach Resources. In the original farm-out agreement in the Ozona Northeast field, Approach had a wellhead gas purchase agreement that expires in 2011.

"We will begin to realize the processing upgrades from the liquids-rich gas stream in Ozona Northeast with the expiration of our current gas purchase agreement after 1Q 2011," Craft said. "These future upgrades added 14 MMbbl of NGLs to our proved reserve base at mid-year 2010. Further, we expect the sale of higher-value NGLs to enhance the economics of our development program in Ozona Northeast and support future growth in the area."

Although he admitted natural gas is a long-term key, Craft said the liquids-rich composition of the Ozona Northeast and Cinco Terry fields is helpful in light of today's depressed natural gas prices.

Approach Resources owns 51% of the Cinco Terry field, which is 2.5 miles northwest of Ozona Northeast. Craft called Cinco Terry "quite oily," with reserves of 30,000 bbl of oil, 40,000 bbl of NGLs, and the rest natural gas. Approach has budgeted drilling 48 gross wells in Ozona Northeast and 38 gross wells in Cinco Terry in 2010. Craft said the company has more than 500 producing locations in the two fields.

Whether it is the vertical wells in the Wolfberry oil resource play, horizontal wells in the Avalon Shale/Bone Spring, or vertical wells targeting gas in the tight Canyon sands as well as conventional oil formations, new technology and improved completion techniques using multistage fracs have pumped new life into the decades-old Permian Basin.

"Just when you think it has been developed, technology and young geologists show you something new," Craft said.

Permian Reveals Unconventional Plays

New plays revitalize the basin.

By Don Lyle
Contributing Editor

The Permian Basin of New Mexico and West Texas, longtime storehouse of conventional liquids from its wealth of pay zones, increases its value due to the potential for billions of barrels of hydrocarbons from its unconventional formations and combinations.

The Wolfberry, a combination of traditional Spraberry, Dean, and more porous Wolfcamp zones, has created the greatest draw after Henry Petroleum Corp. found the technology to release profitable liquids.

The porous portion of the Wolfcamp Formation generally lies along the east and west flanks of the Spraberry Trend, but hot spots occur in the Spraberry section as well. The Railroad Commission of Texas includes the Wolfberry in the Spraberry Trend in its listings.

With more than 300 operators involved in Spraberry, Dean, or Wolfcamp wells, it's tough to isolate the Wolfberry players, but some of the largest players, pioneers, high-potential operators, more innovative players, and newcomers offer prime material for the profiles herein.

Some operators call the Bone Spring Formation in the Delaware Basin sector of the Permian Basin an unconventional play. In this area as well, a multitude of players offer insight into the play. The unconventional nature heightens with the addition of the Leonardian Avalon Shale adjacent to Bone Spring. Chesapeake Energy Corp. has offered this as a spotlight play and EOG Resources Inc. may be another interested participant with its announcement of a high-potential Leonardian shale.

Both the Woodford and Barnett gas shales offer high potential in the Marfa and Delaware basins, but with gas prices at the current level, they don't provide the attractive economics those formations deliver in North Texas and the Arkoma and Anadarko basins.

Profiles in this section were designed to highlight the plays and players. The following list of operators shows companies with existing production from one or more of the zones involved in the unconventional target plays – companies that either have unconventional production or could have production from those zones.

Key Players

ANADARKO PETROLEUM CORP.

Anadarko Petroleum Corp. controls massive projects throughout the world as it constantly seeks profitable development opportunities. Bone Spring in the Permian Basin is among those opportunities.

Although 42% of the company's production comes from onshore the US, much of the US $5.3 billion to $5.6 billion in capital spending will go to Anadarko's offshore mega-projects in the Gulf of Mexico and international waters.

According to a June 2010 presentation by Bob Daniels, senior vice president of worldwide exploration, the company lists a 25 Tcf of gas equivalent resource base onshore the US, including Wattenberg Field in Colorado, the Greater Green River Basin, the Powder River Basin, and the deep Bossier play.

At that time, it held some 30 Tcf of gas equivalent in gross unrisked resources in the Marcellus Shale and 9 Tcf of gas equivalent in the Haynesville Shale.

As gas price languished, Anadarko turned its attention toward liquids-rich resource plays. It held more than 10 Tcf of gas equivalent in the Eagle Ford and Pearsall shales in South Texas, and became increasingly involved in the Bone Spring play in the Delaware Basin.

In a 1Q 2010 report, the company held Bone Spring properties in Haley Field at the corner of Texas and New Mexico, an area where it has a joint-venture (JV) agreement with Chesapeake Energy Corp.

Anadarko operated four rigs in the Delaware Basin in 4Q 2009 and planned to continue that rig count in 2010 with a capital budget of $29 million in 1Q 2010.

It produced 96 MMcf/d of gas and 1,000 b/d of liquids from the properties in 1Q 2010.

"Anadarko is very encouraged by early well results in the Bone Spring and is now focusing its near-term development plans exclusively on this oil-rich play," the company said. It started drilling seven new Bone Spring wells during 1Q 2010 and completed eight wells.

Likewise, it lowered drilling and completion times to 38 days from 45 days. Its Blacktip Johnson 1-39 #1H horizontal well in Ward County, Texas, came in at a maximum production rate of 1,175 b/d of liquids.

In that 1Q 2010 report, James Hackett, chairman and chief executive officer, said, "One of the new areas in which we are actively drilling is the Bone Spring play in the Delaware Basin of West Texas where we control 170,000 net acres. Like the Eagle Ford and Wattenberg areas, Bone Spring is a high-liquid composition. We also anticipate that our partner in this play will be

Summit was tied for fifth most-active Wolfberry driller in terms of wells drilled since 2009, according to a May 2010 report prepared by DI Energy Strategy Partners for the Permian Basin Petroleum Association. *(Map courtesy of Permian Basin* Oil & Gas *magazine)*

increasing their rig count, thereby providing for an active program through the year."

In response to an analyst's question, Daniels added that the company also will look at the Avalon Shale, immediately adjacent to the Bone Spring, where it planned to drill two test wells. The Avalon Shale is prospective on all 170,000 acres of the company's Bone Spring properties.

Charles Meloy, senior vice president of operations, estimated Bone Spring ultimate recoveries at 350,000 to 375,000 bbl of liquids per well and added, "375,000 bbl for $5 million or thereabouts works all day."

Anadarko signed its JV agreement with Chesapeake in 2007 to increase acreage and reduce risk. According to a joint release at the time, the venture gave Chesapeake 25% of Anadarko's existing Deep Haley production, 25% of Anadarko's central and eastern Deep Haley leases, half of Anadarko's leases and rights in the western Deep Haley area, 2,100 net acres in the Fayetteville Shale play in Arkansas, 5,600 net acres of undeveloped properties in western Oklahoma, and real estate in Oklahoma City, Okla.

Deep Haley production comes from Pennsylvanian zones. The Bone Spring is of Permian age.

Anadarko received $310 million in cash and reimbursement for capital expenditures in Deep Haley and a commitment by Chesapeake to fund a portion of Anadarko's Deep Haley capital costs and half of Chesapeake's non-producing leases in Loving County, Texas, an area that is prospective for Bone Spring.

The companies agreed to jointly evaluate and explore more than one million gross acres in the Deep Haley area on a 50-50 basis.

Among recent development wells in Two Georges Field reported by IHS Inc., Anadarko drilled the 2H University 18-40 for 455 b/d of oil and 1 MMcf/d of gas. It also drilled the 2H University 19-29 for 446 b/d of oil and 759 Mcf/d of gas.

APACHE CORP.

Apache Corp., already a major force in the Permian Basin through previous property acquisitions from BP plc predecessor Amoco Corp., approximately doubled its exposure to the basin's giant resource plays and conventional production with recent acquisitions of Mariner Energy Inc. and the remaining BP basin properties in 2010.

Apache already had potential production from Drinkard and Abo in New Mexico and San Andres, Clearfork, and Grayburg in Texas with some 362 well locations chosen at the end of 2009, according to a May 2010 presentation.

That presentation also said Apache got 9,200 boe/d in production, 85.8 MMboe in proved reserves, 203.3 MMboe in unbooked potential, more than 2,000 drilling locations, and upside from de-risking Mariner's Spraberry, Wolfcamp, and Wolfberry potential.

It announced the acquisition of Mariner Energy in March 2010. Mariner's website said it was one of the most active drillers in the Permian Basin with primary operations in the Spraberry Trend. "We are aggressively expanding our presence in the region, targeting a combination of infill drilling activities in established producing trends, including the Spraberry, Dean, Wolfcamp, and Devonian/Fusselman, as well as exploration activities in emerging plays such as the Wolfberry and newer Wolfcamp trends," Mariner said.

That acquisition closed in 4Q 2010.

At the end of 2009, Mariner held 150,000 net acres in the Permian Basin with 515 Bcf of gas equivalent in proved reserves and net production of 18.3 Bcf of gas equivalent in 2009.

In a July 2010 report prepared for *Permian Basin Oil & Gas* magazine, DI Energy Strategy Partners, which tracks Wolfberry activity, said Mariner Energy was the second most active player in the Wolfberry play in terms of producing leases brought on since 2009. It added 27 leases in that time. Concho Resources Inc.'s COG Operating LLC added 30 leases. Henry Resources LLC added another 17 leases.

In a May 2010 report, DI Energy Strategy Partners said Mariner Energy had more new producing wells (25 total) than any other company working the Wolfberry.

A July 2010 presentation called its acquisition of BP properties, due to close in 3Q or 4Q 2010 for US $7 billion, an excellent fit with existing properties. BP hadn't drilled any operated wells in four years, but it had more than 2,000 infill drilling locations, including resource play operations in Spraberry and Yeso.

The BP acquisition was significant for Apache. Apache-Mariner had production of 47,000 b/d of liquids and 108.2 MMcf/d of gas, and BP added another 15,100 b/d of liquids and 80.6 MMcf/d of gas. BP held 183.5 MMboe in proved and probable reserves on 763,000

LUFKIN

The Energy Flows Through Us™

POWERFUL RESULTS. FROM THE GROUND UP.

LUFKIN. OUR FOCUS IS ARTIFICIAL LIFT.

Around the world, energy solutions flow through Lufkin. With a legacy of over 100 years of innovation and an eye to the future, we're developing advanced artificial lift solutions with our precision-engineered product portfolio, leading lifting technology and innovative automation equipment. Most of all, we're elevating performance through the skill, knowledge and expertise of our people. Field experts you can depend on to help maximize your production and lower your total cost of ownership. From precision-engineered products to proven safety and service excellence, the best in the business flows through us.

WWW.LUFKIN.COM

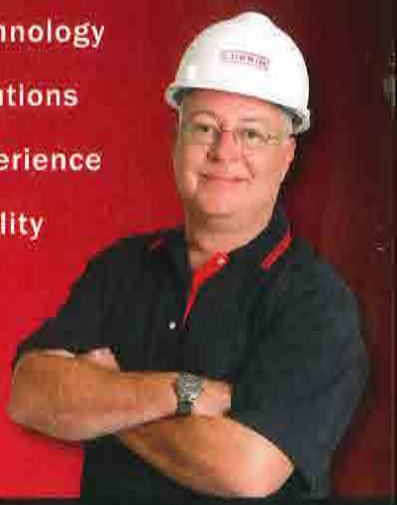
GLOBAL EXPERTISE

Technology

Solutions

Experience

Quality



BEAM PUMPING UNITS | GAS LIFT | PLUNGER LIFT | AUTOMATION | COMPLETION PRODUCTS | AFTERMARKET SERVICES

acres of leases in the Permian Basin. That more than doubled Apache-Mariner's 731,000 net acres.

The Apache and BP properties were spread throughout the Permian Basin in Texas and New Mexico, while the Mariner Energy properties concentrated on the Spraberry Trend.

As an example of the potential, Apache said BP's Wilshire Field, in which Apache will receive an 89% working interest, included 427 drilling locations with Ellenberger re-entry potential, Devonian infill and re-frac potential, uphole Strawn completion potential, and uphole Spraberry-Wolfcamp recompletion potential.

Apache already held Spraberry Trend wells in Reagan and Glasscock counties in Texas.

Among other production, the Mariner Energy acquisition gave Apache Spraberry Trend wells in Reagan, Glasscock, and Midland counties.

BP's Spraberry properties are in Midland and Glasscock counties.

BP properties will give Apache 977 Spraberry drilling locations plus infill drilling and recompletion potential throughout the play with potential expansion to Wolfberry on surrounding acreage.

Apache also was involved in the Bone Spring resource play. It held properties in the 111-well Shugart North Field, one of the larger Bone Spring fields, and in Two Georges Field in Loving County, Texas.

BROAD OAK ENERGY INC.

Bolstered by increased financing, Broad Oak Energy Inc. pushed harder on its aggressive campaign to increase production from its Wolfberry properties in the Midland Basin.

The company began operations in 2006 under the leadership of former Pioneer Natural Resources Co. executive David Braddock with US $150 million in equity backing from Warburg Pincus.

By mid-2010, the company had assembled 65,000 acres of properties in the Wolfberry play. It had drilled more than 200 wells and planned to drill another 120 wells in the second half of 2010. Its properties included both infill and extension prospects in the 3,000-ft Wolfberry, composed of the Upper Spraberry, Lower Spraberry, Dean, and Wolfcamp zones.

By mid-year, it produced approximately 5,000 b/d of oil and 18 MMcf/d of gas, according to the company website.

It received help in its aggressive campaign in February 2010, as its bank group increased its borrowing base to $100 million, up $40 million from the previous level. That increase followed a $20-million addition in October 2009.

"This sizable expansion of our borrowing base is an important milestone in the development of our company. The increased access to capital will enable us to further advance our efforts to develop and produce significant US domestic oil and gas reserves," Braddock said.

Reserves are concentrated in the Wolfberry play where the company planned to run a minimum of five rigs during 2010.

During an April 2010 American Association of Petroleum Geologists presentation titled "Oil and Gas Resource Estimated or Permian Wolfberry Trend Reservoirs in Eastern Reagan County, West Texas," a group from Broad Oak and McGinley Associates Inc. said regional Wolfberry Trend production had reached 132,000 b/d of oil and 335 MMcf/d of gas and had produced 1.59 Bbbl of oil and 3.49 Tcf of gas from a 2,600-sq-mile area.

That trend included Permian Leonardian and Wolfcampian turbidite and debris-flow sediments within the Spraberry, Dean, and Wolfcamp formations.

Previous estimates of in-place volumes had focused only on the non-shale portion of the column. Those estimates ranged from 10 to 30 Bbbl of oil in place with recovery factors ranging from 8% to 15%.

A group that authored the paper chose a 2,800-ft-thick column for Wolfberry, including low-permeability sands, carbonates, and organic-rich shales in the eastern Reagan County portion of the Wolfberry Trend.

That conventional and unconventional Wolfberry reservoir indicated in-place volumes of 132.5 MMbbl/sq mile of oil. With 40-acre spacing and 100,000 boe/well, the numbers suggested only 1% to 3% of in-place resource had been developed.

The group said Broad Oak implemented multistage fracturing designs to tap the full column and found an average improvement in estimated ultimate recoveries of 30% over historical completions. The company also reported initial production rates of approximately 75 boe/d, or nearly double the historical average.

DI Energy Strategy Partners, which tracks Wolfberry activity, ranked Broad Oak fifth in new leases brought

TEAM
Oil Tools
A Division of Tejas Completion Solutions, LP

DRILLABLE FRAC PLUG

Frac Plug

Bridge Plug

FASTER WITHOUT SACRIFICING
QUALITY SAFETY COST

FRAC PLUG

The Omni-Slip Drillable Frac Plug offers a reliable cost-effective solution to independent isolation and treatment of multiple zones in horizontal and deviated wells. The aluminum frac plug is compact in design, PDC bit drillable and features a positive interlocking system. The performance of the plug will not deteriorate, has faster drill-out times, and prevents spinning when drilling multiple plugs.

OMNI-SLIP™

The patent pending Omni-Slip features a non-marking slip design with Omni directional grip, positively anchoring downhole service and production tools. The Omni-Slip is ideal for bridge plugs, frac plugs, CRA tubulars, production packers and liner hangers. High material removal rates require less drilling time.

WWW.TEJASCS.COM

in with 16 leases total. It followed Concho Resources Inc.'s COG Operating LLC with 30, Apache Corp.'s Mariner Energy Inc. with 27, and Henry Resources LLC and Chesapeake Energy Corp. with 17 each.

It also ranked Broad Oak third in the number of new producing wells with 12 behind Mariner's 25 and COG's 22.

Broad Oak's properties are in Reagan and Glasscock counties in Texas.

According to the *Midland Reporter-Telegram*, two Reagan County wells were among the company's better recent wells. The SRH-B-#7K tested for an initial potential of 159 b/d of oil, 267 Mcf/d of gas, and 437 b/d of water on a 2⅝-in. choke. The SRH-C-#13G tested for 150 b/d of oil, 113 Mcf/d of gas, and 121 b/d of water on the same-sized choke.

CHESAPEAKE ENERGY CORP.

Chesapeake Energy Corp. claims the title of most active driller in the US with a record of one out of every eight wells drilled in the nation. It also claims the title of one of the most active operators in the Bone Spring play, with active operations in Wolfberry in the Midland Basin and an inactive position in the Woodford and Barnett shales in the Delaware Basin.

In a July 2010 presentation, Chesapeake said it had 126 rigs working, 80% of them in gas shales and 20% in liquids-rich plays. It was increasing emphasis on liquids plays such as the Wolfberry and Bone Spring.

Low product prices aren't holding the company back. It held 15.8 Tcf of gas equivalent at the end of 1Q 2010 and planned to reach between 20 and 22 Tcf of gas equivalent by 2012.

A March 2010 *Midland Reporter-Telegram* article quoted Steve Turk, vice president of operations in Chesapeake's southern division: "With the continuing broad disparity between the wellhead price for natural gas and the price of oil, in 2010, we will be shifting our exploration focus in some areas of the country, including the Permian Basin, from natural gas to oil," Turk said.

Throughout the Permian Basin, he said, Chesapeake has more than 1.7 million acres of leaseholds with 1,600 wells producing 170 MMcf/d of gas and 10,000 b/d of oil. It budgeted US $300 million to develop those properties in 2010.

Chesapeake was a top-10 operator in the Permian Basin unconventional plays in July 2010 with control over 290,000 net acres. It had room for 70 net risked undrilled wells with an estimated 1.6 Bcf of gas equivalent in recovery per well. Proved reserves had reached 126 Bcf of gas equivalent with 4.1 Tcf of gas equivalent in unrisked unproved resources. At that time, it had four drilling rigs working West Texas and southeastern New Mexico.

Chesapeake concentrated on unconventional liquids in the Permian Basin with strong positions in the Avalon Shale, Bone Spring, Wolfcamp, and Spraberry. In those plays, it estimated approximately 150 MMboe, or 1 Tcf of gas equivalent, of risked, unproved resources and 680 MMboe, or 4 Tcf of gas equivalent in unrisked unproved resource.

During the Independent Petroleum Association of America's 16th Oil and Gas Investor Symposium in April 2010, Chesapeake included information on its shale plays, according to the PLS Inc. Prospect Centre newsletter. In the Permian Basin, the company included the Avalon Shale in Texas and New Mexico where it held 120,000 net acres. It had drilled eight gross horizontal wells and had locations for 750 net unrisked undrilled wells with an unrisked, unproved resource of 350,000 boe/well. It held a 75% net revenue interest in the wells representing 200 MMboe in unrisked, unproved resources to Chesapeake.

EOG Resources Inc. also unveiled a Leonardian shale play in which it had a large position. That probably is the Avalon Shale.

Chesapeake's Bone Spring position includes 70,000 net acres in West Texas where it had drilled 11 horizontal wells and had room for another 425 net unrisked, undrilled wells with an unrisked, unproved resource of 400,000 boe/well. The company's 75% net revenue interest in that play represented a net unrisked, unproved resource of 130 MMboe.

It had drilled 136 gross wells in the four plays by July 2010 and planned to operate six rigs in those unconventional plays in 2010 to drill some 50 net wells.

The company said it and Cimarex Energy Inc. were the most active operators in the Bone Spring play.

One recent Bone Spring well in Culberson County, Texas, the D.F. Ranch State "62-4" #1H, tested for 2.4 MMcf/d of gas and 710 b/d of water through an open choke.

A 2007 agreement with Anadarko Petroleum Corp. gave Chesapeake interests in the Deep Haley Field area with primary production from Pennsylvanian zones. On its side, Chesapeake contributed Delaware Basin properties with Bone Spring potential.

Chesapeake also has strong standing in the Wolfberry play. According to DI Energy Strategy Partners, a company that tracks Wolfberry activity, it ranked fourth among companies that added new Wolfberry leases in Andrews County, Texas, since 2009. Its six leases placed it behind Clayton Williams Energy Inc. with 13, MYCO Industries Inc. with 9, and Henry Resources LLC with 8.

Throughout the play, it ranked fourth among operators with 17 leases brought online. It placed behind Concho Resources Inc.'s COG Operating LLC with 30, Apache Corp.'s Mariner Energy Inc. with 25, and Henry Resources with 17.

It also ranked fourth among wells that produced since 2009 with 11 wells. In the same period, Mariner Energy completed 25 producers, COG had 22 wells, and Broad Oak Energy Inc. had 14.

Chesapeake hasn't forgotten its solid foundation in gas shales just because it has concentrated on liquids-rich prospect. It remains a believer in the potential of the Woodford and Barnett shales in the Delaware Basin.

An article in the July/August edition of *Basin Oil & Gas* written by Stephen Trammel, senior product manager of current activity products for IHS Inc., reviewed Barnett/Woodford activity in the Delaware Basin.

