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Midcontinent

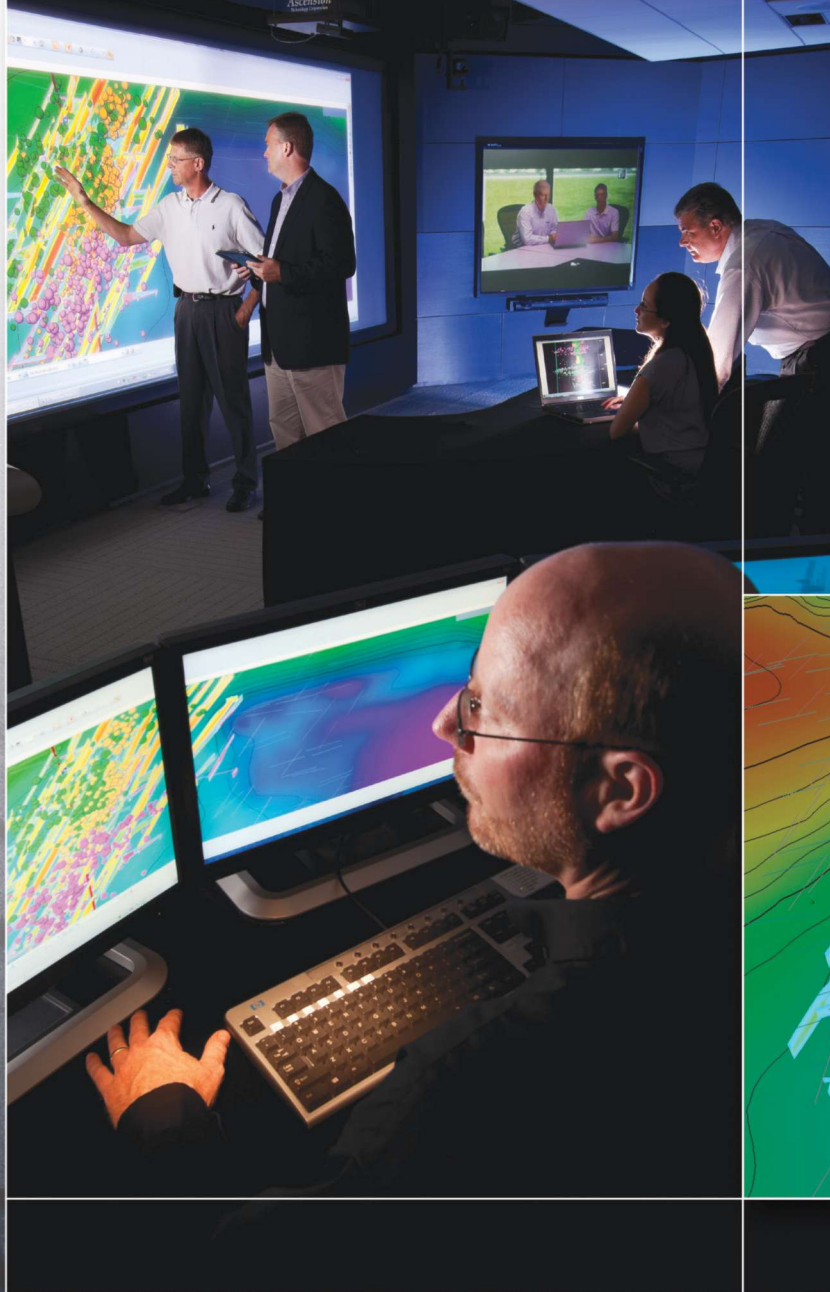
The Playbook – featuring the Mississippi Lime and Woodford plays

A supplement to

Oil and Gas
Investor

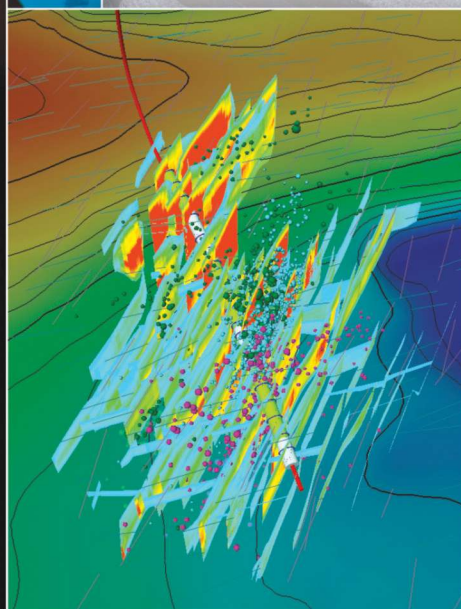
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A supplement to *Oil and Gas Investor*,
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HART ENERGY
1616 S. Voss, Suite 1000 | Houston, Texas 77057
Tel: +1 (713) 260-6400 | Fax: +1 (713) 840-8585
www.hartenergy.com