Chesapeake drilled two remote wildcats, the 781 McKnight "11" and 1 Leoncita State "11-10," to the zones about 20 miles northeast of Fort Davis, Texas, Trammel said. The wells reached 14,000 ft and 11,500 ft, respectively, but were not put on production.

Quicksilver Resources Inc. drilled a horizontal well some 20 miles to the northeast about a year earlier, he added. That well, the 1H Rawhide, reached 11,787 ft and could be completed as a Barnett Shale producer in Golden Corral Field.

Quicksilver Resources holds 150,000 acres in Jeff Davis, Reeves, and Culberson counties in Texas, but is divesting those properties because other plays offer better economics.

Matador Production Company planned the 10,000-ft 1 Guitar Holding Co. "41" in northeastern Hudspeth County, Texas, and EOG Resources completed a Barnett discovery in Culberson County about 30 miles northeast of that planned well.

EOG Resources has 150,000 acres, mostly in Culberson County. It permitted eight wells, drilled three, and ConocoPhillips Co., with 35,000 acres in Reeves County, finished one recompletion for 2 MMcf/d of gas and one new drill for 3.1 MMcf/d of gas from the Barnett/Woodford zones.

A 2006 presentation by Bob Cluff with The Discovery Group in Denver said Chesapeake held 385,000 acres in Reeves, Culberson, Pecos, and Jeff Davis counties in Texas that were prospective for Barnett and Woodford.

At that time, Chesapeake was the largest operator in the area and reported 5 MMcf/d of high CO_2 gas on recent completions.

The Discovery Group said the Barnett/Woodford play was started by EOG Resources and Tom Brown Inc. Tom Brown later was acquired by EnCana Corp. It drilled four wells in 2005, all tight, on more than 580,000 acres of leases.

CHEVRON USA INC.

Chevron USA Inc., one of the biggest producers in the US and the world, operates fields including supergiant Tengiz in Kazakhstan and some of the largest fields off the northwest coast of Australia and in the Tertiary trend in the Gulf of Mexico's ultra-deep water. It also maintains its dominant position in West Texas and southeastern New Mexico.

Acquisitions of TXL Energy LLC and Pure Oil Co. established the company's strong Permian Basin leasehold position and it currently has more CO_2 floods in the basin than any other company except Occidental Petroleum Corp.

The Railroad Commission of Texas lists the company as operator of wells in 10 Spraberry fields; 26 Wolfcamp fields; one Dean Formation field; one Spraberry Trend field in Glasscock County, Texas; the Magutex Barnett Formation field in Andrews County, Texas; and Evetts Bone Spring Formation field in Winkler County, Texas.

Many of the Spraberry and Wolfcamp fields are in counties generally considered the hot spots for the Wolfberry play.

In a 2006 presentation on the Woodford and Barnett formations in West Texas, Bob Cluff of The Discovery Group said Chevron had a fee land position of more than 200,000 acres with Barnett and Woodford potential at its TXL Ranch Field. The company has since entered an agreement under which Anadarko Petroleum Corp. operates that field.

Chevron's 2009 annual report supplement noted, "Another West Texas opportunity the company is actively pursuing involves moving tight carbonate resources to production. Chevron holds a non-operated working interest in a large drilling play in the Permian Basin where the target Wolfcamp Formation had traditionally been considered uneconomic 'tight' rock. However, advances in drilling and completion technologies have opened up widespread targets in areas where Chevron has extensive land positions. The company participated in 132 wells in 2009 and plans to participate in the drilling of another 208 wells in 2010."

The New Mexico Bureau of Mines and Mineral Resources credited the company with the 1999 discovery of the Chevron No. 1 Cable Ranch 26 in the Bone Spring Formation in Eddy County, N.M. It listed that well as a significant discovery even though it showed an initial potential of only 12 b/d of oil.

CIMAREX ENERGY INC.

Cimarex Energy Inc. exercises its competitive advantage by concentrating resources and talent on profitable plays with a current concentration on the Anadarko Basin, the Gulf Coast of southern Texas, and the New Mexico portion of the Permian Basin.

On the Gulf Coast, it drilled 7 gross, 6.6 net, wells, with 6 gross, 5.6 net, successes in the first half of 2010. Production rose to an average 190 MMcf/d of gas in 2Q 2010, up from 61.6 MMcf/d in 2Q 2009.

It drilled 49 gross, 24.2 net, wells in the Midcontinent in the first half of the year and 35 gross, 15.6 net, of those wells were in the Cana-Woodford play. That play was only slightly more active than the company's Permian Basin operations. Most of the additional wells were drilled to the Granite Wash.

Cimarex has properties in the Spraberry Trend in Midland County, Texas, and Bone Spring production in Two Georges Field in Loving County, Texas. Its main concentration is its active drilling program to the Abo, Paddock, Wolfcamp, and Bone Spring formations in New Mexico.

The company operated 12 rigs in the basin at the halfway point of 2010, up from five at the end of 1Q 2010.

In its 2Q 2010 report to shareholders, the company said it drilled and completed 33 gross, 24.7 net, Permian Basin wells with 94% completed as producers. Second-quarter average production dropped to 155.2 MMcf/d of gas equivalent from 168.1 MMcf/d of gas equivalent in 2Q 2009.

Two 2Q 2010 wells show the company's attraction to the Bone Spring Formation. The Parkway State 17 Com 2H, in which the company held a 58% working interest, came in with a first-30-day average production rate of 970 boe/d. The Southern California Fed 15H, with a 100% working interest, produced 1,100 boe/d on average for the first 30 days.

In 1Q 2010, Cimarex completed the Parkway State Com 3H, with a 62% working interest, for 760 boe/d and the Mallon 34 Fed 16H, with an 82% working interest, for 360 boe/d. Those figures represent average production for the first 30 days online.

In 2Q 2010, the company followed with the Parkway 17 2H, with a three-quarters interest, for 960 boe/d in Eddy County, N.M., and the Southern California 29 Fed 15H for 100% of 1,100 boe/d and 83% of oil from the Bone Spring Formation.

Cimarex drilled one horizontal Avalon Shale well by August 2010.

An August 2010 presentation said Cimarex controls 380,000 acres in the Permian Basin. At the end of 2009, it held 487.3 Bcf of gas equivalent in proved reserves in the Bone Spring and Abo formations.

The company planned to spend US $280 million in the Permian Basin in 2010, mostly in the Bone Spring Formation. That was a sharp increase in the $155 million devoted to the basin in 2009.

That extra cash will go into an anticipated 130 gross, 100 net, wells in 2010, an increase from the 49 gross, 36 net, wells drilled and completed in 2009.

Cimarex planned to work two to three rigs in New Mexico's Bone Spring in 2010 to drill new wells and re-entries. It planned to keep two rigs busy in the Abo play.

Cimarex also has a joint-venture agreement in Lea County, N.M., with FieldPoint Petroleum Inc. According to FieldPoint, under that agreement, the companies will partner on two Bone Spring wells in East Lusk Federal Field. The first well is planned for the fall of 2010. FieldPoint will own 43.75% of the first well, with Cimarex holding 37.5%.

CLAYTON WILLIAMS ENERGY INC.

Clayton Williams Energy Inc. holds properties in other parts of Texas, but its stronghold remains near its Midland, Texas, home in the Permian Basin.

The Permian Basin, with 20 MMboe in proved reserves and 1Q 2010 production of 7,500 boe/d, accounted for 59% of the company's year-end 2009 proved reserves.

According to a July investor presentation, the company operates on 188,000 acres in the basin with more than 200 proven drilling locations and several hundred probable and possible locations, primarily focused on oil reserves from San Andres, Spraberry,

Wolfcamp, Pennsylvanian, and Devonian zones from 4,000 to 15,000 ft deep.

By mid-2010, active operations centered on the Wolfberry and San Andres with plans for future activity in the Yeso Formation in southeastern New Mexico and the Bone Spring in Ward County, Texas.

A big part of near-term activity will focus on 8,400 acres of University lands, 5,400 acres of fee lands on which the company holds a 100% interest, and on 5,500 acres of farm-out lands in which it holds a 60% share.

Those properties make up Clayton Williams' Wolfberry play in Andrews County, Texas.

The company did the math. Assuming US $80/bbl oil and $4.50/MMBtu gas, the Wolfberry play offered a 40% rate of return and a 2.2-year payout. Its properties gave 96,100 boe in net reserves. Net authority-for-expenditures on wells totaled $1.83 million and the company has net daily production of more than 3,000 boe/d.

Those numbers provided the incentive for the company to drill 104 Andrews County wells in 2010 and 120 more in 2011. It drilled 13 gross, 11.7 net, wells in the area in 2009.

In late April 2010, Clayton Williams increased its borrowing base to $300 million, a gain of $50 million, to help finance its more aggressive operations.

Plans in May 2010 called for the company to spend $195 million in the Permian Basin during 2010. It spent $36.7 million of that total in the first quarter.

If the plans work out, Permian oil production will rise from an average 4,909 b/d in 1Q 2010 to 6,750 b/d in 4Q 2010. In the same period, gas production should increase from 13.9 to 14.8 MMcf/d and gas liquids production will drop from 272 to 234 b/d.

Clayton Williams planned to keep six rigs working in the Wolfberry during 2010. It has additional Spraberry Trend wells in Texas's Glasscock and Midland counties, according to The Railroad Commission of Texas.

An April 2010 report by DI Energy Strategy Partners said Clayton Williams added 13 leases in Andrews County from 2009 through July 2010. Andrews County

Devon Energy, a growing player in the Avalon Shale play in New Mexico, produces from a well near Artesia. *(Photo courtesy of Devon Energy Corp.)*

is north of the Upton and Midland hot spots in the Wolfberry play.

Among wells completed in Andrews County in 2Q 2010, the Andrews University "16" #3 tested for 54 b/d of oil, 47 Mcf/d of gas, and 472 b/d of water from Wolfberry, and the Andrews University "16B" #1 tested for 88 b/d of oil, 74 Mcf/d of gas, and 358 b/d of water.

CONCHO RESOURCES INC.

Concho Resources Inc. used a combination of acquisitions and a strong drilling campaign to build a dominating position in the Wolfberry play in West Texas and the Bone Spring in southeastern New Mexico.

The company operates its wells under the COG Operating LLC and Henry Petroleum Corp. names and, after dealing with administrative details, should add Marbob Energy Corp. properties to its extensive holdings in the Permian Basin.

It also has production from the Bakken oil shale play in the Williston Basin.

For 2Q 2010, the company produced 3.5 MMboe and booked proved reserves of 234.5 MMboe at the end of the quarter, an 11% gain from the end of 2009. That production included 2.3 MMbbl of oil and 6.7 Bcf of natural gas.

Tim Leach, chairman, chief executive officer, and president, said, "Our first-half 2010 results are a testament to the strength of our team and their continued execution on our core Wolfberry and New Mexico Shelf assets. Additionally, I am pleased by the increased production contribution from the horizontal Abo and Bakken oil plays, which together averaged approximately 3,400 boe/d in the second quarter. While we are continuing to focus on growing our core business, we are also working to complete our Marbob acquisition, which we expect to close in the fourth quarter of 2010. In addition, we have increased our 2010 capital budget by approximately 10% as a result of additional drilling activity in both of our core areas, increased exploration expenditures, and service cost inflation attributable to higher industry activity levels in the Permian Basin. The increased activity in the second half of the year allows us to raise our 2010 production guidance and should provide good momentum as we move into 2011."

Concho started drilling or participated in 294 gross wells, operating 247 of them, in the first half of 2010 and completed 190 as producers. It said 103 of the wells still were in progress at the end of the period and one well was unsuccessful.

It operated 25 drilling rigs at the time in the Permian Basin. Seven of the rigs were working the Yeso in New Mexico, 17 were drilling Wolfberry wells, and one was drilling Lower Abo wells in New Mexico.

Among Wolfberry wells completed by COG Resources by mid-2010, the Morgan #3812 tested for 63 b/d of oil, 74 Mcf/d of gas, and 139 b/d of water, while the Lynch "7" #2 tested for 209 b/d of oil, 148 Mcf/d of gas, and 148 b/d of water.

In 2Q 2010, Concho drilled 74 wells, 71 operated, in Texas with a 100% success rate on the wells completed at the end of the period.

That activity should give the company between 14.1 and 14.3 MMboe of production for all of 2010 with the help of US $700 million in spending, excluding the Marbob acquisition announced in July 2010.

It expected Marbob to add 800,000 to 900,000 boe in November and December of 2010 with capital expenditures of $50 million.

Concho entered the Wolfberry play with maximum exposure in 2008 when it bought Henry Petroleum in Midland for $565 million. Henry is credited with developing the Wolfberry play. The acquisition gave Concho some 163 Bcf of gas equivalent of proved reserves at a cost of $3.47/Mcf of gas equivalent. It also gave the company some 283 Bcf of gas equivalent of probable and possible reserves.

It identified 1,650 drilling locations on the Henry properties, a big addition to Concho's existing 2,500 drilling locations.

The Marbob acquisition, announced in July 2010, was even larger at $1.65 billion in cash and securities.

Nearly all of Marbob's properties were in the southeastern New Mexico sector of the Permian Basin and included acreage near Concho's Yeso play and a substantial amount of Bone Spring properties.

When completed, that acquisition should give Concho 76 MMboe in estimated proved reserves and another 166 MMboe in unproved reserves.

Marbob's 1Q 2010 production averaged 14,000 boe/d and the company had 2,300 drilling locations with about 1,300 in the Yeso play and 1,000 in the Bone Spring area.

At that time, Marbob was running five rigs, including one Yeso rig and four in the Bone Spring.

"We are pleased to announce the largest and most strategic acquisition in our company's history. This acquisition has been one of our highest priorities for the last three years. These assets are a perfect complement to our New Mexico Shelf position, and they double our Yeso drilling inventory. In addition, Marbob's Bone Spring acreage, when coupled with our existing acreage, gives the company over 100,000 net acres in one of the most exciting emerging plays in the industry today and adds a significant new area of growth to the company's portfolio.

"After closing, we plan to increase the activity level and rig count on these acquired properties, which should result in significant production growth over the next several years. Going forward, Concho will be a bigger version of today's company, with a large, high rate of return, high margin drilling inventory that will be complemented by the Bone Spring play," Leach said.

There was a hitch in the acquisition in early July 2010. BP America could exercise its preferential rights on the Marbob properties, and BP was in the process of selling its Permian Basin holdings to Apache Corp. That move put both BP and Apache in the middle of the acquisition until the companies could work out an agreement.

Concho said it believed the BP intervention related to some $400 million of the Marbob properties in New Mexico. Marbob and Concho initiated action in New Mexico District Court asking for a declaratory judgment against BP and Apache to force BP to produce the preferential purchase right notification so the acquisition could move forward.

CONTINENTAL RESOURCES INC.

Continental Resources Inc., the third-largest oil producer in the Rockies and a significant player in unconventional plays throughout the US, took a look at the Barnett Shale play in the Permian Basin and put the project on hold to focus its resources on other plays with better economics.

In April 2006, the company acquired a half interest in a 135,000-acre block in the Marfa Basin of West Texas that had been assembled by TXCO Resources Inc. in 2005. TXCO and Continental jointly re-entered the Simpson 1 – a well originally drilled by El Paso Natural Gas Co. to 12,017 ft in 1972 – to test a 370-ft thick Barnett and Atoka shale section, but the well failed to produce at commercial rates. At that time, it operated the well as Continental Trend.

After successfully fracturing the Barnett, the well produced at instantaneous rates of 140 Mcf/d and 100 b/d of water intermittently over a period of several days, according to an IHS Inc. report.

The Continental well was approximately 12 miles west of a Carrizo Oil & Gas Inc. permit issued in 2007 for a well scheduled to 10,000 ft near the western flank of the Delaware Basin.

Continental moved on to establish one of biggest and most successful positions in the Bakken Shale in Montana and North Dakota and in the Woodford Shale in the Anadarko and Arkoma basins in Oklahoma. The company recently announced a growing position in the Niobrara play in the DJ Basin.

DEVON ENERGY CORP.

Devon Energy Corp., brimming with cash after the sale of its Gulf of Mexico properties and anticipating more inflow from international divestments, is funneling funds into its onshore resource plays in North America, including expanded operations in the Permian Basin.

Devon's competence in resource play development showed in its 2Q 2010 report to shareholders. It drilled 315 wells in the quarter with a 100% success rate. The Barnett Shale in North Texas continued to dominate as the company produced more than 1.1 Bcf/d of gas equivalent during 2Q 2010 and reached a record 1.3 Bcf/d of gas equivalent in 3Q 2010.

The company also pushed Cana-Woodford net production in Oklahoma to 105 MMcf/d of gas equivalent during 2Q 2010 and drilled two Granite Wash wells with an average initial production of 29 MMcf/d of gas equivalent, including 585 bbl of oil or condensate and 1,330 bbl of natural gas liquids (NGLs).

Devon has assembled 947,000 net acres in the Permian Basin and has 13 operating rigs running in the area. The company's activity in the basin is targeting the Wolfberry, Avalon Shale, and Bone Spring formations, as well as several other conventional targets. Devon drilled 79 Permian Basin wells in 2009 and plans to drill 200 in the area this year.

Devon is no stranger to Permian Basin activity. The company had 8,634 producing wells in the basin at the end of 2009, according to the company website. Those wells produced 15 MMboe net to Devon during that year and accounted for 7% of company production. Net reserves reached 161 MMboe, or 6% of Devon's total reserves.

In a July 2010 presentation, Devon said it planned between US $4.4 billion and $4.8 billion in capital expenditures during the year, with 44% going to its shale plays and 15% directed to other unconventional plays. About 41% is allocated to the company's Canadian oil sands and conventional plays. About 69% will go to liquids and liquids-rich gas plays, including the Wolfberry, Avalon Shale, and Bone Spring formations.

Devon's 2009 annual report indicated an increasing interest in New Mexico liquids. The company reported that it had drilled and completed four gas wells, 27 oil wells, and recompleted 22 wells in the area in 2009. Devon planned to raise activity to 22 gas wells, 81 oil wells, and 88 recompletions in 2010.

Devon began targeting the Avalon Shale and Bone Spring formations in 2009, although hydrocarbons have been known to exist in the area for some time. Devon was running two rigs in the area in August 2010 and has drilled six wells. The company holds about 235,000 net acres in the play. New Mexico state records show the company has interests in 32 Bone Spring fields in the state, and has an interest in the Mi Vida Bone Spring Field in Reeves County, Texas.

An average horizontal well in the shale will cost between $3.3 million and $4 million and will return an initial 300 b/d of condensate, 300 b/d of NGLs, and 2 MMcf/d of gas with an estimated ultimate recovery of 600,000 boe, according to *Investopedia.com*. Devon planned to participate in 32 Avalon Shale wells in 2010, operating 20 of the wells.

As with the Avalon Shale, geoscientists have known the Wolfberry Formation held hydrocarbons. While Devon has a history of activity in the area, only recently did the company begin targeting oil from the Spraberry and Wolfcamp formations, together known as Wolfberry. Advanced completion techniques and favorable cost structures led to the play's commercial viability.

Devon's 2009 annual report said the company recently had started working the Wolfberry play and liked it because of its low-risk drilling and attractive economics. At that time, it had 142,000 net acres prospective for Wolfberry. The company now is running four drilling rigs in the Wolfberry and has approximately 200,000 net acres in the play with a 97% working interest. By 2Q 2010, Devon had drilled 26 successful Wolfberry wells, including its best well to date. The company drilled 45 Wolfberry wells in 2009 and plans to drill roughly 100 wells in 2010. It estimated a net risked resource of 120 MMboe in the Wolfberry from more than 1,100 risked locations.

The Railroad Commission of Texas records place Devon with wells in Wolfcamp and the Spraberry Trend in Upton, Glasscock, Winkler, Crane, Ector, Midland, Terrell, Ward, and Dawson counties.

ENDEAVOR ENERGY RESOURCES LP

Endeavor Energy Resources LP built itself into one of the largest privately held companies in the US as it leveraged its activities on its Permian Basin properties, primarily in the Spraberry Trend.

A May 18, 2010, report from DI Energy Strategy Partners (DIESP) said Endeavor had nine new producing wells in the Wolfberry at that time. In March 2010, a report from DIESP said the company had brought 380 Wolfberry wells online since 2000, 51 of them in Upton County, Texas. At that time, Upton County was the sweet spot for the Wolfberry as it accounted for 1,100 of the 2,105 Wolfberry wells drilled to that point.

Autry C. Stephens started Acme Energy Services, which does business as Big Dog Drilling, in 1996. That company subsequently grew to 25 drilling rigs. Stephens started Endeavor in 2000, bought the assets of Perenco from its French owners in 2005, and changed its name to LCX Energy LLC. Those assets later were folded into Endeavor.

RigData ranked Endeavor 21st among operating companies because it drilled at 870,000 ft in 74 well starts from January to May 2010. In comparison, Chesapeake Energy Corp. ranked first with 4.7 million ft and 492 well starts.

PennEnergy ranked Endeavor 12th among private US producers with production of nearly 4.49 MMboe from 4,068 wells. Its largest field was the Spraberry Trend, which includes the Wolfcamp.

The Railroad Commission of Texas lists Endeavor with wells in 50 West Texas fields, including Spraberry Trend wells in Reagan, Upton, and Midland counties; Spraberry Field wells in Upton, Dawson, Martin, Howard, Andrews, Midland, and Borden counties; a Spraberry-Dean field in Midland County; Wolfcamp wells in Upton, Crockett, Reagan, Pecos, Midland, Andrews, Martin, Glasscock, Sterling, Mitchell, and Howard counties; Dean fields in Reagan, Martin, Glasscock, and Howard counties, and Bone Spring production from Two Georges Field in Loving County.

New Mexico records show Endeavor also has Bone Spring production from Lusk East, SWD, and Willow Lake fields in that state.

In June 2010, the *Midland Reporter-Telegram* listed well completions in the Spraberry Trend for Endeavor. The list included the Williams #5 in Reagan County that tested for 41 b/d of oil, the Lone Star "73F" #1 in

LiteProp™ 108
Ultra-Lightweight
Proppant.

These spheres are
neutrally buoyant.

These spheres
are propping
fractures in
tight sands.

These spheres
form a proppant
partial monolayer

with pathways
that optimize
conductivity

to increase
production from
just one well

by 700%

to deliver more
unconventional
gas from

this sphere.

LiteProp™ 108 Ultra-Lightweight Proppant.

Proppant partial monolayers are a proven reality.

The proppant partial monolayers created by BJ Services' new LiteProp 108 proppant system are producing astonishing results in tight gas sands. One customer in the Dakota formation in New Mexico experienced a 700% increase in natural gas production compared to the average production of four offset wells. These kinds of results have major implications for the future development of unconventional gas reservoirs.

Creating the first effective partial monolayers in unconventional wells further demonstrates the technology leadership that BJ Services brings to every well. With our science, our products and services, our expertise, our experience, our capabilities, and our commitment to HSE and quality, we continue to prove that BJ Services does what it takes to get you to the top of your field.

Real world. World class. Worldwide.

www.bjservices.com

BJ

Upton County that tested for 38 b/d of oil and 71 Mcf/d of gas, the Harvard "46" #1 in Glasscock County that tested for 36 b/d of oil and 20 Mcf/d of gas, and the Shaw Farms Unit #1 in Howard County that tested for 27 b/d of oil and 30 Mcf/d of gas.

EOG RESOURCES INC.

EOG Resources Inc. made a name for itself by earning early mover status in big plays and using innovative exploration to extend those plays to areas overlooked by other operators. Its Permian Basin operations enhance that reputation.

For example, EOG was an early entrant into the Bakken Shale play in North Dakota, which is probably the fifth-largest US oil field. The company came into the Eagle Ford early, which is probably the sixth-largest oil field, and was a strong player in the Barnett Shale when it extended that play to the north into the liquids-rich Barnett Combo play, which is possibly the 17th-largest US oil field, according to an August 2010 presentation by EOG.

EOG also has substantial operations in the Wolfberry play in West Texas and the Bone Spring play in New Mexico, but again found added value for its operations as it announced a new liquids resource play in New Mexico, the Leonard Shale in the Delaware Basin.

The new play has big potential. To compare, EOG said its Eagle Ford properties in South Texas had 900 MMboe in resource potential on 505,000 acres, its Bakken/Three Forks leases had 420 MMboe in potential on 580,000 acres, its Barnett Combo had 370 MMboe in potential on 150,000 acres, and it had evaluated the Leonard Shale for a potential 65 MMboe of resource on 31,000 of the 120,000 acres EOG controls.

The Leonard Shale has similar characteristics to the Barnett Combo play, the company said. It drilled four vertical wells and seven horizontal wells to the formation. The Lomas Rojas 26 #1H tested for 710 b/d of oil and 1.7 MMcf/d of gas, and the Lomas Rojas 26 #2 tested for 800 b/d of oil and 1.5 MMcf/d of liquids-rich gas.

At the end of 2Q 2010, it had 150 potential drilling locations in which early production suggested 400 Mboe/well. Production on the wells averaged 34% oil, 34% gas liquids, and 32% gas.

The new play fit perfectly with EOG's stated plans to move more toward liquids production than gas.

The Permian Leonardian contains several formations in New Mexico, including San Andres; Glorietta; Avalon Shale; Bone Spring; Abo; and the Paddock, Blineberry, Tubb, and Drinkard members of the Yeso.

It is probable that EOG is talking about the Avalon Shale, a play in which Chesapeake Energy Corp. also has an extensive position.

During the Independent Petroleum Association of America's 16th Oil and Gas Investor Symposium in April 2010, Chesapeake included information on its shale plays, according to the PLS Inc. Prospect Centre newsletter. In the Permian Basin, the company included the Avalon Shale in Texas and New Mexico where it held 120,000 net acres. It had drilled eight gross horizontal wells and had locations for 750 net unrisked, undrilled wells with an unrisked, unproved resource of 350,000 boe/well. It held a 75% net revenue interest in the wells representing 200 MMboe in unrisked, unproved resources to Chesapeake.

"For the first time in EOG's history, during the second quarter, total revenues generated from crude oil, condensate, and natural gas liquids production exceeded those from natural gas. This mix is in-line with EOG's target to organically evolve toward a predominantly liquids-weighted portfolio in North America by 2011 to 2012," Mark G. Papa, chairman and chief executive officer, said.

The company continued to run significant programs in the Wolfberry and Bone Spring formations.

According to the Railroad Commission of Texas, EOG has Spraberry Trend production in Glasscock County; Spraberry production in Glasscock and Crockett counties; and Wolfcamp production in Terrell, Upton, Crockett, Loving, Pecos, Reynolds, and Ward counties.

The commission doesn't break out Wolfberry production, but DI Energy Strategy Partners (DIESP) follows that play and EOG's involvement in the play since 2004.

According to DIESP, EOG was producing 45,000 bbl/month of oil and 90 MMcf/month from more than 50 Wolfberry wells in June 2010.

Some of EOG's leases produced more than 200 b/d of oil, including the Halff Estate 20 lease that produced 547 b/d of oil, DIESP said.

EOG's 2008 annual report said Permian Basin production averaged 79 MMcf/d of gas and 6,800 b/d of

oil and condensate during that year, with wells drilled in the Wolfcamp, Morrow, Bone Spring, and Permo-Penn formations. It acquired more than 330 sq miles of 3-D seismic that year and added 97,500 acres of land to raise its total to 540,000 net acres.

In addition to the company's Leonard Shale properties in New Mexico, it had Bone Spring wells in Corbin, Corbin South, Draper Mill, Fairview Mills, Hardin Tank, Lea Undesignated, Loco Hills East, Red Hills, Red Hills East, Red Hills North, Sand Dunes South, Shugart North, SWD, Triste Draw, Walters Lake, and Young North fields.

FASKEN OIL & RANCH LTD.

Privately owned Fasken Oil & Ranch Ltd. earned a reputation for sophisticated use of technology to enhance its exploration and production activities, and application of that technology helped give the company a strong foothold in the Wolfberry play.

In prepared papers, Glenn Winters, chief geophysicist for Fasken, outlined techniques used by the company.

Geophysical techniques were used to reduce drilling risk.

It used 3-D seismic, paired with proprietary technology from London-based ViaLogy PLC to enhance analysis of porosity, fracturing, and predictability of recoverable hydrocarbons in the Strawn play in Andrews County, Texas.

Fasken and ViaLogy drilled a well after using the British company's QuantumRD technology to analyze 3-D and multicomponent seismic data, well logs, and geological records to locate well sites in a 12-sq-mile area.

Typically, operators need porosity higher than 3% in the tight Strawn to get economical production. The Fasken-ViaLogy analysis located large areas with porosity of more than 6%.

The technique also works as a direct hydrocarbon indicator with seismic data to characterize Wolfcamp carbonates.

Further, according to Robert Dean, chief executive officer of ViaLogy, "This has been a great partnership that will allow us to enhance and improve the ability of E&P companies to produce from Wolfberry, Strawn, and deeper formations."

According to the Railroad Commission of Texas, Fasken has Spraberry Trend production in Glasscock County; Spraberry production in Midland, Dawson, and Borden counties; and Wolfcamp production in Terrell, Andrews, Sterling, and Midland counties in Texas.

Fasken used spectral decomposition in the Dawson County portion of its Spraberry properties to find seismic anomalies previously missed, and it surveyed and cemented geophones in some 80 well bores to measure microseismic fracturing in its Wolfberry completions.

A July 2010 report by DI Energy Strategy Partners (DIESP), a company that tracks Wolfberry activity, said Fasken had picked up in four Wolfberry leases in Andrews County since 2009, and its "AX" lease in Midland County had four Wolfberry wells that produced 1,544 boe, the highest monthly Wolfberry production of any operator in the county.

A May 2010 report by DIESP said Fasken added eight producing wells throughout the Wolfberry Trend since 2009 and the July report boosted that number to 10. Fasken also held Bone Spring pro-

duction in Apache Ridge and Salt Lake fields in New Mexico.

LINN ENERGY LLC

Linn Energy LLC, founded in 2003 with a few Appalachian properties, has expanded rapidly with a particular focus on the Permian Basin.

It also has operations in the Midcontinent – primarily the Texas Panhandle and western Oklahoma – and California with production from more than 6,900 wells.

According to the 2009 annual report, the company had invested US $268 million in Permian Basin properties in the second half of 2009.

Those properties may not offer the drama of Linn's Black 50-1H Granite Wash horizontal well in the Stiles Ranch area of the Texas Panhandle with an initial maximum test rate of 60.2 MMcf/d of gas equivalent and a 24-hour production rate of 27 MMcf/d of gas equivalent, but they do offer substantial, long-term production.

On March 29, 2010, Linn said it agreed to pay $305 million for Permian Basin properties.

That acquisition doubled the company's oil production and reserves in the Permian Basin with anticipated mid-year 2010 net production of 2,800 boe/d and proved reserves of some 18 MMboe. It also gave the company a sizable entrance into the Wolfberry play and some 120 infill drilling locations.

On July 1, 2010, the company said it signed an agreement to acquire $90 million in Permian Basin properties with closing anticipated in August.

"This bolt-on acquisition in the Wolfberry Trend of the Permian Basin is an attractive addition to our recently acquired assets in this area. This acquisition increases our exposure to oil and adds more than 50 proved low-risk infill drilling opportunities, which could be significantly increased as a result of further downspacing," according to Mark E. Ellis, president and chief executive officer of Linn.

That acquisition gave the company net production of some 950 boe/d and proved reserves of approximately 7 MMboe.

Finally, in September 2010, Linn signed three agreements to buy more Wolfberry Trend properties for a combined price of $352.2 million and planned to close the acquisitions by the end of November. With the addition of the new properties, Linn's production from the Permian Basin will climb to approximately 10,000 boe/d from more than 74 MMboe in proved reserves.

The acquisitions also make the Permian Basin the company's second-largest operating area with approximately 400 proved Wolfberry drilling locations, or a five-year inventory.

Linn did not identify the sellers, but the properties produced a combined 3,300 boe/d from 30 MMboe of proved reserves, 72% of which is oil. The company also included more than 230 Wolfberry drilling locations with proved undeveloped reserves of 23 MMboe and an anticipated reserve life of 25 years.

NADEL AND GUSSMAN HEYCO LLC

Two strong Bone Spring operators – Nadel and Gussman Permian LLC and HEYCO (Harvey E. Yates Co.) – joined forces in 2008 to form Nadel and Gussman Heyco LLC. The goal was to develop HEYCO's Bone Spring properties in Eddy, Lea, and Chavez counties in southeastern New Mexico.

Scott German, president of Nadel and Gussman Permian, manages the 50-50 joint venture under the management team of James Adelson, president of Nadel and Gussman of Tulsa, and George Yates, president of HEYCO.

Outside the area of mutual interest, the companies can develop Bone Spring properties individually under the agreement.

The venture produced 275,788 bbl of liquids in 2008. That year, the New Mexico Oil & Gas Association ranked the company 34th among gas producers with 5.2 Bcf of gas produced during the year.

In 2009, the companies operated 165 wells with combined production of more than 694,000 boe and operations had expanded into Hidalgo County, Texas, and Roosevelt County, N.M.

Among Bone Spring fields in which the companies hold an interest are Corbin, Loco Hills East, Palmillo, Palmillo East, Shugart North, and Watkins.

OCCIDENTAL PETROLEUM CORP.

Occidental Petroleum Corp. (Oxy) likes large operations. It's the largest oil producer in Texas and New Mexico, the largest oil producer in the Permian Basin, the largest CO_2 enhanced recovery producer across the globe, and controls a large position in the Wolfberry play.

The company's worldwide oil and gas operations produced 737,000 boe/d in the first half of 2010, up from 716,000 boe/d in the period a year earlier. Its operations ranged from the Middle East and North Africa to Colombia and Argentina in South America and throughout the western US.

According to Oxy, the Permian Basin accounts for 19% of all US oil production, and Oxy produced 20% of all Permian oil.

Oxy produced some 201,000 boe/d from the Permian Basin in 2009, compared with its production of 135,000 boe/d in California where it is the second-largest producer.

The company's Permian properties initially held some 11.9 Bboe in place, and 4.1 Bboe have been produced, leaving 7.8 Bboe in the ground. That 7.8 Bboe contains some 800 MMboe in proved, probable, and possible reserves; another 1.4 Bboe that could be recovered by enhanced oil recovery (EOR); and another 1 Bboe in EOR potential.

To take advantage of that potential, Oxy will put 10% of its 2010 capital expenditures, or US $450 million, into the Permian Basin. From 2010 through 2014, it will invest 13% of its $27.5 billion budget in the basin, according to a May 2010 presentation.

The Permian Basin is Oxy's largest business unit with production of 180,000 boe/d, according to Bill Albrecht, president of Oxy Oil & Gas USA. Its holdings included 3.6 million gross, 2.2 million net, acres in a 100,000-sq-mile area.

Of the 50 CO_2 projects in the Permian Basin, Oxy operates 28 projects that produce approximately 85,000 boe/d.

It controlled more than 1,000 primary development locations in the Permian Basin and planned to run six or seven rigs during 2010.

More than 200 of those locations were in Delaware sands with more than 20 MMboe in potential production, and it had more than 550 locations in the Wolfberry play with potential production of more than 70 MMboe.

Its largest Wolfberry project is its 250-well Dora Roberts Field program in southern Midland County, Texas.

Among Oxy's holdings in Texas, it has interests in Wolfcamp production from fields in Terrell, Glasscock, Pecos, Loving, Reeves, Ector, Andrews, Winkler, and Ward counties. It produces from the Spraberry Trend in Midland and Glasscock counties and Spraberry-Wolfcamp in Ector County. It has production from the Woodford Shale in Andrews County and the Bone Spring in Winkler County.

New Mexico Bone Spring production comes from Corral Draw, Cotton Draw, Cotton Draw East, Lusk North, Mesa Verde, Pierce Crossing, Pierce Crossing East, Red Bluff, Red Tank, Red Tank East, and Shugart North fields.

PDC ENERGY CO.

PDC Energy Co., the new name for Petroleum Development Corp., joined the rush to the Wolfberry for the same reason as several other companies; the economics of oil production look better than gas production returns.

PDC started operations in Appalachia in 1969 and worked there for 30 years before branching into the Rocky Mountains with a strong base in Wattenberg Field in the Denver Basin of northeastern Colorado and additional Niobrara production from Garfield County, in the Piceance Basin of northwestern Colorado.

It also returned to Appalachia with Marcellus properties.

According to the company's 2Q 2010 presentation, it produced 8 Bcf of gas equivalent from the Rockies in 1Q and 2Q 2010 and anticipated 32.6 Bcf of gas equivalent for the year with two rigs working Wattenberg Field and one working the Piceance properties.

It produced 1.2 Bcf of gas equivalent from Appalachia in the first half and planned to reach 2.5 Bcf of gas equivalent for the year with one rig returning to active work in September 2010.

It purchased its Permian properties from a private company for US $45 million plus PDC's Michigan properties, valued by the seller at $30 million.

Its key development areas in the Wolfberry play are in Roy Parks, Mabee, and Ratliff fields. Throughout the basin, it has 120 Wolfberry locations on some 8,300 acres with wells offset by production from Concho Resources Inc., Devon Energy Corp., Cabot Oil & Gas Corp., and Endeavor Energy Resources LP.

PDC expected to bring eight wells to production in 3Q and 4Q 2010 for $1.25 million, recomplete two wells in 4Q 2010 for $1.5 million, and drill two new Wolfberry or deeper wells for $3.5 million in 4Q 2010. It anticipated 600 MMcf of gas equivalent in production in 2010 and planned to repeat that program in 2011 to add another 700 MMcf of gas equivalent in production.

The Wolfberry properties already have 72 producing wells and the company has identified some 1,200 locations on 40-acre spacing, according to DI Energy Strategy Partners.

PIONEER NATURAL RESOURCES CO.

Pioneer Natural Resources Co. held more acreage in the Spraberry Trend, the second-largest producing field in the US, than all other companies combined, a position that puts it in place to be a dominant player in the trend.

Pioneer holds 900,000 acres of leases in the Spraberry and more than 20,000 drilling locations. All other operators hold a combined 800,000 acres.

Pioneer started work as Parker & Parsley Petroleum Co. early in the production history of the Spraberry play.

In the 1950s through the 1970s, the company drilled through the Upper Spraberry and Lower Spraberry zones and completed wells with two fracture stages. During the following two decades, it added the Dean Formation and completed wells with four frac stages. By 2008 and 2009, it drilled deeper into the upper Wolfcamp zone and completed wells with six-stage frac treatments.

Currently, Pioneer is drilling deeper to the lower Wolfcamp and Strawn zones, and is completing shale/silt intervals in the Spraberry and Wolfcamp zones using 10-stage fracs.

Operators refer to completions in the Spraberry, Dean, and Wolfcamp formations as the Wolfberry play. Pioneer also plans to drill one horizontal well each in 3Q and 4Q 2010 in the Wolfcamp.

Strong economics account for the increased activity in the Spraberry play. Pioneer estimates a 50% internal rate of return before taxes using current strip prices at an average well cost of US $1.1 million to $1.2 million. Additional recoveries from deeper drilling to the lower Wolfcamp and Strawn will improve these economics.

The Strawn covers 30% to 40% of Pioneer's Spraberry Trend acreage. By adding lower Wolfcamp and Strawn recovery, the company expects a 20% to 30% increase in production above the typical 110,000 bbl recovery from Spraberry-Dean-Upper Wolfcamp completions.

Pioneer already is the biggest producer in the Spraberry, and it plans to get much bigger.

Wolfberry Economics

	Wattenberg	Niobrara	Wolfberry
Full cycle cash margin ($/Mcfge)	$8.10	$9.59	$8.60
Drilling F&D cost ($/Mcfge)	$2.00	$2.65	$2.15
% oil	56	91	69
Capital efficiency	260%	490%	290%

Wolfberry economics compare favorably with PDC's Wattenberg and Niobrara properties in Colorado. *(Chart courtesy of PDC Energy Co.)*

In 2010, the company will spend $580 million to drill approximately 440 Spraberry wells. It had 20 rigs running at the end of July and planned to ramp that number up to 25 to 30 rigs by the end of the year and bump the number to 40 rigs in 2012.

Pioneer anticipated drilling approximately 700 wells in 2011 and 1,000 wells each in 2012 and 2013. By the end of that period, Spraberry production should reach between 60,000 and 66,000 boe/d, the company said.

It produced a net 32,000 boe/d from the trend at mid-year 2010.

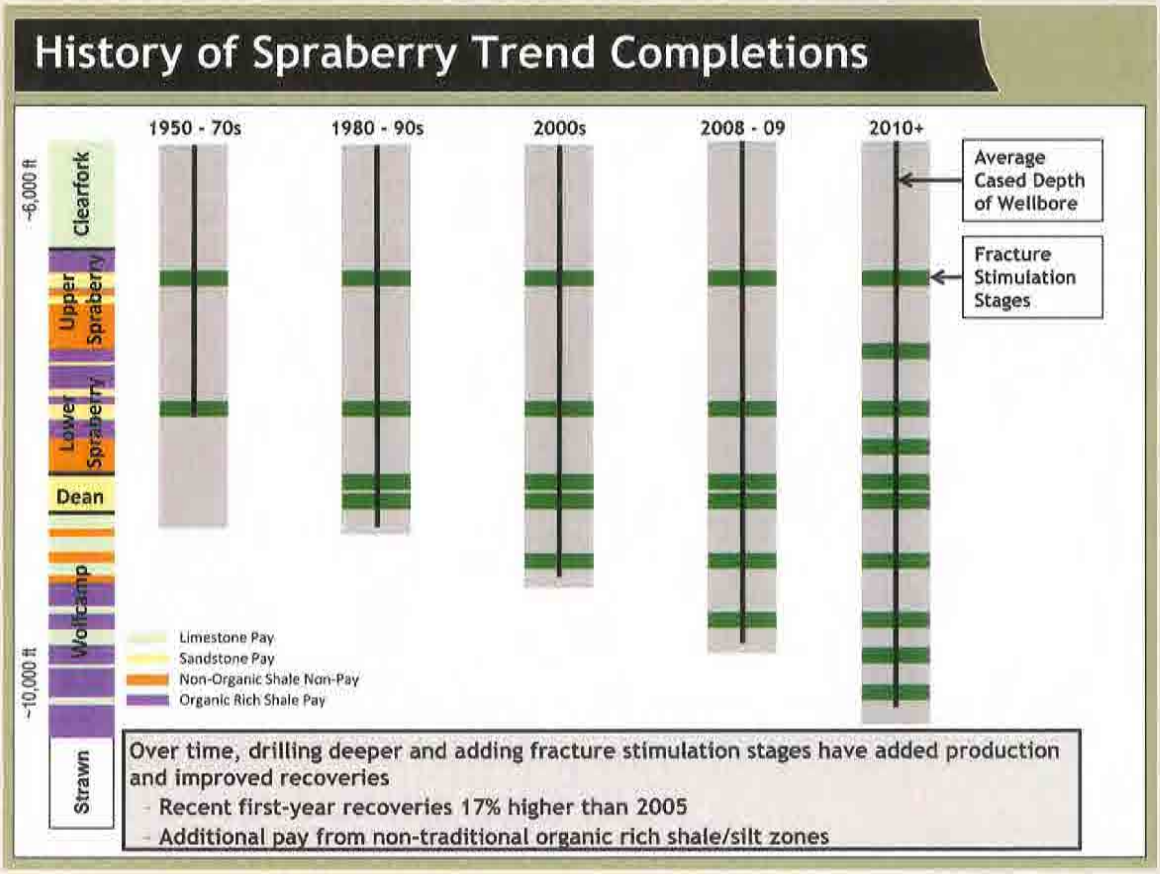
At the end of 2009, Pioneer had 998 MMboe in proved reserves at $80/bbl oil and $6/MMcf gas, and 513 MMboe of those reserves were in the Spraberry where the company had 4,100 proved undeveloped locations.