Group Managing Editor **JO ANN DAVY**
E&P

Editors **RHONDA DUEY**
E&P
LESLIE HAINES
Oil and Gas Investor
PAUL HART
Midstream Business

Contributing Editors **DON LYLE**
GLENN R. MEYERS
NARMADHA NAVANEETHAN
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Corporate Art Director **ALEXA SANDERS**

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JAMES GRANT
NATASHA PITTMAN

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
Midstream Business **DAVID PARKER**

Director of
Business Development **ERIC ROTH**

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On the cover: Rig hands add a section of pipe to a stand in the rat hole during drilling of the #1-16H Nielsen for Devon Energy. Projected total depth is 15,869 ft. (Photo courtesy of Lowell Georgia)



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The UG Center's new report on the Woodbine contains geological descriptions, news, company activities, go-to reference links and more.

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Newfield Exploration has operated in the Cana Woodford for more than a decade and has drilled more than 400 horizontal wells.
(Photo courtesy of Newfield Exploration)

Devonian Period Left Behind Midcontinent Playground

Ancient seas deposited enticing leftovers in the Mississippi Lime and Woodford shales.

By Steve Thornhill
Contributing Editor

Though many oil men would date the Mississippi Lime and Woodford Shale plays to 1905 and the 1930s, respectively, the story actually begins 385 million years earlier during the Devonian Period.

During the Middle Devonian Period, much of modern-day Oklahoma was at the bottom of a shallow sea covering the continental shelf of the adjoining Euramerica continental landmass. By Woodford

time, during the Late Devonian 25 million years later, the sea covered nearly all of Oklahoma and had spread north to cover most of Kansas as well.

This vast, shallow sea teemed with near-surface life and deposited a steady source of organic matter on the seafloor. While wave action provided shallow water oxygenation, the less oxygenated deeper waters, combined with bacterial metabolic oxygen consumption, created hypoxic and/or anoxic bottom conditions, thereby preserving the Woodford's organic-rich shales. As the seafloor gradually filled in closer to wave base, conditions in the Early Mississippian became ideal for the formation of the areally vast Mississippian carbonate reefs that followed.

For the next 20 million years the area was fairly stable. To the south, however, the South American and African continental plates were steadily moving northward on a collision course with the Euramerica continental plate.

To further understand continental plate movement and collision using a modern-day analog, one only has to look to the Himalayas. The Himalayan range, geologically, is very young, and is still under formation. The Himalayas are the result of an ongoing tectonic collision between the Indian and Eurasian plates. The Indian Plate is piling up against and being slowly subducted under the Eurasian Plate, causing regional faulting, folding, sediment stacking, and uplifting of the Eurasian Plate, creating the Himalayan range. Approximately 45 mil-



The Late Devonian Midcontinent. (Map by Ron Blakey, Colorado Plateau Geosystems Inc.)



The Early Mississippian Midcontinent. (Map by Ron Blakey, Colorado Plateau Geosystems Inc.)

lion years ago, the Indian Plate was located south of the equator, about 3,750 miles south of its present location. Not only has the Indian Plate spent the last 45 million years traveling north, but according to earth scientists, it is still moving north at a rate of slightly more than 2.6 in/year while the Himalayas are still being uplifted. Remembering that the earth's history is measured in billions of years, for a tectonic event to take millions of years simply is not that long from a geological perspective.

Just as the Himalayan range is currently and slowly, by human standards, being formed, the tectonic collision of these continental landmasses at the end of the Mississippian Period caused regional faulting, folding, sediment stacking, and mountain building across southwestern Arkansas, southern Oklahoma, and the Texas Panhandle. The resulting tectonic forces gave rise not only to the Ouachita, Wichita, and Arbuckle Mountain uplifts, but also to the adjoining Anadarko, Ardmore, and Arkoma sedimentary basins.