It has 5,100 locations – not counting the 4,100 proved undeveloped locations – and 350 MMboe on 40-acre spacing. The Railroad Commission of Texas already has approved 20-acre spacing in the trend, and that would add 9,500 locations and 500 MMboe in potential reserves. The company already has started a waterflood on 7,000 acres. A waterflood over 40% of its acreage should add another 300 MMboe for a potential total of 1.15 Bboe from the Spraberry.

SUMMIT PETROLEUM LLC

Summit Petroleum LLC has strong roots in the Wolfberry play in the Permian Basin. The president was credited as one of the founders of the play. Dennis Johnson, president of Summit, and Jim Henry, chairman of Henry Resources LLC, took over some old Arco properties that later belonged to BP plc when it took over that company, according to an article written by Al Pickett in the August 2010 issue of *PB Oil & Gas*, the magazine of the Permian Basin Petroleum Association. Johnson and Henry were Dave Feavel's bosses at Henry Petroleum Corp. at that time. Feavel generally is considered the founder of the Wolfberry play.

Together, they analyzed the Wolfcamp and found the fracture combination that made the Spraberry-Dean-Wolfcamp combination work. That combination later was named the Wolfberry.



Pioneer progressively added depth and frac stages to its Spraberry Trend wells, adding production as it drilled through the Dean and Wolfcamp. Now, the company is adding Strawn production. *(Diagram courtesy of Pioneer Natural Resources Co.)*

"Jim and Dennis agreed to the company taking the risk to chase the play. We figured out its potential," Feavel said in the magazine article.

The company quietly began working the new play.

Concho Resources Inc. acquired Henry Petroleum for US $565 million in 2008. With it, the company acquired 163 Bcf of gas equivalent in Wolfberry proved reserves.

Although 80 of Henry's employees went to Concho with handsome bonuses, Jim Henry formed Henry Resources and started working three rigs in new Wolfberry properties. Feavel became a partner with ExL Resources LLC, a company that proves up Wolfberry prospects and sells them.

Johnson left Henry Petroleum in 2007 to form Summit.

An activity chart prepared in May by DI Energy Strategy Partners for the June 2010 issue of *PB Oil & Gas* listed companies by the number of new Wolfberry wells drilled since 2009. Mariner Energy Inc., now part of Apache Corp., topped the list with 25 wells. Concho affiliate COG Operating LLC was second with 22 and Henry and Summit were tied for fifth at 11 wells each.

Summit's wells were in Upton, Midland, and Andrews counties in Texas. At that time, Upton was the best-producing county with 3,705 b/d of oil from the Wolfberry, Andrews was third at 1,819 b/d, and Midland County produced 1,730 b/d from the formation.

When the August *PB Oil & Gas* article was written, 83 of the 203 rigs working the Permian Basin were active in Andrews, Ector, Midland, Reagan, and Upton counties, generally considered the Wolfberry fairway, according to *Wellreports.com*. That was the highest level of activity since November 2008.

Of the 680 drilling permits filed in March 2010, 332 permits were in those five counties.

YATES PETROLEUM CORP.

Yates Petroleum Corp., the seventh-largest oil producer and the sixth-largest gas producer in New Mexico, also holds a strong position in Bone Spring fields in the southeastern part of the state. Its affiliate companies have both Bone Spring and Wolfberry connections.

Yates, a family-owned company that drilled New Mexico's first commercial well on government land in 1923, has been a New Mexico producing landmark company since that time.

The company also has strong operations in the Greater Green River and Powder River basins in Wyoming.

According to an *Energy Today* article written by Eric Slack, Martin Yates founded the company. He was Frank Yates's great-grandfather; Frank Yates is a past president of Yates Petroleum.

Three families grew out of the original company, and all three participate in ownership of Yates Petroleum with a one-third share. The three sons that remained in the oil and gas business – John Sr., Martin III, and S.P. – each participate in the base company, and each family has its own exploration and production business.

Frank Yates is a grandson of Martin Yates III and that branch of the company is MYCO Industries Inc. The John Yates Sr. branch is ABO Petroleum Corp. and the S.P. Yates arm is Yates Drilling Co.

John Yates Jr. is the current president of Yates Petroleum. Those affiliates frequently act as nonoperating partners of the core company.

Yates Petroleum's Bone Spring properties in New Mexico include interests in Airstrip, Avalon East, Berry North, Berry South, Bilbrey Basin South, Cass Draw, Cedar Canyon, Corral Canyon South, Cotton Draw East, Eddy Undesignated, Grama Ridge North, Hardin Tank, Ingle Wells, Leo South, Magruder West, Pierce Crossing East, Red Tank, San Lorenzo North, San Simon Northeast, Sand Dunes South, Sand Tank, Scharb, Shugart North, SWD, Walters Lake, and Willow Lake West fields, according to New Mexico records.

Yates Drilling has interests in Corral Canyon South and Winchester West Bone Spring fields.

ABO has an interest in Avalon North Field, a Bone Spring producer.

MYCO has an interest in the San Lorenzo Field, but it also branched out to take a foothold in the Wolfberry play in Texas.

In a July 2010 roundup, DI Energy Strategy Partners said MYCO brought nine Wolfberry leases online since 2009. A May report by the organization said MYCO brought nine new wells online in Midland and Andrews counties in Texas since 2009. ■

DISTINCT ADVANTAGE

Eagle Ford Shale

- Liquids-rich gas
- 2,000 square miles of 3-D seismic
- Logs from more than 150 operated wells
- 2,000 potential drilling locations
- Ramping up drilling
- Successful joint venture provides accelerated development

Permian - Spraberry

- Oil and liquids
- ~ 6,000 operated wells
- ~ 20,000 drilling locations
- Capturing additional pay from lower Wolfcamp, shale/silt intervals and deeper Strawn
- Accelerating drilling - 440 wells in 2010
- Ramping up to 1,000 wells by 2012

PIONEER
NATURAL RESOURCES

For more information on Pioneer, visit www.pxd.com. NYSE: PXD

Shortages Challenge Permian Basin Operators

The vast and diverse Permian Basin presents plenty of challenges. There are solutions for most of those challenges, but severe shortages of experienced personnel, equipment, and supplies are creating more stress.

By Dick Ghiselin
Contributing Editor

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

This is but one of the examples of the challenges faced by West Texas drillers over the years. But with ingenuity, they adapted offshore logging units from

As directional drilling has become more commonplace, so has the use of MWD systems that can deliver accurate directional survey and toolface data in all types of drilling environments. *(Illustration courtesy of Weatherford)*

the Gulf of Mexico that could be modified with extra-large winches and high-strength cables to reach the depths being drilled. Many folks did a double-take when they came across a deepwater offshore unit staked out on the caliche hardpan next to a drilling rig.

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

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

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

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

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

target deep saltwater aquifers to get enough water to frac.

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

Focusing on pay identification

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

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

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

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

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

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

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

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

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

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

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

New ideas take hold

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

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

Recent enhancements in external packer sliding sleeve methodology now allow for 20 or more fracture points offering improvements over existing

methods. This interventionless stimulation technology, Delta Stim Plus 20 completion service, has been used in the Williston Basin and in the Northeastern US as a cost-effective means of completing horizontal wells. While new to the Permian Basin, the Plus 20 system should prove equally effective for operators in this region.

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

'Knowledge is power'

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

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

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

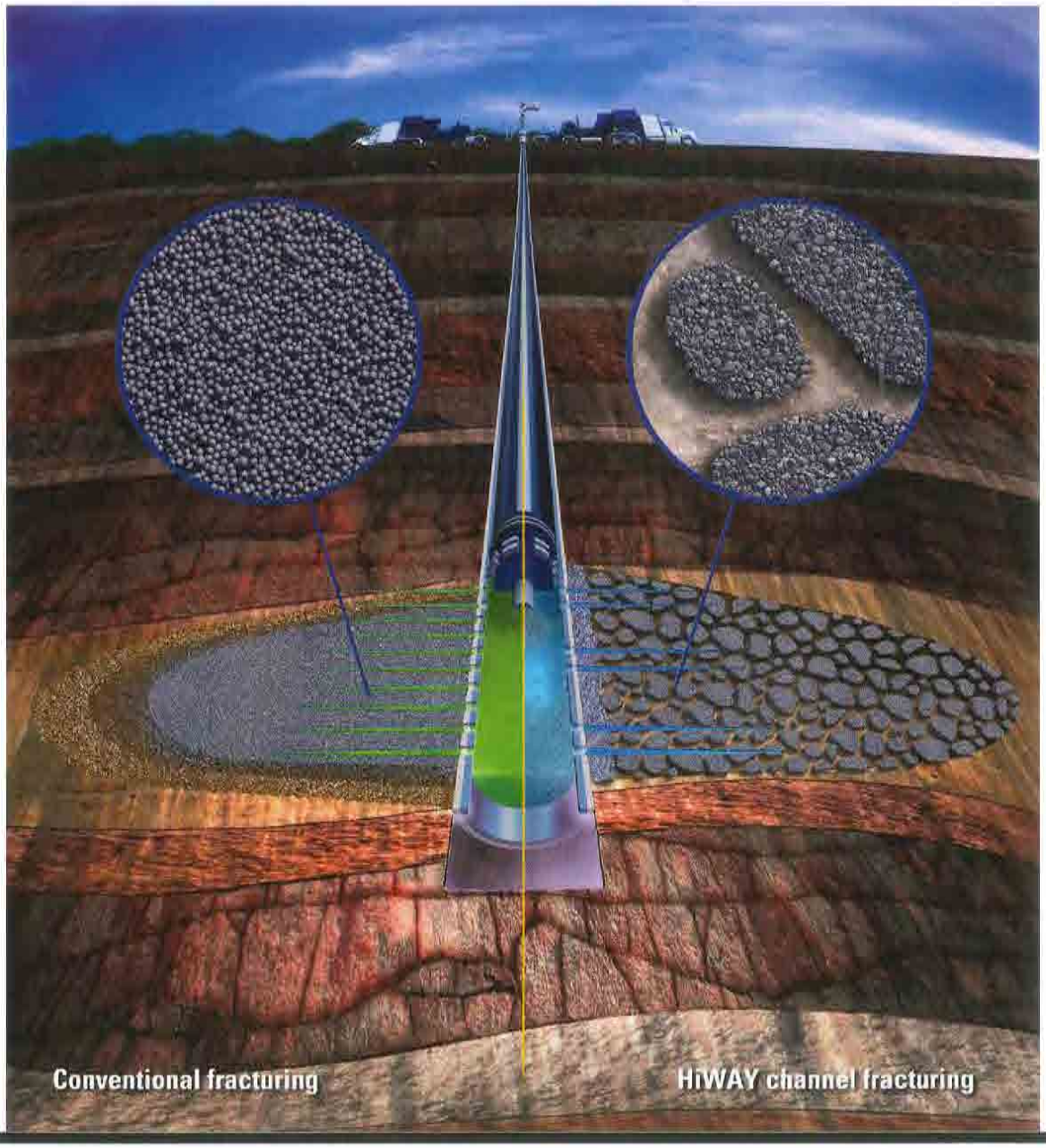
BJ Services recognizes that there is no "one-size-

The DirectStim multistage completion system provides an efficient means to ensure proper treatment volumes reach the entire length of long, openhole horizontal wells in the Permian Basin. *(Photo courtesy of BJ Services)*

fits-all" solution for the geologically diverse Permian Basin, and it is using its deep knowledge base to develop the best solutions for each well. For example, in many cases, it has found that crosslinked fluids achieve superior results compared to slickwater fracs in some areas. Knowing which areas react positively to these treatments helps execute fracs that result in sustained reservoir performance.

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

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



HiWAY channel fracturing redefines hydraulic fracturing by removing the link between fracture flow and proppant conductivity and achieves infinite fracture conductivity. *(Photo courtesy of Schlumberger)*

receives the proper treatment. It is effective particularly in horizontal completions.

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

Multidiscipline technology for optimum completions

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

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

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

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

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

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

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

Diverse products and services for total well solutions

By integrating its diverse product and service offerings, Baker Hughes strives to deliver a complete solution to its clients from well construction through completion and production. According to the company, two Permian Basin areas are commanding high operator interest these days: the Third Bone Spring Formation of Ward and Reeves

counties in Texas, and in New Mexico; and the Wolfberry play that includes the Spraberry and Wolfcamp formations in Martin, Midland, Upton, Reagan, and Ector counties in Texas.

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

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

Maximizer pumping units are applied frequently in West Texas oil fields. *(Photo courtesy of Weatherford)*

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

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

You no longer need to strike a balance between your need for information...

...and the time it takes to get it.

UGcenter.com

Hart Energy's exclusive **Unconventional Gas Center™** delivers the *data* and *analysis* you want about the world's unconventional oil and gas resources.

Individual subscriptions, group discounts and site licenses available – call:

(713) 260-6400

HART

Recently, the Vision service has been integrated with monitored and optimized AddFRAC balanced chemical treatments that help reduce scale and wax deposition as well as corrosion, leading to greater uptime.

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

Focusing on drilling and production

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

The company's directional services group in Midland, Texas, has drilled over 550 short-radius, re-entry wells during the past seven years. These wells are horizontal with the curve radius ranging from 85 to 135 ft, hole sizes between 3½ and 4¾ in., and target zones of roughly 10 ft in thickness.

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

Weatherford used a BHA consisting of a 4¾-in. performance motor and its hostile-environment LWD system with azimuthal gamma ray, and real-time drilling support services to geosteer through a 10-ft hydrocarbon-bearing zone in a 6.125-in. horizontal well for Manzano Oil & Gas in Lea County, New Mexico. The curve was built at 15 degrees/100 ft and a total vertical section of 4,368 ft was drilled in about 148 drilling hours. The lateral was drilled in two runs, one for the curve and one for the lateral, and all tools performed well.

Working on a client's first-ever horizontal well, in Cochran County, Texas, Weatherford re-entered 5½-in. casing and exited via whipstock, using 3¾-in. performance motors and EM MWD with LWD gamma ray sensors. The curve was built at 20 degrees/100 ft. The curve and lateral were drilled in one run. A total of 4,230 ft of total vertical section had been drilled by total depth, with the well bore remaining in the zone the entire time. A total of 4,525 ft of curve and lateral were drilled in 64.75 drilling hours.

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

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

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

MARCELLUS MIDSTREAM

CONFERENCE & EXHIBITION

MARCH 21-22, 2011 | PITTSBURGH, PENNSYLVANIA

MAKE PLANS NOW TO ATTEND THE 2ND ANNUAL MARCELLUS MIDSTREAM CONFERENCE & EXHIBITION.

Midstream operators are experiencing a new era of opportunities and challenges in the prolific Marcellus shale gas play. The 2nd Annual Marcellus Midstream Conference & Exhibition showcases the latest information from pipeline, gas processing and storage operators and their capital and service suppliers. Industry experts will discuss the secrets of their current successes and reveal their strategies for 2011 and beyond. Don't miss this one-day information-packed conference.

VIEW THE AGENDA AND REGISTER AT
MARCELLUSMIDSTREAM.COM

THE CONFERENCE & EXHIBITION SOLD OUT IN 2010, REGISTER TODAY!

EXHIBIT & SPONSORSHIP OPPORTUNITIES ARE AVAILABLE. FOR MORE INFORMATION CONTACT MARK IMMEKUS AT 713-260-6492

PRESENTED BY:
MIDSTREAM Business
Oil and Gas Investor
UG
UGcenter.com

Permian Players Focus on Capacity and Processing Concerns

Improved technology and new play areas drive a need for more infrastructure in the Permian Basin.

By Kelly Gilleland
Contributing Editor

Permian Basin producers are expressing concern that current pipeline and storage capacities might be inadequate to handle production in the near future. Although too much oil and gas sounds like a problem every oilman dreams of, not being able to get that product out of the ground and to market can cause serious headaches for producers and investors.

"It's a sort of 'Catch 22,'" said Permian Basin Petroleum Association (PBPA) president Taylor Mayne. "There is quite a bit of concern at the moment in Midland-Odessa about pipeline capacity. The PBPA has formed a task force with producers and pipeline companies to address the problems of capacity limits that we are starting to see in the region — it is getting that serious."

The current dilemma stems from a combination of improved technology as well as a new play that is proving successful. The Wolfberry play is a multizone play with production coming from the Spraberry and Wolfcamp formations in the Midland Basin. The Spraberry Formation is a massive sand body that has produced sweet crude and gas at about 6,000- to 12,000-ft depths for years, but has poor quality sand and shale sequence. The Wolfcamp Formation is a packed limestone layer below the Spraberry Trend that, until recently, was largely overlooked. However, horizontal drilling and new hydraulic fracturing technology now is allowing for massive fracturization, commingling these zones and making these wells more productive.

The Wolfberry play is causing a stir among explorationists in the region. A recent land sale brought nearly US $207 million, compared to $54.4 million previously.

"Acreage costs are shooting up, and a lot of people are investing," Mayne said. "Traditionally, wells in the region have been fairly low risk. It's not exactly a 'drill and not miss' situation, but it's pretty successful. There are a lot of wells, and a lot more planned. Even if a portion of them hit, there won't be enough pipeline capacity to get this oil and gas to market efficiently."

In the Permian area, intrastate natural gas systems such as the Southern Union Intrastate Pipelines and Energy Transfer Partners' Oasis Pipeline Co. interconnect with the interstate network via the El Paso Natural Gas Co., Transwestern Pipeline Co., Natural Gas Pipeline Co. of America, and the Northern Natural Gas Co. pipeline systems. The first two companies provide shippers access to Arizona and California markets. Energy Transfer's pipeline affiliates provide access, both east and west, to power plants and major city gates and hubs in Texas. The El Paso system and Transwestern provide transportation to Midwest markets and are the principal sources of gas for the Public Service Co. of New Mexico, the primary intrastate gas pipeline in New Mexico, according to the Energy Information Agency.

Market-center hub links provide transportation flexibility to gas shippers looking to reach alternative markets. For example, the Guadalupe Pipeline Co. (formerly TECO), and Energy Transfer Partners LP's Oasis Pipeline systems provide transportation between west (Waha hubs) and southeast Texas (Katy Hub) markets, while the Atmos Energy Corp.'s Atmos Pipeline (formerly TXU Lone Star), provides a similar service between the same Waha hubs but to interconnections in northeast Texas (Carthage Hub). Shippers using the Enterprise Products Partners LP's Texas intrastate system (the portion that was formerly Valero Transmission Co.) can deliver to either the Katy or Carthage hubs from the Waha area.

Also, Mayne noted that many producers are trucking product outside of the area because storage is becoming harder to come by. Another problem is the limited processing facilities for gas liquids.

But the most immediate problem, Mayne said, is increasing pressures in the pipelines. "They are packing the pipelines, which is causing production problems at the wellhead. Wellsite equipment can't handle the rising pressures and vapor recovery units aren't performing as well."

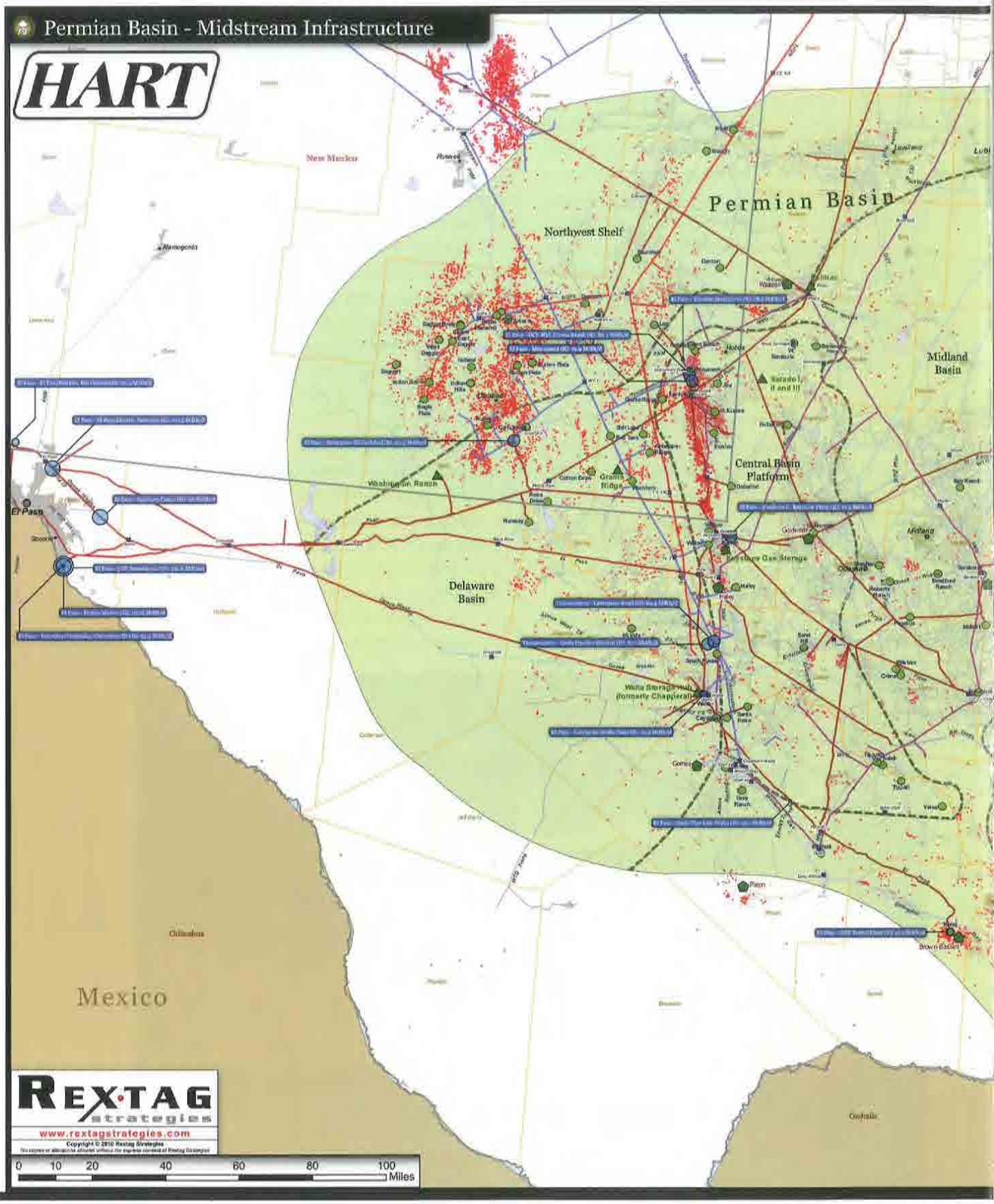
The PBPA's task force now is meeting regularly to discuss capacity and processing concerns for the region. "We are trying to get all the parties together to discuss 'what-if' scenarios as well as the current challenges we are beginning to face," Mayne said. "At this stage, the pipeline companies may not be quite ready to sink major amounts of capital into infrastructure upgrades and expansions, but they are definitely taking notice of the situation. We are starting to work together to address the imminent and long-term needs of the Permian Basin region."

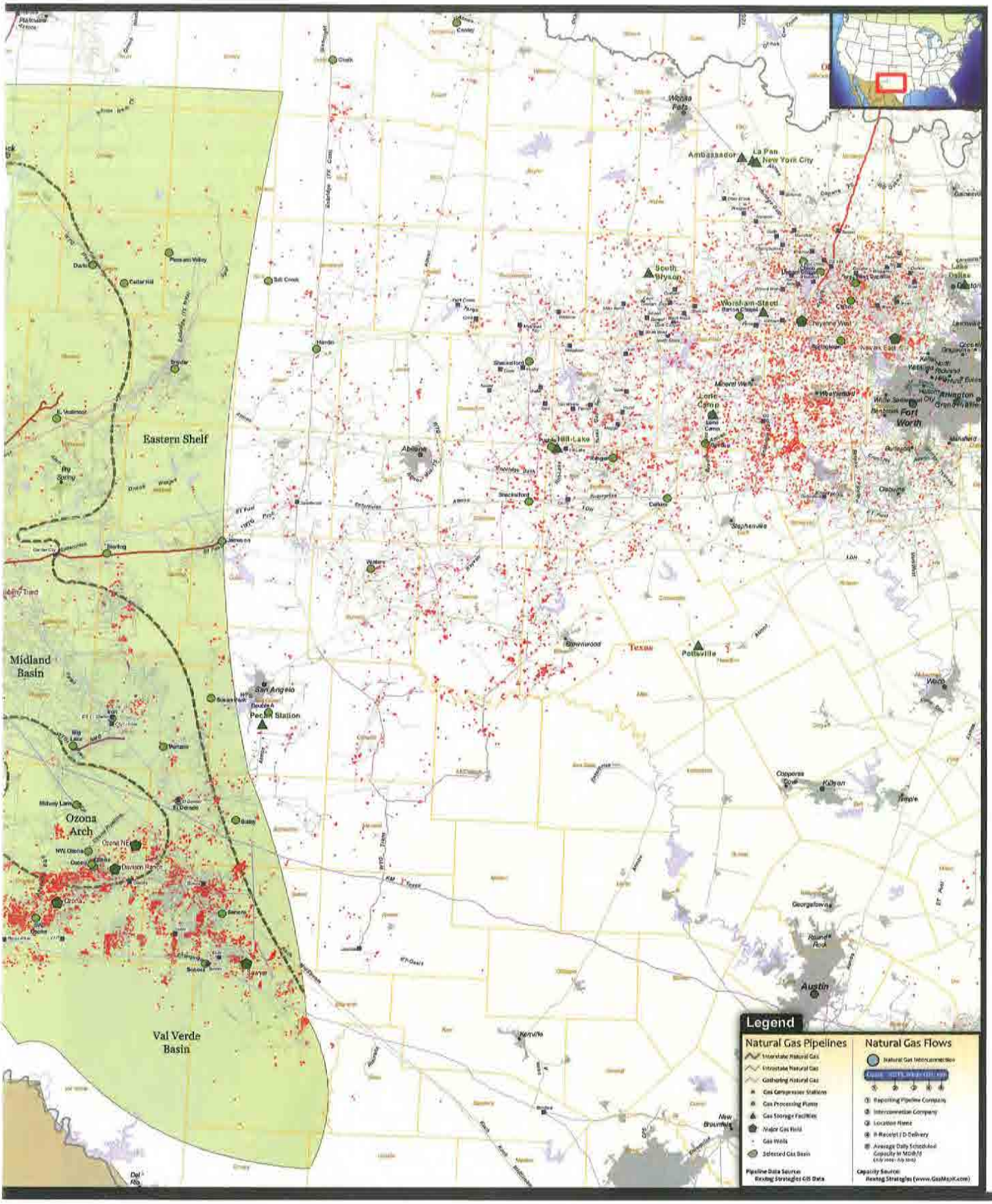
Meanwhile, drilling rig counts in the Permian Basin have risen more than 200% during the last year. "With rig counts going up and more acreage being leased, there is going to be a pipeline and storage bottleneck very soon," he said. Producers in the area are counting on some of the key midstream owners and operators to head off potential bottlenecks.

Apache Corp.

In August 2010, Houston-based Apache Corp. joined other operators in picking up BP plc's assets at fire-sale prices. Bundled within its $3.1 billion acquisition of BP's upstream Permian Basin oil and gas properties, Apache acquired two gas-processing plants. Although the sale has been finalized, Apache will not take over operations of the assets until December 2010.

Solar panels provide electric power for monitoring equipment on a pipeline in Texas.


Permian Basin - Midstream Infrastructure
HART
New Mexico
Permian Basin
Northwest Shelf
Midland Basin
Central Basin Platform
Delaware Basin
Washington Ranch
Grama Ridge
El Paso
Midland
Mexico
Chihuahua
Coahuila
REX·TAG strategies
www.rextagstrategies.com
Copyright © 2010 Rextag Strategies
0 10 20 40 60 80 100 Miles


Eastern Shelf
Midland Basin
Ozona Arch
Val Verde Basin
Fort Worth
Austin
Legend
Natural Gas Pipelines
Natural Gas Flows

"BP was a motivated seller," a spokesperson for Apache said. "They moved very quickly on this, and we are still evaluating the upside of these assets."

"This is a rare opportunity to acquire legacy positions from a major oil company with oil and gas production, acreage, infrastructure, seismic data, field studies, exploration prospects, and other essential aspects of our business," G. Steven Farris, Apache's chairman and chief executive officer, said. "We seldom have an opportunity like this in one of our core areas let alone three [Permian Basin, Egypt, and Canada]. This is a step change that will add muscle, enabling Apache to add value for decades to come through our demonstrated exploitation capabilities and exploration drilling."

From BP, Apache acquired 10 field areas in the Permian Basin with estimated proved reserves of 141 MMboe (65% liquids), first-half 2010 net production of 15,110 b/d of liquids and 81 MMcf/d of gas, two BP-operated gas-processing plants at Block 31 and Crane, and BP's non-operated interests in the Terrell gas-processing facility.

Apache already considered the Permian one of its key core operating areas and had acquired controlling interest in a substantial amount of acreage and assets from Anadarko in 2007.

Atlas Pipeline Partners LP

Moon Township, Pa.-based Atlas Pipeline Partners LP provides gas-gathering services and gas processing and treating services in the Permian Basin. Its systems gather gas from oil and gas wells and process the raw gas into merchantable, or residue, gas by extracting gas liquids and removing impurities. As of Dec. 31, 2009, the company's Midkiff/Benedum gathering system near Midland, Texas, consisted of approximately 3,000 miles of active gas-gathering pipelines and about 2,800 receipt points across four counties within the Permian Basin. The Midkiff-Benedum system has 139 MMcf/d of average throughput.

DCP Midstream LLC

In addition to its Permian assets, Denver-based DCP Midstream LLC, a 50-50 joint venture between Spectra Energy Corp. and ConocoPhillips Co., is one of the nation's largest gas gatherers and processors, the largest natural gas liquids (NGLs) producer, and one of the largest NGL mar-

A petroleum pipeline traverses Texas, home to a majority of the midstream systems that support Permian Basin production.

keters in the US. The company has a substantial presence in the Permian Basin.

El Paso Natural Gas Co.

The largest capacity gas pipeline in the region is Houston-based El Paso Natural Gas Co.'s system. It can transport up to 6.2 Bcf/d of gas production from the Permian Basin in West Texas and the San Juan Basin in southern Colorado. A company spokesperson said El Paso has no plans to expand its midstream capacities in the basin at this time.

However, the company's parent, El Paso Corp., was the winning bidder for leases covering about 123,100 acres in Reagan, Crockett, Upton, and Irion counties in the Sept. 22, 2010, University of Texas Permian Basin lease sale. The acquired leases target the Wolfcamp shale and add to some 12,000 net acres of existing leasehold in the play. El Paso now has a material position in a new oil-shale program with significant resource and production potential.

"We are very excited to announce our entry into a promising new oil shale," Brent Smolik, president of El Paso Exploration & Production Co., said. "Our acreage acquisition is the culmination of an extensive regional study by our technical team, and we expect it to become a new oil-focused core area."

Energy Transfer Partners

Dallas-based Energy Transfer Partners' (ETP) operations in the Permian Basin primarily consist of intrastate and interstate transmission services and a dew-point conditioning facility. The assets include some 400 miles of 24- to 36-in. intrastate transportation pipes with 35,000 hp of compression and a capacity in excess of 1.3 Bcf/d. These assets are owned by ETP's Oasis Pipeline and Energy Transfer Fuel affiliates.

ETP's Permian Basin interstate assets are owned by its subsidiary Transwestern Pipeline and consist of about 500 miles of 8- to 36-in. pipelines with 6,000 hp of compression and a capacity of 600 MMcf/d. Additionally, the company's gathering affiliate owns and operates a 225-MMcf/d hydrocarbon dew-point conditioning plant.

"The Permian Basin has played a significant role in providing gas production for consumers in Texas and much of the nation for many years," Mackie McCrea, ETP president and COO, said. "With new shale plays combined with existing reservoirs, the Permian Basin will continue to play an important role in providing gas supplies for the US."

ETP is a publicly traded partnership owning and operating a diversified portfolio of energy assets. The company owns the largest intrastate pipeline system in Texas and has pipeline operations in Arizona, Colorado, Louisiana, New Mexico, and Utah. Its strategy is to gather non-pipeline quality gas, remove impurities, separate out gas liquids, and redeliver pipeline-quality gas and liquids to market. ETP gas operations include approximately 17,500 miles of gathering and transportation pipelines, treating and processing assets, and three storage facilities in Texas. Also, ETP is one of the three largest retail marketers of propane in the US, serving more than one million customers across the country.

"There are challenges present in the Permian Basin region due to the existing gathering and processing infrastructure being largely operated as low-pressure, low-volume assets," McCrea said. "However, due to the advancements in drilling technology, and depending on the economic drivers for hydrocarbons, we feel that the Permian Basin will remain a strong basin for the exploration of gas, oil, and petroleum liquids."

Enstor Inc.

Houston-based Enstor Inc.'s Waha Storage Hub is near a major trading hub with excellent pipeline access. Formerly called the Chaparral Energy Center, the site was acquired as part of Enstor's acquisition of assets from Aquila Inc. a few years ago.

The ability to cycle gas inventory on demand is part of the business model of Enstor, third-largest independent storage operator in North America. It is owned by PPM Energy Inc. of Portland, Ore., and is part of Spain's Iberdrola group of companies.

The Waha facility is a high-deliverability salt cavern about three miles from the Waha trading hub in West Texas. It has 10 Bcf of working capac-

ity with high-turn capability. Peak injection capacity is 450,000 MMBtu/d and peak withdrawal capacity is 800,000 MMBtu/d.

In 2010, Enstor held a non-binding open season from March 1 to March 12 for firm storage service at its Houston Hub storage project under development approximately 30 miles northeast of Houston. According to the company, storage capacity of 16 Bcf of working capacity will provide deliverability of 1 Bcf/d and interconnect with as many as five pipelines. The project is expected to begin service in June 2013.

According to Enstor marketing director Kay Atchinson, the company's analysis shows that a Houston Hub is "ideally situated to gain full utility from the shift in natural gas supply dynamics, including growing shale production, planned LNG imports, and Houston Ship Channel demand."

When fully completed, the facility could provide for an ultimate capacity of 30 Bcf of working gas and pipeline interconnects with Natural Gas Pipeline Co. of America (400,000 cf/d) and Transcontinental Gas Pipeline Corp. (400,000 cf/d). Additional interconnects are planned with Trunkline Gas Co., Energy Transfer-Houston Pipeline, and Kinder Morgan.

Enterprise Products Partners LP

Houston-based Enterprise Products Partners LP's Carlsbad Gathering System gathers gas from Permian Basin wells in Texas and New Mexico, extracts mixed NGLs from the gas stream, and delivers the gas into the El Paso, Transwestern, and Oasis pipelines. Through its NGL pipeline network, Enterprise transports mixed NGLs to fractionators and distributes and receives NGL

Like this facility, storage tanks play an important role in the midstream business for Permian operators.

The current dilemma stems from a combination of improved technology as well as a new play that is proving successful. The Wolfberry play is a multizone play with production coming from the Spraberry and Wolfcamp formations in the Midland Basin.

products between petrochemical plants and refineries. Generally, it delivers purity products, such as propane, to end-users in the Midwest.

Northern Natural Gas Co.

Northern Natural Gas Co., based in Omaha, Neb., is owned by MidAmerican Energy Holdings Co. and operates an interstate gas pipeline extending from the Permian Basin in Texas to Minnesota, Iowa, Nebraska, South Dakota, Wisconsin, Illinois, and the Upper Peninsula of Michigan. Its system includes approximately 15,000 miles of gas pipeline with 5.5 Bcf/d of market area design capacity plus 2 Bcf of field area capacity.

The company provides transportation and storage services to 76 utilities and numerous end-use customers in the Upper Midwest. It also manages cross-haul and grid transportation between other interstate and intrastate pipelines in the Permian, Anadarko, Hugoton, and Midwest areas.

Also, Northern operates three natural gas storage facilities and two LNG peaking units, which are fully contracted and are central to meeting its customers' peak-day system requirements. Including these facilities, the company manages 73 Bcf of total firm and operational capacity, including 4 Bcf of LNG. Its operations are managed by more than 874 employees.

In addition to the Permian, Northern Natural accesses supply from every major Midcontinent basin, as well as the Rocky Mountain and Western Canadian basins.

Occidental Petroleum Corp.

Los Angeles, Calif.-based Occidental Petroleum Corp. (Oxy) is the largest oil producer in the Permian Basin of Texas and New Mexico, and the leading operator among more than 1,500 operators in the area. Oxy's oil production from acreage spanning 3.6 million gross acres and more than 2,000 drilling locations accounts for 20% of the basin's total production.

Oxy uses copious amounts of CO_2 for enhanced-recovery well operations. As a result, construction is under way at its Century Plant in Pecos County, Texas, and associated pipelines, to process and move high-CO_2 gas. The plant is expected to begin initial operation in late 2010 and will further increase Oxy's CO_2 supply while providing methane for the marketplace. Oxy's domestic US wet-gas production, as well as its third-party production, is processed through the company's 15 gas plants, including 13 in the Permian Basin.

Permian Energy Inc.

Based in Andrews, Texas, Permian Energy Inc. is an oil and gas service and development company that provides gas compression and enhanced oil and gas recovery services. The company sells techniques for enhanced oil recovery, gas lift compression, and general surface compression for gathering and processing systems.

Pioneer Natural Resources Co.

Irving, Texas-based Pioneer Natural Resources Co. is the largest acreage holder, driller, and producer in the Spraberry Field, with interests in more than 5,600 active wells. The company processes its own gas through the Midkiff/Benedum gas-processing facility in which it holds a 27% interest. Pioneer also is actively progressing initiatives to capture additional resource potential, including ongoing 40-acre field development, ongoing 20-acre downspacing, horizontal drilling potential deeper zones, evaluating potential from shale/silt intervals, and implementing enhanced oil recovery through a 7,000-acre waterflood project.

Sweet Economics

Unconventional resources could equal conventional resources.

By Stephen Berman
Senior Research Analyst, Pritchard Capital Partners LLC

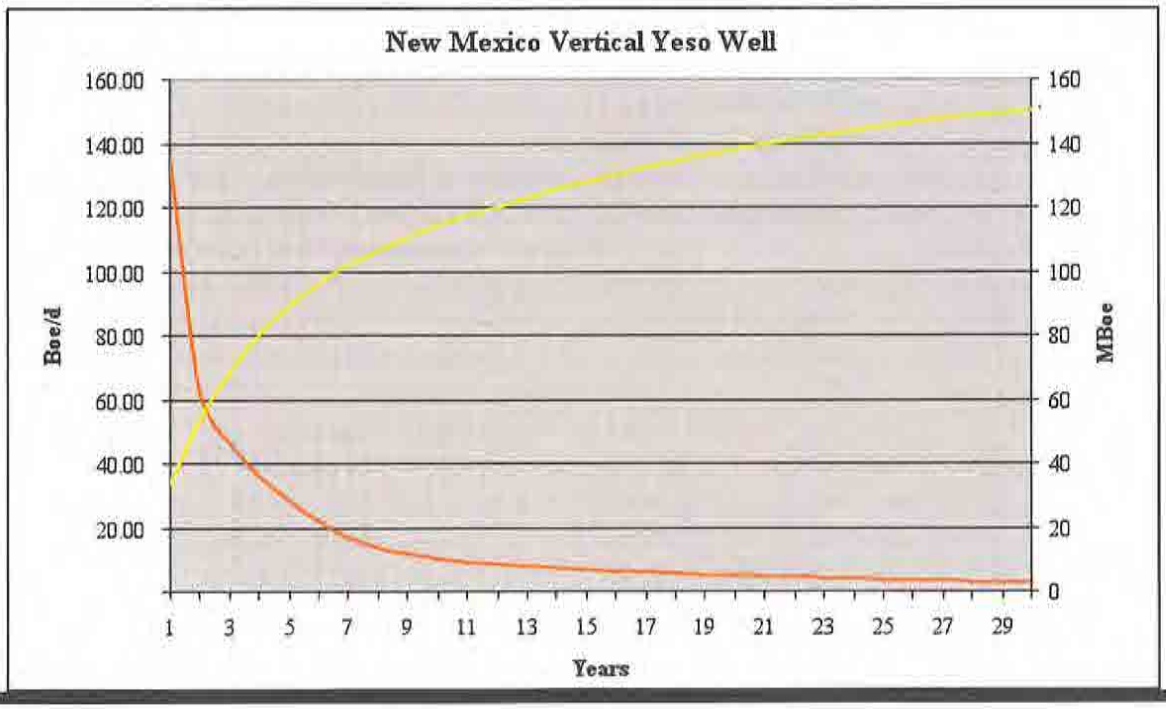
In 2007, the US Geological Survey estimated that from conventional reservoirs in the Permian Basin there were approximately 100 Bbbl of original oil in place (OOIP), of which the industry had produced roughly 40 Bbbl to date. There is a growing belief that resources from unconventional reservoirs in the Permian could be just as large.

Today, production from the Permian Basin is closing in on 1 MMbbl/d of oil and more than 4 Bcf/d of gas. There are roughly 300 drilling rigs running in the Permian, with one-third of the activity Wolfberry/Spraberry production.

Permian opportunities

One of the most active players in the Wolfberry is Concho Resources Inc., with 17 rigs currently drilling vertical wells at depths typically ranging from 7,500 to 11,000 ft. The drilling cost today is approximately US $1.35 million, with estimated ultimate recoveries (EURs) up to 140,000 boe and initial production (IP) rates around 120 boe/d. Depending on depth, wells typically take 12 to 15 days to drill, with spud to sales in 30 days. Concho estimates internal rates of return (IRRs) at today's commodity prices of around 50%.