As the mountains were uplifted, classic foreland basins formed alongside the uplifts. These adjoining basins became progressively deeper, all the while being filled with sediments eroded from the adja-

cent mountains. The Anadarko Basin is the deepest of the area basins. Geologists have determined through drilling and seismic data that the Anadarko Basin's deepest area, adjoining the Wichita Mountain Uplift to the south, contains over 40,000 ft of accumulated sediment. The basin is bound by the Nemaha Uplift to the east and the Central Kansas Uplift to the north. The Ardmore Basin contains up to 30,000 ft of sediment and the Arkoma Basin contains up to 20,000 ft of sediment. By measuring the amount of sediments filling the basins, geologists have determined that the adjoining mountains at one time may have reached substantial altitudes, just as today's Himalayas have.

The Anadarko Basin

The Anadarko Basin covers a 58,000 sq mile area, stretching from the Texas Panhandle across much of Oklahoma and north into southern Kansas. It is deepest along its southern margin with sediment thicknesses in excess of 40,000 ft while it thins to the north over what had been a broad shallow shelf, resulting in sediment thicknesses of less than 5,000 ft in northern Oklahoma and southern Kansas. There are several different types of unconventional Mississippian to Late Devonian plays being pursued in the Anadarko Basin. These plays include the Mississippi "Chat" play, the Mississippi Lime play, and the Late Devonian Woodford Shale play.

The Anadarko Basin's Mississippi Chat and Lime plays

The Mississippi Chat play has been pursued by oil men since the 1950s. Drilling vertical wells through the porous and low-permeable, fractured rock, the Mississippi Chat was produced for many years. Eventually the easily recoverable oil ran out, even though geologists and engineers calculated a total formation recovery of only 10%. However, the play is turning around. Based on the horizontal drilling and hydraulic fracturing successes achieved in the Texas Barnett Shale, seasoned operators reasoned that with horizontal drilling the Mississippi Chat could once again produce economic oil volumes, and indeed it has.

The Mississippi Chat is found in north-central Oklahoma and extends up into south-central

Kansas. There are several areas, such as the north/south-trending Nemaha Uplift and the northwest- to southeast-trending Central Kansas

| SYSTEM | | UNIT |
|---------------|---|--------------------------------|
| PERMIAN | U | |
| | L | Leonardian Wolfcampian |
| PENNSYLVANIAN | U | Virgilian Missourian |
| | M | Desmoinesian Atokan |
| | L | Morrowan |
| | L | Chesterian |
| MISSISSIPPIAN | U | Meramecian |
| | L | Osagean Kinderhookian |
| | L | Woodford – Chattanooga |
| DEVONIAN | U | |
| | M | Misener |
| SILURIAN | U | |
| | L | Hunton Group |
| ORDOVICIAN | U | Maquoketa Viola – Kimmswick |
| | M | Simpson – St. Peter – Decorah |
| | L | |
| | L | Arbuckle Group |
| CAMBRIAN | U | |
| | M | Reagan – Lamotte |
| PRECAMBRIAN | L | |
| | L | Undifferentiated |

A strat map of common formations in north-central Oklahoma and south-central Kansas. (Source: US Geological Survey)

Uplift farther to the west, where the Mississippi Chat thins significantly or has eroded away completely. Based on decades of research, geologists are fairly confident of how the Mississippi Chat, found at the unconformity between the Mississippian and overlying Pennsylvanian strata, was formed. The formation began as a limestone with high silica content, thought mainly to be from sponges that covered the shallow Mississippian ocean bottom. When the sponges died, silica sponge spicules were left behind. Gradually the seafloor was uplifted until it was at wave base and above, at which point erosion and diagenesis of the limestone occurred. Over time and through numerous transgressive and regressive sea level changes with subsequent ero-

sion and deposition, the limestone gradually was replaced by silica from the accumulated sponge spicules, as well as with silica from fluvial sediments that accumulated in the shallow seas. The limestone replacement created the highly porous but largely impermeable rock that remained. The resulting Mississippi Chat is an extremely heterogeneous and often compartmentalized rock that can have porosities ranging from 0% to more than 50%. Typically it has low permeability, but fortunately it often is naturally fractured. Chat reservoirs can vary in gross pay thickness from a few feet to over 80 ft. Geochemical analysis of hydrocarbons produced from the Mississippi Chat points to the underlying Woodford Shale formation as the source rock. Operators have found that production tends to be oilier east of the Nemaha Uplift. In addition, the formation produces a great deal of water with its liquid hydrocarbons. Therefore, an operator producing from the Mississippi Chat must commit to drilling one water disposal well for every five to six oil wells.

The Mississippi Chat overlies the Mississippi Lime. Production from the Mississippi Lime was first established in 1905 by two brothers, Frank and L.E. Phillips. Their wells were so successful that the brothers drilled 80 additional wells without one dry hole, going on to form Phillips Petroleum, one of the predecessors of today's ConocoPhillips. In the Anadarko Basin, the Mississippi Lime reservoir thicknesses vary in thickness from a few feet to over 400 ft. As with the Mississippi Chat, hydrocarbons are sourced from the underlying Woodford Formation. Hydrocarbons typically are produced from reservoir depths ranging from 3,500 ft to 22,000 ft. However, gas is the expected production below 13,500 ft. Like the Mississippi Chat, the key to economic production from the Mississippi Lime is laterals as long as 5,000 ft or more, as well as staged hydraulic fracturing with six to 12 stages per well. The Mississippi Lime has been compared to North Dakota's Bakken. Typically, it does not produce as much, and it produces quite a bit of water, making water disposal wells mandatory. However, with the shallower depths and very friable formation, the Mississippi Lime is much cheaper to develop than the Bakken. The 2012 edition of the Shale Shaker reported an average production of 306 Mcf/d and

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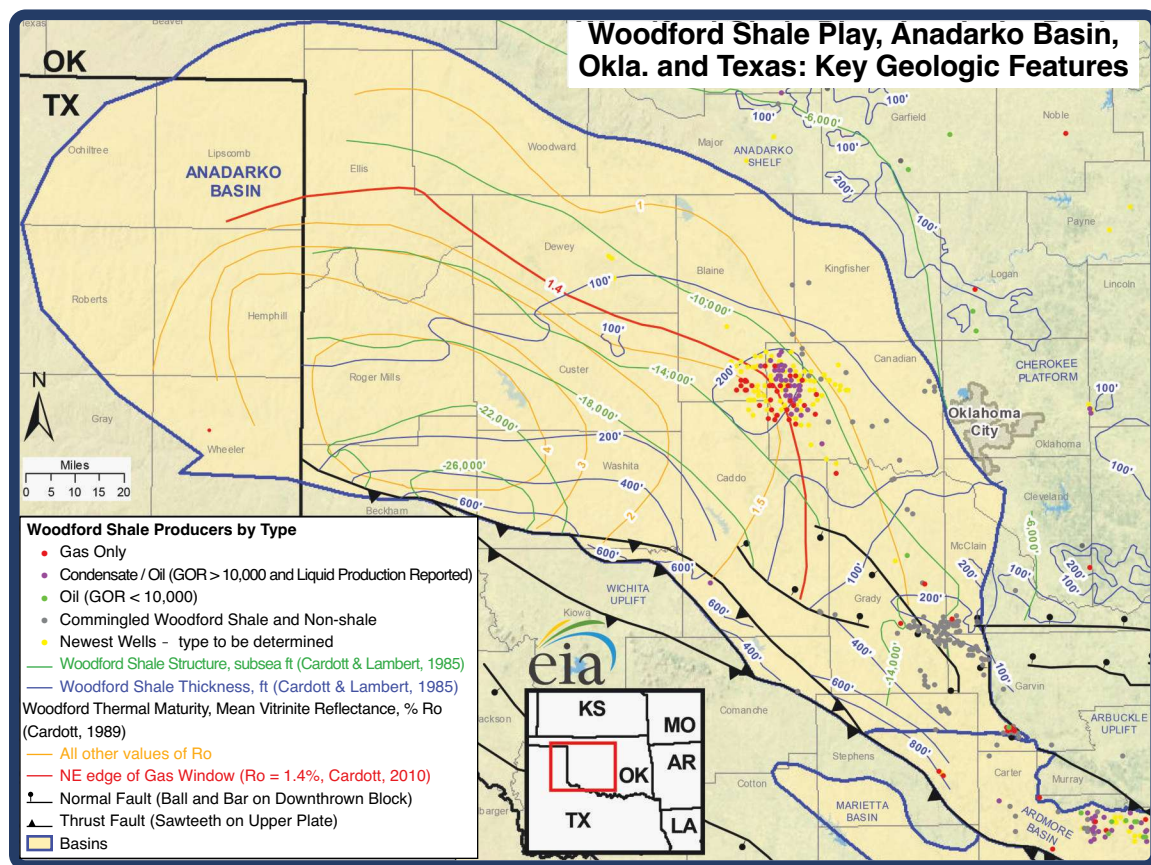
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25 b/d from 241 producing horizontal Mississippi Chat/Lime wells.