In the Yeso play in the New Mexico portion of the Permian Basin, where Concho has seven rigs drilling, the company gets consistent results from vertical wells at less than 7,000 ft deep. Drilling cost today is approximately $1.45 million, with payout in roughly 14 months. Average EURs are 140,000 to 150,000 boe with IP rates generally around 200 boe/d, and the company estimates IRRs at today's commodity prices are approximately 70%. Since it



(Source: Pritchard Capital Partners LLC)

Vertical Yeso Well IRR

Well Cost (Smm)	Oil Price ($/bbl) $55.00	$60.00	$65.00	$70.00	$75.00	$80.00	$85.00	$90.00	$95.00
$1.60	35%	42%	49%	56%	63%	70%	78%	85%	92%
$1.50	39%	46%	54%	62%	69%	77%	85%	93%	101%
$1.40	44%	52%	60%	68%	77%	85%	93%	102%	110%
$1.30	49%	58%	67%	76%	85%	94%	103%	112%	121%
$1.20	56%	66%	75%	85%	95%	105%	114%	124%	134%

(Source: Pritchard Capital Partners LLC)

started drilling Yeso wells in 2006, enhanced efficiencies have allowed Concho and others to drill more wells with the same number of rigs, further enhancing the economics of the play. Opportunities to enhance returns for Concho going forward include drilling on 10-acre spacing in the Blinebry interval, continued evaluation of the use of larger frac jobs in the Blinebry waterfloods, and refracing existing Yeso wells. The company began testing the Blinebry interval on 10-acre spacing in 2008 with encouraging initial results. Shallower zone opportunities also are being considered. While on a reserve basis Concho is about two-thirds crude oil, the associated gas in its Permian plays is rich (1,300 Btu), so looking at the total revenue stream, Concho has been 80% to 85% liquids in this high oil price relative to gas environment.

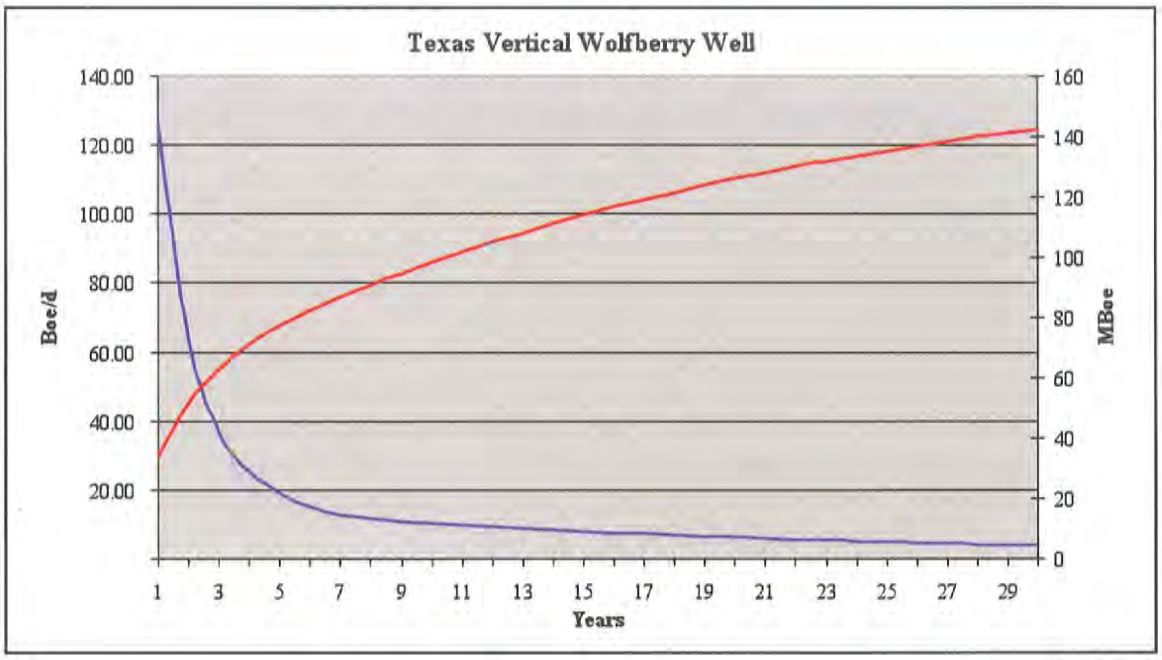
Another major player in the Permian is Pioneer Natural Resources Co., the largest acreage holder in the Spraberry Trend. Over time, drilling deeper and adding frac stimulation stages have resulted in increased production and improved recoveries for the company. Pioneer has expected recovery of OOIP per section of 12% to 13% from 40-acre field development, 6% from 20-acre downspacing, and 9% from waterflooding. A full-scale waterflood project is under way, with water injection having commenced in 3Q 2010 and first oil response expected in the first half of 2011, with at least a 50% uptick in production from the flooded zone. Pioneer also is testing potential from lower Strawn and Wolfcamp zones, and early results suggest a 20% to 30% increase over the company's 2010 type curve of 110,000 boe is achievable. Pioneer generates IRRs of 50% at current strip prices in the Spraberry at an average well cost of $1.1 million to $1.2 million.

Rising costs recently have put a crimp in Permian economics. For example, from the end of 2009 to its mid-year engineering update, Concho saw an overall capital cost increase of roughly 6% across the board. Most of that was coming from pressure pumping and pipe costs. Pioneer continues to focus on controlling Spraberry well costs in the Permian in a variety of ways, including expanding frac fleet ownership; having long-term contracts in place for sand, tubulars, and pumping units; and increasing its ownership of rigs. Pioneer plans to internally provide 30% to 60% of its service requirements by 2012 as part of its cost control efforts.

Horizontal oil plays

The excitement going forward lies in the emerging horizontal oil plays in the Permian. Just north of Concho's Yeso acreage in New Mexico is the horizontal Lower Abo play, where the company currently is running one rig. Lower Abo wells typically take 25 to 35 days to drill at a capital cost of $4 million. Concho's type curve IRR of a Lower Abo well at $70 oil and/or $4 gas is approximately 64%. While the company's type curve shows an EUR of 300,000 boe based on an IP rate of 350 boe/d, some wells have initially produced up to 1,750 boe/d, implying a higher recovery (500,000 boe or more). In addition to its complimentary Yeso acreage, Concho acquired Marbob Energy Corp. for its Bone Spring position, one of the most exciting horizontal oil plays emerging onshore the US. There currently are approximately 30 rigs drilling Bone Spring horizontal wells. Marbob has operated 20% of the 250 horizontal Bone Spring wells in the play to date. At his early stage in the play, Concho is assuming EURs in the 200,000 to 400,000 boe range at a well cost of $3 million to $5 million, although some recent well results suggest EURs could be meaningfully higher. Cimarex Energy, an early mover in the horizontal Permian oil plays, has had some impressive recent horizontal well results in both the Lower Abo and Bone Spring. Two Lower Abo wells had 30-day average rates of 875 and 590 boe/d, respectively, while two Bone Spring horizontals had 30-day average rates of 970 and 1,100 boe/d, respectively. On the heels of these recent results, Cimarex now estimates an average EUR on

(Source: Pritchard Capital Partners LLC)



its Bone Spring wells is approximately 570,000 boe versus its earlier estimate of 200,000 to 250,000 boe. The company assumes an average Bone Spring horizontal well cost of $4 million.

Concho plans to operate eight rigs in the Bone Spring during 2011, doubling Marbob's current rig count. Concho initially would be targeting the Upper Bone Spring, commonly referred to as the Avalon Shale. EOG Resources is an early mover in the Avalon (or Leonard) Shale, where it has drilled and completed seven horizontal wells. IP rates have averaged more than 600 b/d of oil, in addition to 2 MMcf/d of liquids-rich gas. Early production indicates EURs of approximately 400,000 boe, broken down about one-third each of oil, natural gas liquids, and gas.

Strong economics

The strong economics of the Permian result in high cash margins. For example, in the first half of 2010, Concho had an unhedged cash margin of $45.73/boe, 65% higher than the median of a peer group of companies. Strong economics also have been a main driving force behind the Permian consistently being one of the most active areas for merger, acquisition, and divestiture activity. In 2Q 2010, for example, the Permian saw four deals worth a total of $2.5 billion, with average metrics of approximately $19.25/boe of proved reserves (two-thirds oil) and $112,500/flowing boe of daily production. The largest transaction was SandRidge Energy's acquisition of Arena Resources for $1.4 billion. More recent transactions include Apache Corp. acquiring BPs Permian assets for $3.1 billion ($22/boe of proved reserves, $108,650/flowing boe of daily production) and Concho's $1.65 billion acquisition of privately-held Marbob Energy Corp. ($21.70/boe of proved reserves, $117,860/flowing boe of daily production). While Apache Corp. is acquiring Mariner Energy mostly for its robust portfolio of deepwater Gulf of Mexico assets, it also was attracted to the company's onshore assets, which primarily are in the Permian.

Permian Basin economics and the emerging horizontal plays contributed to a record-breaking lease sale for the University of Texas land program totaling $206.5 million in September 2010, nearly four times the previous record. In all, there were more than 100 tracts of land that sold for more than $1 million. A total of 191,254 acres out of the 260,800 available in 15 West Texas counties sold during the sale. The average bonus of $1,079.89/acre also was a record. El Paso Corp. was the winning bidder for leases covering 123,100 acres in the emerging Wolfcamp Shale in the Delaware Basin, adding acreage in Reagan, Crockett, Upton, and Irion counties. ■

Additional Information on the Permian Basin

For more details on the Permian Basin, consult the selected sources below.

By Ann Priestman, Editor, Unconventional Gas Center

General References

Broadhead, R.F. 1993, Permian Basin Permian (PB) Plays: Overview. Robertson, J.M.; Broadhead, R.F., eds. Atlas of Major Rocky Mountain Gas Reservoirs, New Mexico Bureau of Mines and Mineral Resources, pp. 138-53.

Dutton, S.P.; Kim, E.M.; Broadhead, R.F.; Raatz, W.D.; Breton, C.L.; Ruppel, S.C.; Kerans, C. 2005, Play Analysis and Leading-Edge Oil-Reservoir Development Methods in the Permian Basin: Increased Recovery Through Advanced Technologies. American Association of Petroleum Geologists Bulletin, V. 89, No. 5, pp. 553-76.

Galley, John E. 1963, Oil and Geology in the Permian Basin of Texas and New Mexico. American Association of Petroleum Geologists Bulletin.

Galloway, W.E.; Ewing, T.E.; Garrett Jr., C.M.; Tyler, N.; Bebout, D.G. 1983, Atlas of Major Texas Oil Reservoirs. The University of Texas at Austin, Bureau of Economic Geology Special Publication, p. 139.

Hanson, Bernold M. 1985, Truncated Devonian and Fusselman Fields and Their Relationship to Permian Basin Reserves. American Association of Petroleum Geologists Bulletin.

Hills, John M. 1972, Late Paleozoic Sedimentation in West Texas Permian Basin. American Association of Petroleum Geologists Bulletin.

Hills, John M.; Hoenig, Margaret Allen. 1979, Proposed Type Sections for Upper Silurian and Lower Devonian Subsurface Units in Permian Basin, West Texas. American Association of Petroleum Geologists Bulletin.

Holtz, M.H.; Garrett Jr., C.M.; Tremblay, T.A. 1993, Update of Atlas of Major Texas Oil Reservoirs Data Base and Atlas of Major Texas Gas Reservoirs Data Base. The University of Texas at Austin, Bureau of Economic Geology Contract Report Prepared for the US Geological Survey Under Contract No. 1434-93-C-40079, p. 14 plus data tape.

Johnson Jr., Raymond L.; Rodgerson, James L. 1998, More Effective Hydraulic Fracturing in Secondary, In-Fill Developments, Permian. SPE-39781.

Jones, Theodore S.; Smith, Harold M. 1963, Relationships of Oil Composition and Stratigraphy in Permian Basin of West Texas and New Mexico, Part 2. American Association of Petroleum Geologists Bulletin.

Jones, Theodore S.; Smith, Harold M. 1965, Relationships of Oil Composition and Stratigraphy in the Permian Basin of West Texas and New Mexico, Part 1. American Association of Petroleum Geologists Special Volumes.

Kosters, E.C.; Bebout, D.G.; Seni, S.J.; Garrett Jr., C.M.; Brown Jr., L.F.; Hamlin, H.S.; Dutton, S.P.; Ruppel, S.C.; Finley, R.J.; Tyler, Noel. 1989, Atlas of Major Texas Gas Reservoirs. The University of Texas at Austin, Bureau of Economic Geology Special Publication, p. 161.

Tyler, Noel; Bebout, D.G.; Garrett Jr., C.M.; Guevara, E.H.; Hocott, C.R.; Holtz, M.H.; Hovorka, S.D.; Kerans, C.; Lucia, F.J.; Major, R.P.; Ruppel, S.C.; Van der Stoep, G.W. 1991, Integrated Characterization of Permian Basin Reservoirs, University Lands, West Texas: Targeting the Remaining Resource for Advanced Oil Recovery. The University of Texas at Austin, Bureau of Economic Geology Report of Investigations, No. 203, p. 136.

Abo

Bensing, Joel P.; Mozley, Peter S.; Dunbar, Nelia W. 2005, Importance of Clay in Iron Transport and Sediment Reddening: Evidence from Reduction Features of the Abo Formation, New Mexico, US. Journal of Sedimentary Research.

Benton, Jerry P.; Maslanka, Paul M.; Smith, Robert L. 1981, Early Implementation of a Full-Scale Waterflood in the Abo Reef, Terry County, Texas: A Case History. Permian Basin Oil and Gas Recovery Conference (Midland, Texas), SPE 9720.

Boneau, David F.; Braswell, Joe; Stall, Albert R.; Tisdale, Robert E. 1982, Completion Practices and Reserve Estimates for Pecos Slope Abo Gas Field. Society of Petroleum Engineers Production Technology Symposium (Hobbs, NM), SPE 11336.

Broadhead, R.F. 1983, "Tight" Abo Gas Sands, East-Central New Mexico. American Association of Petroleum Geologists Bulletin.

Christianson, S. 1977, Performance and Unitization of the Empire Abo Pool. Society of Petroleum Engineers Permian Basin Oil and Gas Recovery Conference (Midland, Texas), SPE 6384.

Crabaugh, Jeff P.; McPherson, John G. 1984, Transitions in a Fluvial System: Abo Formation, Southeastern Nacimiento Mountains, New Mexico. American Association of Petroleum Geologists Bulletin.

D'Agostino, Anthony E.; Party, J. Michael. 2006, Facies and Sequence Stratigraphy of the Abo Formation in the Kingdom Field Area, Terry and Hockley Counties, West Texas. Houston Geological Society.

Gutierrez, Alberto A. 1983, Exploration Geology and Depositional Modeling of a Continental Tight Sand Reservoir: The Abo Formation, Chaves County, New Mexico. American Association of Petroleum Geologists Bulletin.

Hueni, G.B.; Schuessler, K.L. 1993, Associated Gas Reservoirs. Atlas of Major Rocky Mountain Gas Reservoirs, New Mexico Bureau of Mines and Mineral Resources, p. 190.

Kelley, V.C. 1971, Geology of the Pecos Country, Southeastern New Mexico. New Mexico Bureau of Mines and Mineral Resources Memoir, No. 24, p. 75.

Kerans, C.; Kempter, K.; Rush, J. 2000, Facies and Stratigraphic Controls on a Coastal Paleokarst, Lower Permian, Apache Canyon, West Texas. Lindsay, R.; Trentham, R.; Ward, R.F; Smith, A.H., eds. Classic Permian Geology of West Texas and Southeastern New Mexico, 75 Years of Permian Basin Oil & Gas Exploration & Development, West Texas Geological Society Publication, No. 00-108, pp. 55-81.

Killough, J.E.; Foster Jr., H.P. 1979, Reservoir Simulation of the Empire Abo Field: The Use of Pseudos in a Multilayered System. SPE 7418.

LeMay, William J. 1960, Abo Reefing in Southeastern New Mexico. A Symposium of Oil and Gas Fields of Southeastern New Mexico Supplement, Roswell Geological Society, pp. xvii-xxi.

LeMay, William J. 1972, Empire Abo Field, Southeast New Mexico: Case Histories. American Association of Petroleum Geologists Special Volumes.

Mack, Greg H.; Cole, David R.; Giordano, Thomas H.; Schaal, William C.; Barcelos, Jose H. 1991, Paleoclimatic Controls on Stable Oxygen and Carbon Isotopes in Caliche of the Abo Formation (Permian), South-Central New Mexico, US. Journal of Sedimentary Research.

Mack, Greg H.; James, W.C. 1986, Cyclic Sedimentation in the Mixed Siliciclastic-Carbonate Abo-Hueco Transitional Zone (Lower Permian), Southwestern New Mexico. Journal of Sedimentary Research.

Mazzullo, S.J. 1982, Stratigraphy and Depositional Mosaics of Lower Clear Fork and Wichita Groups (Permian), Northern Midland Basin, Texas. American Association of Petroleum Geologists Bulletin, V. 66, pp. 210-27.

Party, J.M.; D'Agostino, A.E.; Welch, J.P.F.; Lindsay, R.F. 1998, Geology, Facies, and Stratigraphy of Kingdom and Kingdom North (Abo) Fields, Terry and Hockley Counties, Texas. DeMis, W.D.; Nelis, M.K., eds. The Search Continues into the 21st Century, West Texas Geological Society Publication, No. 98-105, pp. 139-66.

Perusek, Cy. 1984, Geology of Abo Gas-Producing Areas of Pecos Slope, Chaves County, New Mexico. American Association of Petroleum Geologists Bulletin.

Sanchez, Steve; Engler, Thomas W.; Kelly, Mike. 2001, Evaluation of Fracture Stimulation Treatments by Integrated Reservoir Description and Fure Treatment Analysis in the Pecos Slope Abo Tight-Gas Reservoir, Southeastern New Mexico. Society of Petroleum Engineers Permian Basin Oil and Gas Recovery Conference (Midland, Texas), SPE 70005.

Sax, N.A.; Stenzel, William K. 1968, Oils from Abo Reservoirs of Northwestern Shelf. American Association of Petroleum Geologists Bulletin.

Snyder, D.O. 1962, Geology of the Empire Abo Field, Eddy County, New Mexico. University of New Mexico, MS Thesis, p. 77.

Speer, Stephen W.; Scott, Alan J. 1983, Evolution of a Fluvial Clastic Wedge, Abo Formation (Wolfcampian), Sacramento Mountains, New Mexico. American Association of Petroleum Geologists Bulletin.

Stenzel, William K. 1965, Times of Migration and Accumulation of Petroleum in Abo Reef of Southeastern New Mexico: A Hypothesis. American Association of Petroleum Geologists Special Volumes.

Stone, Donald S. 1997, Sample from Wild Cow Formation, Abo Pass, New Mexico. Geoquiz Answers, Rocky Mountain Association of Geologists.

Stramp, Rylan L. 1980, The Use of Horizontal Drainholes in the Empire Abo Unit. Society of Petroleum Engineers Annual Technical Conference and Exhibition (Dallas, Texas), SPE 9221.

Zeng, H.; Kerans, C. 2003, Seismic Frequency Control on Carbonate Seismic Stratigraphy: A Case Study of the Kingdom Abo Sequence, West Texas. American Association of Petroleum Geologists Bulletin, V. 87, pp. 273-93.

Bone Spring

Cornell, William C. 1983, Some Permian (Leonardian) Radiolarians from Bone Spring Limestone, Delaware Basin, West Texas. American Association of Petroleum Geologists Bulletin.

Downing, A.; Mazzullo, J. 2000, Slope Fan Deposits of the 2nd Bone Spring Sand, Young North Field, Lea County, New Mexico. DeMis, W.D.; Nelis, M.K.; Trentham, R.C., eds. The Permian Basin: Proving Ground for Tomorrow's Technologies, West Texas Geological Society Publication, No. 00-109, p. 73.

Gawloski, T.F. 1987, Nature, Distribution, and Petroleum Potential of Bone Spring Detrital Sediments Along the Northwest Shelf of the Delaware Basin. Cromwell, D.; Mazzullo, L., eds. The Leonardian Facies in West Texas and Southeastern New Mexico and Guidebook to the Glass Mountains, West Texas, Permian Basin Section Society of Economic Paleontologists and Mineralogists Publication, No. 87-27, pp. 84-105.

Howard, A.D.; Fraga, J.A. 1984, Volan Interpretation and Application in the Bone Spring Formation (Leonard Series) in Southeastern New Mexico. Society of Petroleum Engineers Production Technology Symposium (Hobbs, NM), SPE 13397.

Mazzullo, L.J.; Reid II, A.M. 1987, Stratigraphy of the Bone Spring Formation (Leonardian) and Depositional Setting in the Scharb Field, Lea County, New Mexico. Cromwell, D.; Mazzullo, L., eds. The Leonardian Facies in West Texas and Southeastern New Mexico and Guidebook to the Glass Mountains, West Texas, Permian Basin Section Society of Economic Paleontologists and Mineralogists Publication, No. 87-27, pp.107-11.

Montgomery, S.L. 1997, Permian Bone Spring Formation: Sandstone Play in the Delaware Basin Part I, Slope. American Association of Petroleum Geologists Bulletin, V. 81, pp. 1239-58.

Montgomery, S.L. 1997, Permian Bone Spring Formation: Sandstone Play in the Delaware Basin Part II, Basin. American Association of Petroleum Geologists Bulletin.

Pearson, R.A. 1999, Sequence Stratigraphy and Seismic-Guided Estimation of Log Properties of the Second Sand Member of the Bone Spring Formation, Delaware Basin, New Mexico. New Mexico Institute of Mining and Technology, MS Thesis, p. 124 plus appendices.

Saller, A.H.; Barton, J.W.; Barton, R.E. 1989, Mescalero Escarpe Field, Oil from Carbonate Slope Detritus, Southeastern New Mexico. Flis, J.E.; Price, R.C.; Sarg, J.F., eds. Search for the Subtle Trap: Hydrocarbon Exploration in Mature Basins, West Texas Geological Society Publication, No. 89-85, pp. 59-74.