The Anadarko Basin's Late Devonian Woodford Shale play

The Woodford Shale formation, or its geological time equivalent, is a major petroleum source rock that covers much of the Midcontinent from Nevada, Idaho, and western Montana eastward through Illinois, Indiana, and Ohio, into New York and Pennsylvania. For years, when operators spoke of drilling the Woodford Shale in Oklahoma, it was assumed they meant the Arkoma Basin Woodford Shale. All that has changed. With the introduction of horizontal drilling, operators are now drilling economic wells in western Oklahoma Woodford in the Anadarko and Ardmore basins. The Cana Woodford play began in 2007 in Canadian County with a successful Devon drilled horizontal well. Since 2007,

the play has been spreading southeast from its origin in Canadian County into the western Ardmore Basin and operators have begun calling it the South Central Oklahoma Oil Play, or SCOOP. The Anadarko Basin Woodford Shale is made up of layers of siltstone and silty black organic-rich shale, deposited under hypoxic/anoxic conditions. The shale reaches an observed thickness of 900 ft, with Total Organic Carbon (TOC) averaging 5.7% from Type II kerogen made up largely of plankton and plant debris. Though the Woodford ranges in depth from 6,000 ft to 11,000 ft, it typically has been produced from depths between (7,500 ft and 8,500 ft, where formation thicknesses can vary between 50 ft and 300 ft or more. The shale has a Ro ranging from 0.51% to 2.6% with the thermal maturity generally increasing from the northeast to the southwest with greater burial depth. According to a report by the Oklahoma Geological Survey of a western



(Source: US Energy Information Administration based on well data from HPDI and B. Cardott, Oklahoma Geological Survey) Only wells producing from the Woodford Shale with first production after Jan. 1, 2001, are shown. Basins and faults from Northcutt & Campbell (1995); Cardott (1985). Updated: June 1, 2011.

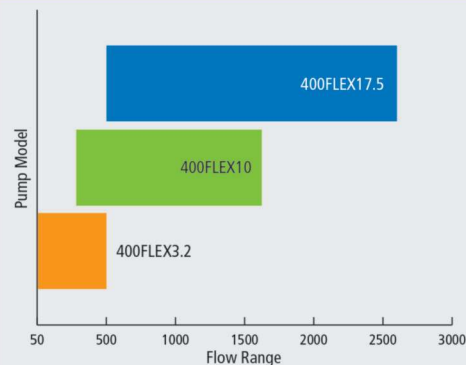
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Oklahoma (Anadarko Basin) Woodford play, and based on 86 horizontal wells and one vertical well all ranging in depth from 11,075 ft to 14,654 ft with laterals ranging from 2,230 ft to 6,536 ft, the wells had gas IPs ranging from 668 Mcf/d to 8,367 Mcf/d and oil/condensate IP's ranging from 2 b/d to 310 b/d. The 2012 edition of the Shale Shaker, bulletin of the Oklahoma City Geological Society, reported an average production of 960 Mcf/d and 11 b/d from 346 producing horizontal wells.