Wiggins, W.D.; Harris, P.M. 1985, Burial Diagenetic Sequence in Deep-Water Allochthonous Dolomites, Permian Bone Spring Formation, Southeast New Mexico. Crevello, P.D.; Harris, P.M., eds. Deep-Water Carbonates: Buildups, Turbidites, Debris Flows, and Chalks: A Core Workshop. SEPM Core Workshop, No. 6, pp. 140-73.

Leonard

Anonymous. 2002, Geological Controls on Reservoir Development in a Leonardian (Lower Permian) Carbonate Platform Reservoir, Monahans Field, West Texas. The University of Texas at Austin, Bureau of Economic Geology Report of Investigations, No. 266, p. 58.

Anonymous. 2003, Lower Leonardian (Clear Fork – Abo) Reservoir Architecture: Insights from Outcrops and Fullerton Field, West Texas. Hunt, T.J.; Lufholm, P.H., eds. The Permian Basin: Back to Basics, West Texas Geological Society Publication, No. 03-112, pp. 45-46.

Atchley, S.C.; Kozar, M.G.; Yose, L.A. 1999, A Predictive Model for Reservoir Distribution in the Permian (Leonardian) Clear Fork and Glorieta Formations, Robertson Field, West Texas. American Association of Petroleum Geologists Bulletin, V. 83, pp. 1031-56.

Broadhead, R.F. 1993, Yeso Platform. Robertson J.M.; Broadhead, R.F., eds. Atlas of Major Rocky Mountain Gas Reservoirs, New Mexico Bureau of Mines and Mineral Resources, pp. 146-48.

Burnham, D.E. 1991, Depositional Environments and Facies Distribution of the Permian Paddock Member of the Yeso Formation, Vacuum (Glorieta) Field, Lea County, New Mexico. The University of Texas of the Permian Basin, MS Thesis, p. 140.

Fitchen, W.M.; Starcher, M.A.; Buffler, R.T.; Wilde, G.L. 1995, Sequence Stratigraphic Framework and Facies Models of the Early Permian Platform Margins, Sierra Diablo, West Texas. Garber, R.A.; Lindsay, R.F., eds. Wolfcampian-Leonardian Shelf Margin Facies of the Sierra Diablo: Seismic Scale Models for Subsurface Exploration, West Texas Geological Society Publication, No. 95-97, pp. 23-66.

Hoffman, C.L. 2002, Reservoir Characterization of the Drinkard Formation of the Justis Tubb-Drinkard Field, Lea County, New Mexico: A Valuable Tool in Optimizing Field Development. Hunt, T.J.; Lufholm, P.H., eds. The Permian Basin: Preserving Our Past and Securing Our Future, West Texas Geological Society Publication, No. 02-111, pp. 115-16.

Holtz, M.H.; Ruppel, S.C.; Hocott, C.R. 1992, Integrated Geologic and Engineering Determination of Oil-Reserve Growth Potential in Carbonate Reservoirs. Journal of Petroleum Technology, V. 44, No. 11, pp. 1250-57.

Jennings Jr., J.W.; Lucia, F.J.; Ruppel, S. C. 2002, 3-D Modeling of Stratigraphically Controlled Petrophysical Variability in the South Wasson Clear Fork Reservoir. Society of Petroleum Engineers Annual Technical Conference and Exhibition (Sept. 29, 2002 to Oct. 2, 2002, San Antonio, Texas) Transactions, SPE 77592, p. 15.

Johnson, I.G.; Brown, J.L.; Asquith, G.B. 1997, Using Sinusoidal Drilling Techniques in a Diagenetically Complex Carbonate Reservoir: West Dollarhide Drinkard Unit (Mid-Leonardian), Lea County, Southeast New Mexico. DeMis, W.D., ed. Permian Basin Oil and Gas Fields: Turning Ideas into Production, West Texas Geological Society Publication, No. 97-102, pp. 93-95.

Jones, R.H.; Lucia, F.J.; Ruppel, S.C.; Kane, J.A. 2003, Better Than a Porosity Cutoff: The Rock-Fabric Approach to Understanding Porosity and Permeability in the Lower Clear Fork and Wichita Reservoirs, Fullerton Field, West Texas. Hunt, T.J.; Lufholm, P.H., eds. The Permian Basin: Back to Basics, West Texas Geological Society Publication, No. 03-112, pp. 47-66.

Kerans, C.; Ruppel, S.C. 1994, San Andres Sequence Framework, Guadalupe Mountains: Implications for San Andres Type Section and Subsurface Reservoirs. Garber, R.A.; Keller, D.R., eds. Field Guide to the Paleozoic Section of the San Andres Mountains: Permian Basin Section, SEPM Publication, No. 94-35, pp. 105-16.

Kincheloe, D.; David, E.K. 1977, Oil Center Blinebry. A Symposium of the Oil and Gas Fields of Southeastern New Mexico Supplement, Roswell Geological Society, pp. 142-43.

Kinder Morgan. 2004, South Wasson Clearfork Unit: http://www.kindermorgan.com/business/co2/success_clearfork.cfm.

Marshall, L.R.; Foltz, G.A. 1960, Justis Blinebry. A Symposium of the Oil and Gas Fields of Southeastern New Mexico Supplement, Roswell Geological Society, pp. 114-15.

Martin, R.L.; Hickey, K.F. 2002, Horizontal Drilling at Vacuum Glorieta West Unit, Lea County, New Mexico: A Case History. Hunt, T.J.; Lufholm, P.H., eds. The Permian Basin: Preserving Our Past and Securing Our Future, West Texas Geological Society Publication, No. 02-111, pp. 117-24.

Martin, R.L.; Raines, M.A.; Cole, R.M. 1999, Stratigraphic Styles of the Drinkard (Leonardian) Trend on the Northwest Shelf, Lea County, New Mexico: Finding Oil in a Mature Area. Grace, T.D.; Hinterlong, G.D., eds. The Permian Basin: Providing Energy for America, West Texas Geological Society Publication, No. 99-106, p. 87.

Mazzullo, S.J. 1982, Stratigraphy and Depositional Mosaics of Lower Clear Fork and Wichita Groups (Permian), Northern Midland Basin, Texas. American Association of Petroleum Geologists Bulletin, V. 66, pp. 210-27.

Mazzullo, S.J.; Reid, A.M. 1989, Lower Permian Platform and Basin Depositional Systems, Northern Midland Basin, Texas. Crevello, P.D.; Wilson, J.L.; Sarg, J.F.; Read, J.F., eds. Controls on Carbonate Platform and Basin Development, Society of Economic Paleontologists and Mineralogists Special Publication, No. 44, pp. 305-20.

Montgomery, S.L. 1998, Permian Clear Fork Group, North Robertson Unit: Integrated Reservoir Management and Characterization for Infill Drilling, Part I: Geological Analysis. American Association of Petroleum Geologists Bulletin, V. 82, pp. 1797-1814.

Montgomery, S.L.; Davies, D.K.; Vessell, R.K.; Kamis, J.E.; Dixon, W.H. 1998, Permian Clear Fork Group, North Robertson Unit: Integrated Reservoir Management and Characterization for Infill Drilling, Part II: Petrophysical and Engineering Data. American Association of Petroleum Geologists Bulletin, V. 82, pp. 1985-2002.

Nevans, J.W.; Kamis, J.E.; Davies, D.K.; Vessell, R.K.; Doublet, L.E.; Blasingame, T.A. 1999, An Integrated Geologic and Engineering Reservoir Characterization of the North Robertson (Clear Fork) Unit, Gaines County, Texas. Schatzinger, R.A.; Jordan, J.F., eds. Reservoir Characterization: Recent Advances, American Association of Petroleum Geologists Memoir, No. 71, pp. 109-24.

Presley, M.W. 1987, Evolution of Permian Evaporite Basin in Texas Panhandle. American Association of Petroleum Geologists Bulletin, V. 71, pp. 167-90.

Ruppel, S.C. 1992, Styles of Deposition and Diagenesis in Leonardian Carbonate Reservoirs in West Texas: Implications for Improved Reservoir Characterization. Society of Petroleum Engineers Annual Exhibition and Technical Conference, SPE Publication, No. 24691, pp. 313-20.

Ruppel, S.C.; Kerans, C.; Major, R.P.; Holtz, M.H. 1995, Controls on Reservoir Heterogeneity in Permian Shallow Water Carbonate Platform Reservoirs, Permian Basin: Implications for Improved Recovery. The University of Texas at Austin, Bureau of Economic Geology Geological Circular, No. 95-2, p. 30.

Ruppel, S.C.; Ward, W.B.; Ariza, E.E.; Jennings Jr., J.W. 2000, Cycle and Sequence Stratigraphy of Clear Fork Reservoir-Equivalent Outcrops: Victorio Peak Formation, Sierra Diablo, Texas. Lindsay, R.; Trentham, R.; Ward, R.F.; Smith, A.H., eds. Classic Permian Geology of West Texas and Southeastern New Mexico, 75 Years of Permian Basin Oil & Gas Exploration & Development, West Texas Geological Society Publication, No. 00-108, pp. 109-30.

Tyler, N.; Bebout, D.G.; Garrett Jr., C.M.; Guevara, E.H.; Hocott, C.R.; Holtz, M.H.; Hovorka, S.D.; Kerans, C.; Lucia, F.J.; Major, R.P.; Ruppel, S.C.; Van der Stoep, G.W. 1991, Integrated Characterization of Permian Basin Reservoirs, University Lands, West Texas. Targeting the Remaining Resource for Advanced Oil Recovery, The University of Texas at Austin, Bureau of Economic Geology Report of Investigations, No. 203, p. 136.

Wang, F.P.; Lucia, F.J.; Ruppel, S.C. 2003, 3-D Reservoir Modeling and Simulation of the Fullerton Clear Fork Unit, Andrews County, Texas. Hunt, T.J.; Lufholm, P.H., eds. The Permian Basin: Back to Basics, West Texas Geological Society Publication, No. 03-112, p. 347.

Zeng, H.; Ruppel, S.C.; Jones, R.H. 2003, Reconditioning Seismic Data for Improved Reservoir Characterization, Lower Clear Fork and Wichita, Fullerton Field, West Texas. Hunt, T.J.; Lufholm, P.H., eds. The Permian Basin: Back to Basics, West Texas Geological Society Publication, No. 03-112, pp. 67-78.

Spraberry

Anonymous. 2002, Waterflood Performance in the Naturally Fractured Spraberry Trend Area, West Texas. Conference on Naturally Fractured Reservoirs (June 3 and 4, 2002, Oklahoma City, Okla.) Proceedings, Mewbourne School of Petroleum and Geological Engineering, University of Oklahoma, Oklahoma Geological Survey, p. 18 and CD-ROM.

Baker, R.O.; Bora, Rupam; Schechter, D.S.; McDonald, P.; Knight, William H. 2001, Development of a Fracture Model for Spraberry Field, Texas, US. Society of Petroleum Engineers Annual Technical Conference (New Orleans, La.), SPE 71635.

Banik, A.K.; Schechter, D.S. 1996, Characterization of the Naturally Fractured Spraberry Trend Shaly Sands Based on Core and Log Data. Society of Petroleum Engineers Paper, No. 35224, p. 11.

Barba Jr., R.E.; Meyer, B.R. 1993, Integrating Wireline Data with Three-Dimensional Hydraulic Fracture Simulators in the Spraberry Trend. Society of Petroleum Engineers Production Operations Symposium, SPE 25509.

Barba Jr., R.E. 1989, Optimizing Hydraulic-Fracture Length in the Spraberry Trend. Society of Petroleum Engineers Formation Evaluation, V. 4, No. 3, pp. 475-82.

Barba, Jr., R.E.; Cutia, A.S. 1992, Evaluating Horizontal Well Potential in the Spraberry Trend. Permian Basin Oil and Gas Recovery Conference, SPE 23949.

Barfield, E.C.; Jordan, J.K.; Moore, W.D. 1959, An Analysis of Large-Scale Flooding in the Fractured Spraberry Trend Area Reservoir. Society of Petroleum Engineers Journal of Petroleum Technology, V. 11, No. 4, pp. 15-19.

Blauer, R.E.; Onat, I.N.; Lemieux, M.J. 1992, Production Data Indicate Reservoir and Fracture Performance in the Spraberry. Permian Basin Oil and Gas Recovery Conference, SPE 23995.

Brelsford, Clay; Kuiper, Craig A. 2003, Well Casing Cathodic Protection Evaluation Program in the Spraberry (Trend Area) Field. National Association of Corrosion Engineers International, (San Diego, Calif.), No. 3201.

Brooks, Thomas P.; O'Quinn, Percy C.; Life, Warner E. 1955, Fracturing at High Injection Rates, Spraberry Trend Area Field. Society of Petroleum Engineers Journal of Petroleum Technology, V. 7, No. 5, pp. 14-17.

Brownscombe, E.R.; Dyes, A.B. 1952, Water-Imbibition Displacement: A Possibility for the Spraberry. Drilling and Production Practice, No. 52-383.

Cather, M.; Guo, B.; Schechter, D.S.; Banik, A.K. 1998, An Integrated Geology-Reservoir Description and Modeling of the Naturally Fractured Spraberry Trend Area Reservoirs. Petroleum Society of Canada Annual Conference (Calgary, Alberta, Canada), No. 98032.

Cheatwood, Chris J.; Guzman, Alfredo E. 2001, Comparison of Reservoir Properties and Development History: Spraberry Trend Field, West Texas and Chicontepec Field, Mexico. Society of Petroleum Engineers International Conference, SPE 74407.

Christie, R.S.; Blackwood, J.C. 1952, Characteristic and Production Performance of the Spraberry. Drilling and Production Practice, No. 52-044.

Dyes, A.B.; Johnston, O.C. 1953, Spraberry Permeability from Build-Up Curve Analyses. SPE 228.

Edlund, P.A. 1988, Application of Recently Developed Medium-Curvature Horizontal-Drilling Technology in the Spraberry Trend Area. Journal of Petroleum Technology, V. 40, No. 9, pp. 1178-82.

Elkins, L.F.; Skov, A.M.; Gould, R.C. 1968, Progress Report on Spraberry Waterflood Reservoir Performance, Well Stimulation, and Water Treating and Handling. Society of Petroleum Engineers Journal of Petroleum Technology, V. 20, No. 9, pp. 1039-49.

Elkins, Lincoln F., 1953, Reservoir Performance and Well Spacing, Spraberry Trend Area Field of West Texas. SPE 953177.

Elkins, Lincoln F.; Skov, Arlie M. 1963, Cyclic Water Flooding the Spraberry Utilizes End Effects to Increase Oil Production Rate. Journal of Petroleum Technology, V. 15, No. 8, pp. 877-84.

Erwinsyah Putra; Schechter, David S. 1999, Reservoir Simulation of Waterflood Pilot in Naturally Fractured Spraberry Trend. Society of Petroleum Engineers Asia Pacific Oil and Gas Conference and Exhibition, SPE 54336.

Franklin, Leonard O. 1952, Drilling and Completion Practices, Spraberry Trend. Drilling and Production Practice, No. 52-128.

Gorssman, Waldo L. 1951, Hydrafrac Operations in the Spraberry Production, West Texas. AIME (Oklahoma City, Okla).

Guevara, E.H. 1988, Geological Characterization of Permian Submarine Fan Reservoirs of the Driver Waterflood Unit, Spraberry Trend, Midland Basin, Texas. The University of Texas at Austin, Bureau of Economic Geology Report of Investigations, No. 172, p. 44.

Guidroz, George M. 1967, E.T. O'Daniel Project a Successful Spraberry Flood. Journal of Petroleum Technology, V. 19, No. 9, pp. 1137-40.

Guo, B.; Schechter, D.S.; Baker, R.O., 1998, An Integrated Study of Imbibition Waterflooding in the Naturally Fractured Spraberry. Society of Petroleum Engineers Permian Basin Oil and Gas Recovery Conference, SPE 39801.

Guo, B.; Schechter, D.S.; Banik A., 1998, Use of Single-Well Test Data for Estimating Permeability Anisotropy of the Naturally Fractured Spraberry. Society of Petroleum Engineers Permian Basin Oil and Gas Recovery Conference, SPE 39807.

Handford, C.R. 1981, Sedimentology and Genetic Stratigraphy of Dean and Spraberry Formations (Permian), Midland Basin, Texas. American Association of Petroleum Geologists Bulletin, V. 65, pp. 1602-16.

Houde, Richard F.; Eby, David E. 1979, Sedimentology and Source-Bed Geochemistry of Spraberry Sandstone, Midland Basin, West Texas. American Association of Petroleum Geologists Bulletin.

Long, Scott W.; Smith, Elton J.; Hoff, Charlie R.; Garza, Alberta A. 2001, Best Practices in the Preston Spraberry Unit. Society of Petroleum Engineers Production and Operations Symposium, SPE 67270.

Lorenz, J.C. 1997, Non-Congruent Natural Fracture Sets in Adjacent Beds at Depth: Data from Horizontal Cores from the Spraberry Formation, Midland Basin, Texas. American Association of Petroleum Geologists Hedberg Conference on Reservoir Scale Deformation, Characterization, and Prediction (June 22 to 28, 1997, Bryce, Utah) Abstracts.

Lorenz, J.C.; Sterling, J.L.; Schechter, D.S.; Whigham, C.L.; Jensen, J.L. 2002, Natural Fractures in the Spraberry Formation, Midland Basin, Texas. The Effects of Mechanical Stratigraphy on Fracture Variability and Reservoir Behavior, American Association of Petroleum Geologists Bulletin, V. 86, pp. 505-24.

Marshall, Joseph W. 1952, Spraberry Reservoir of West Texas. American Association of Petroleum Geologists Bulletin, Geological Notes.

McDonald, Paul; Lorenz, John C.; Sizemore, Charlie. 1997, Fracture Characterization Based on Oriented Horizontal Core from the Spraberry Trend Reservoir: A Case Study. Society of Petroleum Engineers Annual Technical Conference (San Antonio, Texas), SPE 38664.

Montgomery, S.L.; Schechter, D.S.; Lorenz, J.C. 2000, Advanced Reservoir Characterization to Evaluate Carbon Dioxide Flooding, Spraberry Trend, Midland Basin, Texas. American Association of Petroleum Geologists Bulletin, V. 84, pp. 1247-73.

Schechter, D.S. 2002, Waterflooding and CO_2 Injection in the Naturally Fractured Spraberry Trend Area. Journal of Canadian Petroleum Technology, V. 41, No. 10, pp. 9-14.

Schechter, D.S.; Banik, A.K. 1997, Integration of Petrophysical and Geological Data with Open-Hole Logs for Identification of the Naturally Fractured Spraberry Pay Zones. Society of Petroleum Engineers Paper, No. 38913, p. 10.

Schechter, D.S.; Guo, B. 1998, An Integrated Investigation for Design of a CO2 Pilot in the Naturally Fractured Spraberry Trend Area, West Texas. Society of Petroleum Engineers Paper, No. 39881, p. 16.

Schechter, D.S., McDonald, P. 1999, Advanced Reservoir Characterization and Evaluation of CO2 Gravity Drainage in the Naturally Fractured Spraberry Trend Area. Annual Report Submitted to US Department of Energy (DOE), No. DOE/BC/14942-7, p. 170.

Schechter, D.S.; Putra, E.; Baker, R.O.; Knight, W.H.; McDonald, W.P.; Leonard, P.; Rounding, C. 2001, CO2 Pilot Design and Water Injection Performance in the Naturally Fractured Spraberry Trend Area, West Texas. Society of Petroleum Engineers Paper, No. 71605, p. 16.

Schechter, David S.; McDonald, Paul; Sheffield, Tom. 1996, Integration of Laboratory and Field Data for Development of a CO2 Pilot in the Naturally Fractured Spraberry Trend. Society of Petroleum Engineers Annual Technical Conference (Denver, Colo.), SPE 36657.

Schechter, David S.; McDonald, Paul; Sheffield, Tom. 1996, Reservoir Characterization and CO2 Pilot Design in the Naturally Fractured Spraberry Trend Area. Permian Basin Oil and Gas Recovery Conference, SPE 35469.

Schmitt, George T. 1954, Genesis and Depositional History of Spraberry Formation, Midland Basin, Texas. American Association of Petroleum Geologists Bulletin.

Tyler, N.; Galloway, W.E.; Garrett Jr., C.M.; Ewing, T.E. 1984, Oil Accumulation, Production Characteristics, and Targets for Additional Recovery in Major Oil Reservoirs of Texas. The University of Texas at Austin, Bureau of Economic Geology Geological Circular No. 84-2, p. 31.

Tyler, N.; Gholston, J.C. 1988, Heterogeneous Deep-Sea Fan Reservoirs, Shackelford and Preston Waterflood Units, Spraberry Trend, West Texas. The University of Texas at Austin, Bureau of Economic Geology Report of Investigations, No. 171, p. 38.

Tyler, N.; Gholston J.C.; Guevara, E.H. 1997, Basin Morphological Controls on Submarine-Fan Depositional Trends: Spraberry Sandstone, Permian Basin, Texas. The University of Texas at Austin, Bureau of Economic Geology Geological Circular, No. 97-6, p. 43.

Warn, G. Fredeick; Sidwell, Raymong. 1953, Petrology of the Spraberry Sands of West Texas. Journal of Sedimentary Research.

White, C.W. 1989, Drilling and Completion of a Horizontal Lower Spraberry Well Including Multiple Hydraulic Fracture Treatments. Society of Petroleum Engineers Annual Technical Conference (San Antonio, Texas), SPE 19721.

Wilkinson, Walter M. 1953, Fracturing in Spraberry Reservoir, West Texas. American Association of Petroleum Geologists Bulletin.