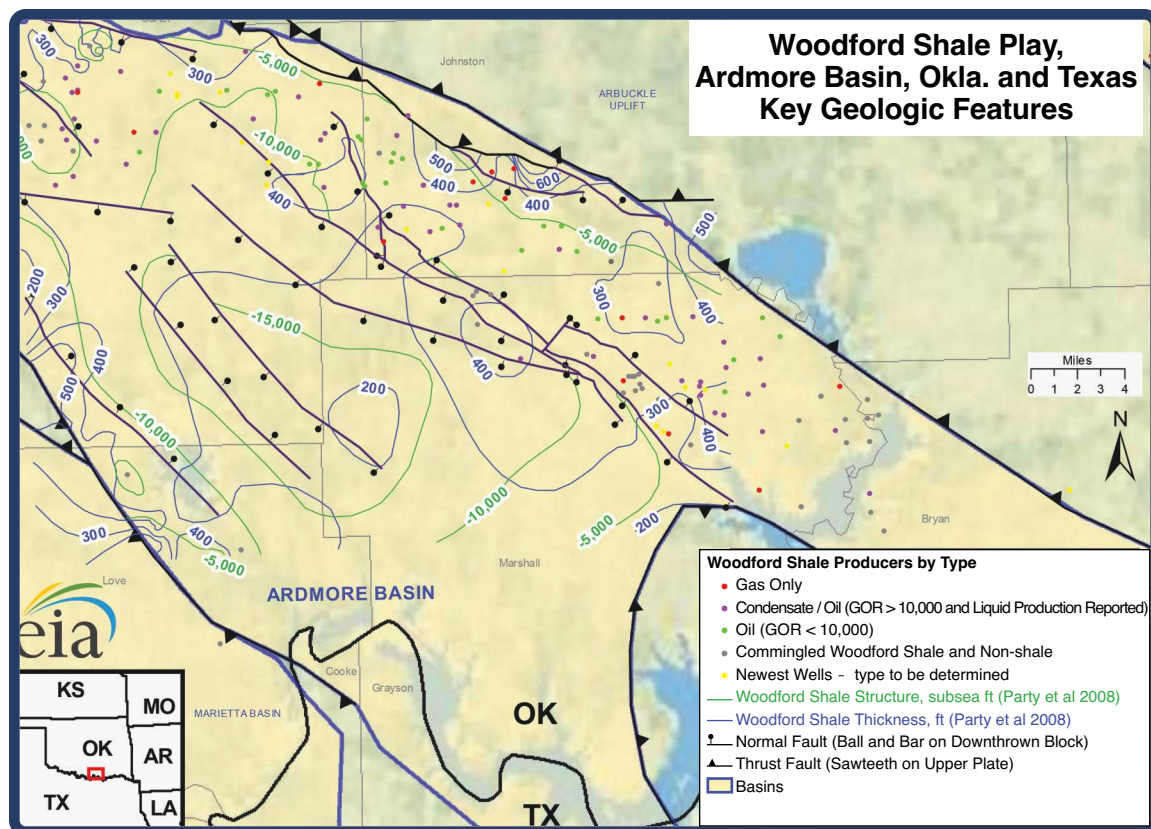
The Ardmore Basin

The Ardmore Basin, located in the area of Ardmore, Okla., is a small basin covering approximately 1,800 sq miles. Basin creation began in the Cambrian with a failed rifting or splitting up of continental landmasses. This failed rift created an elongated trough in the Ardmore area. Later the trough received sediments from three separate but adjoining tectonic uplifts. The first uplift was the Ouachita Orogeny, next was the Wichita

Orogeny, and last the Arbuckle Orogeny. The uplifting of the adjoining mountains and subsequent erosion filled the deep elongated trough with sediments to depths of over 30,000 ft. Today that elongated trough is known as the Ardmore Basin.

The Ardmore Basin's Late Devonian Woodford Shale play

In the Ardmore Basin, the Woodford Shale is described as a brittle organic-rich black shale with interbedded chert, deposited under hypoxic/anoxic conditions in a transgressing sea, ranging in thickness from 25 ft to greater than 600 ft. The Woodford Shale's TOC averages 4% from Type II kerogen. Though the Woodford ranges in depth from 5,000 ft to 17,500 ft, it is being produced from the basins northern and northwestern margin at depths between 5,000 ft and 10,000 ft, where formation thicknesses can vary between 300 ft to 600 ft and more. Horizontal Woodford wells being drilled in



(Source: US Energy Information Administration based on well data from HPDI and B. Cardott, Oklahoma Geological Survey) Only wells producing from the Woodford Shale with first production after Jan. 1, 2001, are shown. Basins and faults from Northcutt & Campbell (1995); Party et al (2008). Updated: June 1, 2011.



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the northwestern Carter County area of the Ardmore Basin are part of the SCOOP oil play that originated in the adjoining Anadarko Basin. The Woodford Shale's Ro ranges from 0.5% to >3.0% with thermal maturity generally increasing in a northeast to southwest direction with greater burial depth, according to a report by the Oklahoma Geological Survey of an Ardmore Basin Woodford play and based on 98 horizontal and vertical wells, all ranging in depth from 1,750 ft to 12,200 ft. The wells had gas IPs ranging from 10 Mcf/d to 3,307 Mcf/d and oil/condensate IPs ranging from 1 b/d to 371 b/d. The 2012 edition of the Shale Shaker reported an average production of 960 Mcf/d and 11 b/d from 111 producing horizontal wells.

The Arkoma Basin

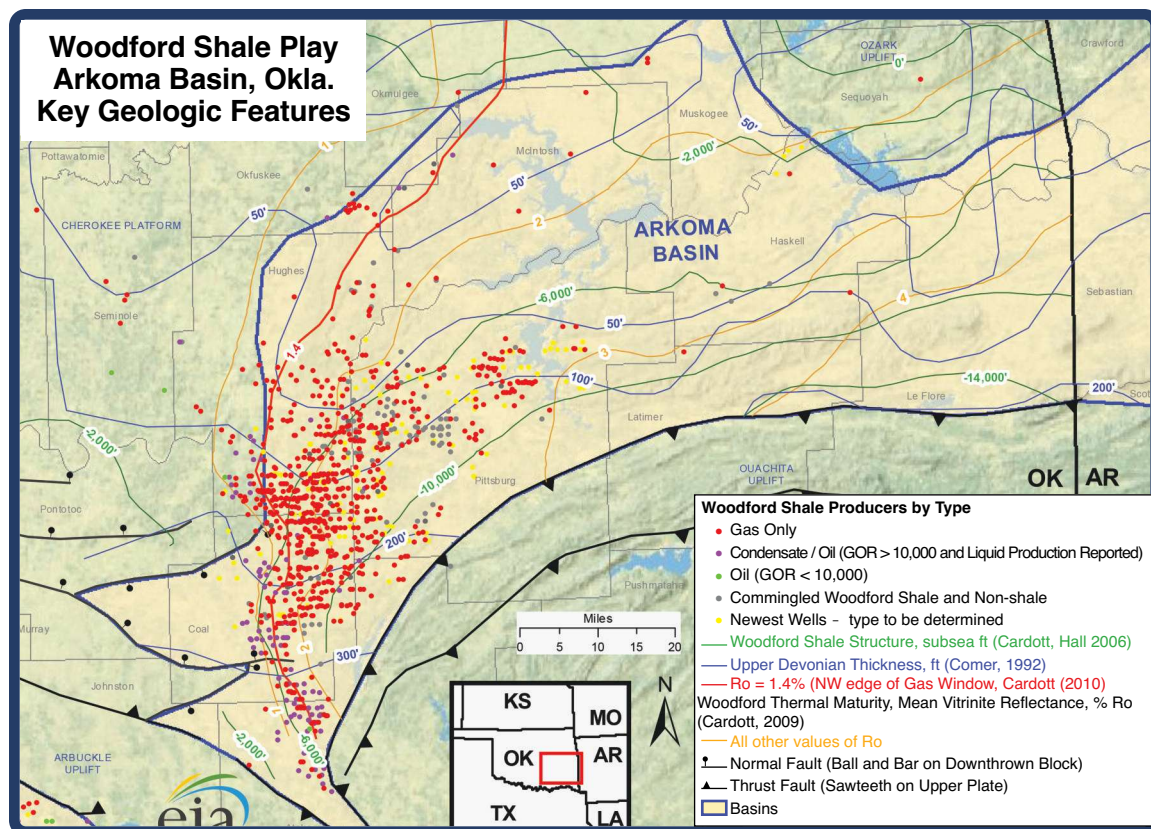
The Arkoma Basin, located east of the Anadarko Basin on the Arkansas/Oklahoma border is similar to the Anadarko Basin in many ways, including its

tectonic history. However, with an approximate 33,800-sq-mile area, it is smaller, and with a maximum 20,000 ft depth it is quite a bit shallower.

The Arkoma Basin is bound to the north in Oklahoma by the Cherokee Platform and to the north in Arkansas by the Ozark Uplift. The basin is deepest along its southern margin, adjacent to the Ouachita Mountain Uplift where it reaches a depth of 20,000 ft, while thinning out to the north. There are several different types of unconventional Mississippian plays being pursued in the Arkoma Basin. These plays include the Mississippi Chat and Lime plays and the Woodford Shale play.

The Arkoma Basin's Mississippi Chat and Lime plays

Operators exploring along the Arkoma Basin's northern boundary have been using horizontally drilled wells and multi-staged fracturing to make productive Mississippi Lime wells. In addition, adjacent to and just north of the Arkoma Basin on the



(Source: US Energy Information Administration based on well data from HPDI and B. Cardott, Oklahoma Geological Survey) Only wells producing from the Woodford Shale with first production after Jan. 1, 2001, are shown. Basins and faults from Northcutt & Campbell (1995) and Cardott (2008). Updated: June 1, 2011.