Wolfcamp

Anonymous. 1985, Permian Patch-Reef Reservoir, North Anderson Ranch Field, Southeastern New Mexico. Roehl, P.O.; Choquette, P.W., eds. Carbonate Petroleum Reservoirs, New York, Springer-Verlag, pp. 265-76.

Anonymous. 1985, Sedimentary Facies and Biota of Early Permian Deep-Water Allochthonous Limestone, Southwest Reagan County, Texas, in Crevello, P.D.; Harris, P.M., eds. Deep-Water Carbonates – A Core Workshop: SEPM Core Workshop No. 6, pp. 93-139.

Anonymous. 1989, Lower Permian Platform and Basin Depositional Systems, Northern Midland Basin, Texas. Crevello, P.D.; Wilson, J.L.; Sarg, J.F.; Read, J.F., eds. Controls on Carbonate Platform and Basin Development, SEPM Special Publication, No. 44, pp. 305-20.

Anonymous. 2000, Models of Porosity Evolution in Pennsylvanian Lowstand Carbonates (Now in Slope-to-Basinal Settings) and in Lower Permian, Highstand-Resedimented Basinal Carbonates. Reid, S.T., ed. Geo-2000: Into the Future, American Association of Petroleum Geologists Transactions, Southwest Section Publication, No. SWS 2000-107, pp. 130-38.

Asquith, G.B. 1997, The Importance of Determining Pore Type from Petrophysical Logs in the Evaluation of a Permian Wolfcamp Reentry Northern Midland Basin. The Log Analysis, V. 38, No. 3.

Bangia, V.K.; Yau, F.F.; Hendricks, G.R. 1993, Reservoir Performance of a Gravity-Stable, Vertical CO2 Miscible Flood: Wolfcamp Reef Reservoir, Wellman Unit. Society of Petroleum Engineers Reservoir Engineering, V. 8, No. 4, pp. 261-69.

Becher, J.W.; Von der Hoya, H.A. 1990, Wolfcampian and Early Leonardian Fore-Reef Debris Fans: Midland Basin, West Texas. Flis, J.E.; Price, R.C., eds. Permian Basin Oil and Gas Fields: Innovative Ideas in Exploration and Development, West Texas Geological Society Publication, No. 90-87, pp. 153-55.

Bowsher, A.L.; Abendshein, M. 1988, Wantz Granite Wash (Oil). A Symposium of Oil and Gas Fields of Southeastern New Mexico Supplement, Roswell Geological Society, pp. 328-29.

Brown Jr., L.F. 1971, Virgil and Wolfcamp Fluvial, Deltaic, and Inter-Deltaic Embayment Depositional Systems in North and West-Central Texas. American Association of Petroleum Geologists Bulletin.

Candelaria, M.P.; Sarg, J.F.; Wilde, G.L. 1992, Wolfcamp Sequence Stratigraphy of the Eastern Central Basin Platform. Mruk, D.H.; Curran, C., eds. Permian Basin Exploration and Production Strategies: Application of Sequence Stratigraphic and Reservoir Characterization Concepts, West Texas Geological Society Publication, No. 92-91, pp. 27-44.

Carlisle, Philip H. 2003, The Attributes of a Wolfcamp Reef Play, Pecos County, Texas. Fort Worth Geological Society.

Chuber, Stewart; Rodgers, Elton E. 1968, Pennsylvanian-Wolfcamp Study. American Association of Petroleum Geologists Bulletin.

Clone, Clifford. 1970, Case History of the University Block 9 (Wolfcamp) Field: A Gas-Water Injection Secondary Recovery Project. Society of Petroleum Engineers Journal of Petroleum Technology, SPE 2837.

Conti, R.D.; Wirojanagud, P. 1984, Porosity Distribution in Wolfcamp Strata, Palo Duro Basin, Texas Panhandle: Implications for Deep-Basin Ground-Water Flow. American Association of Petroleum Geologists Bulletin.

Cys, J.M. 1986, Lower Permian Grainstone Reservoirs, Southern Tatum Basin, Southeastern New Mexico. Ahlen, J.L.; Hanson, M.E., eds. Southwest Section, American Association of Petroleum Geologists Transactions and Guidebook of 1986 Convention (Ruidoso, NM), New Mexico Bureau of Mines and Mineral Resources, pp. 115-20.

Cys, J.M.; Mazzullo, S.J. 1985, Depositional and Diagenetic History of a Lower Permian (Wolfcamp) Phylloid-Algal Reservoir, Hueco Formation, Morton Field, Southeastern New Mexico. Roehl, P.O.; Choquette, P.W., eds. Carbonate Petroleum Reservoirs, New York, Springer-Verlag, pp. 277-88.

Dufford, S.; Holland, T. 1993, Wolfcamp Detrital: A 3-D Case History, Glasscock County, Texas. Gibbs, J.; Cromwell, D., eds. New Dimensions in the Permian Basin, West Texas Geological Society Publication, No. 93-93, p. 75.

Fisher, R.S.; Posey, H.H. 1990, Deposition and Diagenesis in a Marine-to-Evaporite Sequence: Permian Upper Wolfcamp Formation and Lower Wichita Group, Palo Duro Basin Texas Panhandle Bureau of Economic Geology, No. RIO195, p. 34.

Galloway, W.E.; Ewing, T.E.; Garrett Jr., C.M.; Tyler, N.; Bebout, D.G. 1983, Atlas of Major Texas Oil Reservoirs. The University of Texas at Austin, Bureau of Economic Geology Special Publication, p. 139.

Gibson, Wayne. 1993, Recent Wolfcamp Carbonate Oil Reservoir Discoveries Utilizing 3-D Seismic Data in the Midland Basin of West Texas. Houston Geological Society.

Hobson, J.P.; Caldwell, C.D.; Toomey, D.F. 1985, Early Permian Deep-Water Allochthonous Limestone Facies and Reservoir, West Texas. American Association of Petroleum Geologists Bulletin, V. 69, pp. 2130-47.

Johnson Jr., Raymond L., Walters, Wallace W.; Conway, Michael W.; Burdett, Bruce S.; Stanley, Rod G. 1998, CO Energized and Remedial 100% CO Treatments Improve Productivity in Wolfcamp Intervals, Val Verde Basin, West Texas. Society of Petroleum Engineers Permian Basin Oil and Gas Recovery Conference (Midland, Texas), SPE 39778.

Kaufman, J.; Fiske, D.; Caputo, J. 2001, Contrasting Depositional Models for Wolfcamp Periplatform Carbonate Reservoirs, Reagan and Upton Counties, Midland Basin, Texas. Stoudt, E.L.; Sivils, D.J., eds. Wolfcampian of West Texas (Permian Basin, Sierra Diablo, and Hueco Mountains): Shelfal and Periplatform Carbonate Reservoirs and Outcrop Analogs. Permian Basin Section SEPM Core Workshop and Field Trip Guidebook Publication, No. 2001-41, p. 1-1-1-2.

Kim, J.S. 1990, Compositional Simulation of the Coyanosa Wolfcamp Field Gas Cycling Operation. Permian Basin Oil and Gas Recovery Conference (Midland, Texas), SPE 20130.

Lambach, J.T.; Whiteman, D.L. 1985, Drilling to the Wolfcamp, Strawn, and Fusselman Formations, Glasscock County, Texas: A Case History. Society of Petroleum Engineers Annual Conference (Las Vegas, Nev.), SPE 14426.

Leung, Charles. 1987, Foredeep: Wolfcamp Biohermal Mounds, Upton County, Texas. American Association of Petroleum Geologists Special Volumes.

Loucks, R.G.; Brown, A.A.; Achauer, C.W.; Budd, D.A. 1985, Carbonate Gravity Flow Sedimentation on Low Angle Slopes Off the Wolfcampian Northwest Shelf of the Delaware Basin. Crevello, P.D.; Harris, P.M., eds. Deep-Water Carbonates: A Core Workshop, SEPM Core Workshop, No. 6, pp. 56-92.

Martin, R.L.; Welch, C.L.; Hinterlong, G.D.; Meyer, J.; Evans, R. 2002, Using Crosswell Seismic Tomography to Provide Better Resolution in the Wolfcamp Formation in Lea County, New Mexico. Hunt, T.J., Lufholm, P.H., eds. The Permian Basin: Preserving Our Past and Securing Our Future, West Texas Geological Society Publication, No. 02-111, pp. 25-34.

Mazzullo, L.J.; Arrant, B.G. 1988, Scharb Wolfcamp (Oil). A Symposium of Oil and Gas Fields of Southeastern New Mexico Supplement, Roswell Geological Society, pp. 289-90.

Mazzullo, S.J. 1997, Permian "Wolfcamp" Limestone Reservoirs: Powell Ranch Field, Eastern Midland Basin. American Association of Petroleum Geologists Bulletin Discussion.

Mazzullo, S.J. 1997, Stratigraphic Exploration Plays in Ordovician to Lower Permian Strata in the Midland Basin and on the Eastern Shelf. DeMis, W.D., ed. Permian Basin Oil and Gas Fields: Turning Ideas into Production, West Texas Geological Society Publication, No. 97-102, pp. 1-37.

Mazzullo, S.J. 1982, Types and Controls on Permo-Pennsylvanian Carbonate Stratigraphic Traps of Shallow-Marine Origin in Permian Basin: Exploration Models. Oil and Gas Journal, V. 80, pp. 127-41.

Mazzullo, S.J.; Reid, A.M. 1989, Lower Permian Platform and Basin Depositional Systems, Northern Midland Basin, Texas. Crevello, P.D.; Wilson, J.L.; Sarg, J.F.; Read, J.F., eds. Controls on Carbonate Platform and Basin Development, SEPM Special Publication, No. 44, pp. 305-20.

Mazzullo, S.J.; Reid, A.M.; Mazzullo, L.J. 1987, Basinal Lower Permian Facies, Permian Basin, Part 1: Stratigraphy of the Wolfcampian-Leonardian Boundary. West Texas Geological Society Bulletin, V. 26, No. 7, pp. 5-9.

Merriam, C.H. 2001, Depositional History of Lower Permian (Wolfcampian-Leonardian) Carbonate Buildups, Midland Basin, Upton County, Texas. Stoudt, E.L.; Sivils, D.J., eds. Wolfcampian of West Texas (Permian Basin, Sierra Diablo and Hueco Mountains): Shelfal and Periplatform Carbonate Reservoirs and Outcrop Analogs. Permian Basin Section SEPM Core Workshop and Field Trip Guidebook Publication, No. 2001-41, p. 2-1-2-22.

Metcalf, Arthur S.; Coronado, Juan; Fisher, Kelvin. 2008, A Case Study of Hydraulically Fractured Eddy County, New Mexico, Horizontal Wolfcamp Producers. Society of Petroleum Engineers Annual Meeting (Denver, Colo.), SPE 116646.

Montgomery, S.L. 1996, Permian "Wolfcamp" Limestone Reservoirs: Powell Ranch Field, Eastern Midland Basin. American Association of Petroleum Geologists Bulletin, V. 80, pp. 1349-65.

Pacht, J.A.; Brooks, L.; Messa, F. 1995, Stratigraphic Analysis of 3-D and 2-D Seismic Data to Delineate Porous Carbonate Debris Flows in Permian Strata along the Northwestern and Eastern Margins of the Midland Basin. Martin, R.L., ed. In Search of New Permian Basin Oil and Gas Fields: Using Today's Technologies and Tomorrow's Ideas for Exploration, Development, and 3-D Seismic in a Mature Basin. West Texas Geological Society Publication, No. 95-98, pp. 83-86.

Ruppel, S.C. 2001, Stratal Architecture and Facies Development in a Middle Wolfcampian Platform Carbonate Reservoir: University Block 9 Field Andrews County, Texas. Stoudt, E.L.; Sivils, D.J., eds. Wolfcampian of West Texas (Permian Basin, Sierra Diablo and Hueco Mountains): Shelfal and Periplatform Carbonate Reservoirs and Outcrop Analogs. Permian Basin Section SEPM Core Workshop and Field Trip Guidebook Publication, No. 2001-41, p. 3-1-3-18.

Saller, A.H.; Dickson, J.A.D.; Boyd, S.A. 1994, Cycle Stratigraphy and Porosity in Pennsylvanian and Lower Permian Shelf Limestones, Eastern Central Basin Platform, Texas. American Association of Petroleum Geologists Bulletin, V. 78, pp. 1820-42.

Saller, A.H.; Dickson, J.A.D.; Matsuda, F. 1999, Evolution and Distribution of Porosity Associated with Subaerial Exposure in Upper Paleozoic Platform Limestones, West Texas. American Association of Petroleum Geologists Bulletin, V. 83, pp. 1835-54.

Simo, J.A.; Wahlman, G.P.; Beall, J.L.; Stoklosa, M.L. 2000, Lower Permian (Wolfcampian) in the Hueco Mountains: Stratigraphic and Age Relations. DeMis, W.D.; Nelis, M.K.; Trentham, R.C., eds. The Permian Basin: Proving Ground for Tomorrow's Technologies, West Texas Geological Society Publication, No. 00-109, pp. 63-64.

Simpson, R.; Lemone, D. 1981, Brachiopod Biostratigraphy of Hueco Group (Wolfcamp), Franklin Mountains, Texas and New Mexico. American Association of Petroleum Geologists Bulletin.

Sivils, D.J. 2001, Examples of Wolfcampian Debris Flow Deposits from the Eastern Shelf of the Midland Basin, Glasscock County, Texas. Stoudt, E.L.; Sivils, D.J., eds. Wolfcampian of West Texas (Permian Basin, Sierra Diablo and Hueco Mountains): Shelfal and Periplatform Carbonate Reservoirs and Outcrop Analogs. Permian Basin Section SEPM Core Workshop and Field Trip Guidebook Publication, No. 2001-41, p. 4-1-4-9.

Sivils, D.J.; Stoudt, E.L. 2001, Basinal Wolfcampian Carbonate Debris Flow, Midland Basin, Texas. Stoudt, E.L.; Sivils, D.J., eds. Wolfcampian of West Texas (Permian Basin, Sierra Diablo and Hueco Mountains): Shelfal and Periplatform Carbonate Reservoirs and Outcrop Analogs. Permian Basin Section SEPM Core Workshop and Field Trip Guidebook Publication, No. 2001-41, p. 5-1-5-3.

Speer, S.W. 1993, Granite Wash (Permian). Atlas of Major Rocky Mountain Gas Reservoirs, New Mexico Bureau of Mines and Mineral Resources, p. 162.

Stoudt, E.L.; Prezbindowski, D.R.; Sivils, D.J. 2001, Phillips Edwards West Field, Ector County, Texas: Controls on Reservoir Distribution in Wolfcamp Shelfal Carbonates. Viveiros, J.J.; Ingram, S.M., eds. The Permian Basin: Microns to Satellites, Looking for Oil and Gas at All Scales, West Texas Geological Society Publication, No. 01-110, p. 55.

Tyler, N.; Bebout, D.G.; Garrett Jr., C.M.; Guevara, E.H.; Hocott, C.R.; Holtz, M.H.; Hovorka, S.D.; Kerans, C.; Lucia, F.J.; Major, R.P.; Ruppel, S.C.; Van der Stoep, G.W. 1991, Integrated Characterization of Permian Basin Reservoirs, University Lands, West Texas. Targeting the Remaining Resource for Advanced Oil Recovery, The University of Texas at Austin, Bureau of Economic Geology Report of Investigations, No. 203, p. 136.

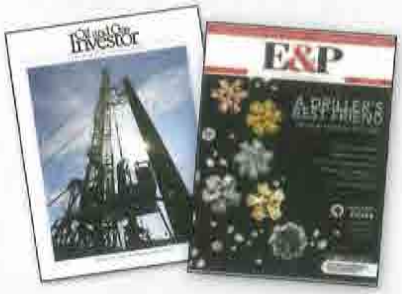
Wahlman, G.P. 2001, Pennsylvanian-Lower Permian Mounds and Reefs in the Permian Basin (West Texas-New Mexico): Composition, Evolution, Distribution, and Reservoir Characteristics. Viveiros, J.J.; Ingram, S.M., eds. The Permian Basin: Microns to Satellites, Looking for Oil and Gas at All Scales, West Texas Geological Society Publication, No. 01-110, pp. 57-64.

Van der Loop, M. 1990, Amacker Tippett Wolfcamp Field, Upton County, Texas. Flis, J.E.; Price, R.C., eds. Permian Basin Oil and Gas Fields: Innovative Ideas in Exploration and Development, West Texas Geological Society Publication, No. 90-87, pp. 133-51.

Zaikowski, A.; Kosanke, B.; Hubbard N. 1984, Radiometric Dating of Wolfcamp Ground. American Association of Petroleum Geologists Bulletin.

the big picture

expert observers



daily updates

word-of-mouth

regional details

in-depth analysis

local color

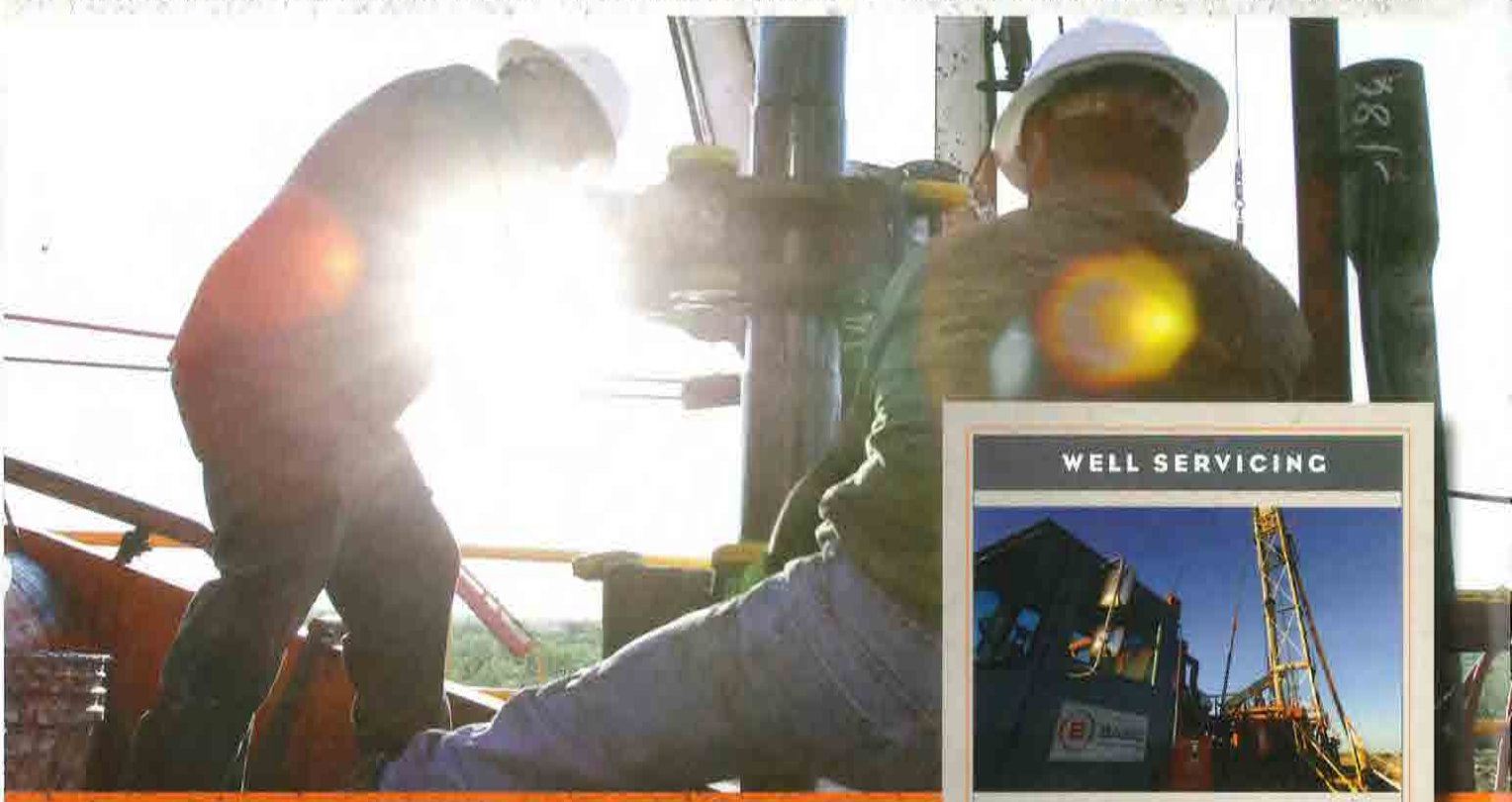
We cover unconventional resources from every angle — for you.

We capture data, text and comments from our worldwide sources, then organize and analyze it all to produce insightful information delivered as you prefer. From print and online to conferences, research and more, Hart Energy Publishing provides actionable intelligence for everyone in today's global energy markets.

HART
Actionable Intelligence™

It's about national strength and local leadership.

ARK-LA-TEX | MID CONTINENT | PERMIAN BASIN | ROCKY MOUNTAINS | GULF COAST



WELL SERVICING

From well completion, wellbore maintenance and workovers to plugging and abandonment, Basic provides a comprehensive range of well servicing tasks performed by people who know the fields best.

Our deep knowledge of the basins in which we operate, backed by our national strength, enables us to better meet the demands of the area and respond more quickly and effectively. Count on the people who are close to the field, Basic Energy Services.

- **Well Servicing**
- **Fluid Services**
- **Pumping Services**
- **Rental / Fishing Tools**
- **Contract Drilling**
- **Wireline**
- **Rig-Assisted Snubbing**
- **Well Site Construction**

www.basicenergyservices.com

OUR LIFE'S WORK IS THE LIFE OF THE WELL.™

BASIC ENERGY SERVICES

Rated 1st in Workovers & Well Servicing