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Cherokee Platform, operators have been using seismic anomaly data to target the Mississippi Chat, a thin siliceous erosional surface located on top of the Mississippi Lime. The Arkoma Basin's Mississippi Chat also requires horizontal drilling but typically has adequate natural fracturing for economic hydrocarbon production. Both the Chat and the Lime produce substantial amounts of formation water and currently require drilling a water disposal well for every five to six production wells.

The Arkoma Basin's Late Devonian Woodford Shale play

In the Arkoma Basin, the Woodford Shale is described as a brittle silica-rich organic black shale deposited under hypoxic/anoxic conditions in a transgressing sea, ranging in thickness from 15 ft in the north part of the basin to 240 ft in the southwest basin area, and to depths of 12,000 ft in the current productive area.

The Woodford Shale's TOC ranges from 2% to 6.5% from Type II kerogen. The shale's Ro ranges

from 0.8% to 4% with thermal maturity generally increasing in a northwest to southeast direction with greater burial depth. The Oklahoma Geological Survey published a report highlighting an eastern Oklahoma (Arkoma Basin) Woodford play based on 1,007 horizontal wells, all ranging in depth from 11,075 ft to 14,654 ft with laterals ranging from 2,230 ft to 6,536 ft. The wells had gas IPs ranging from 668 Mcf/d to 8,367 Mcf/d and oil/condensate IPs ranging from 2 b/d to 310 b/d. The 2012 edition of the Shale Shaker reported an average gas production of 751 Mcf/d, with almost no petroleum liquids, from 1,119 producing horizontal wells.

A new age is upon the industry

Oklahoma's Anadarko, Ardmore, and Arkoma basins are becoming spectacular examples of how the use of modern drilling and completion technologies are revolutionizing the oil industry by breathing new life into mature producing petroleum provinces. ■

References available.

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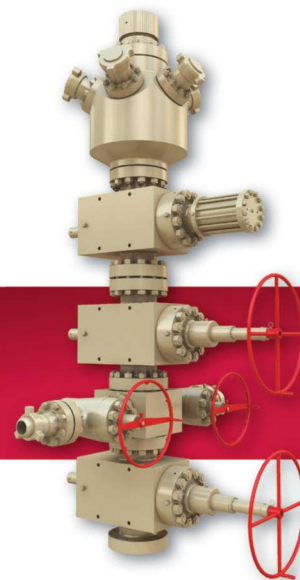
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Midcontinent Pushes Oil Shale Boom

The Woodford sources the hottest Oklahoma and Kansas shale plays.

By Don Lyle
Contributing Editor

Horizontal Mississippi Lime and Woodford liquids plays are drawing majors and independents seeking new profit sources.

The Mississippi Lime in northern Oklahoma and most of central Kansas presents few surprises for operators, but horizontal drilling combined with attractive economics is cranking up the activity in this Woodford Shale sourced formation.

Vertical wells cost around US \$350,000, and operators there have drilled those wells for some 50 years. A completed horizontal well drains the wallet of about \$3.5 million compared to \$8 million for a Bakken well since operators use lower horsepower rigs and less-expensive fracture programs to see returns of around 75%.

Operators are feeling out the play in the opening rounds of development, particularly as they seek the sweet spots in Kansas.

The Woodford source rock, deeper and more expensive to develop, has grown from the Cana Woodford play in western Oklahoma, southeast through the Golden Trend into the South Central Oklahoma Oil Province (SCOOP) trend in the Ardmore Basin.

In the following section, Hart Energy attempts to profile the most active operators in the Mississippi Lime and Woodford liquids plays and, through them, the evolution of these significant prospects.

US Key Players

Alta Mesa Holdings LP

- *Land: Approximately 40,000 net acres*
- *Completed first horizontal Mississippi Lime well in April 2013*

Alta Mesa Holdings LP, a relatively small player in the Mississippi Lime, is building the company in the stacked pays of northern Oklahoma.

Speaking at Hart Energy's DUG Midcontinent conference in April 2013, Hal Chappelle, Alta Mesa president and CEO, said his company is directing 20% of its US \$250 million to \$270 million capex for 2013 to its Kingfisher County, Okla., properties where it has 8,700 boe in proved reserves composed of 75% liquids. The company had 1,000 boe/d of production in 4Q 2012.

The company's wells are in the Sooner Trend, and it currently is using horizontal wells to tap oil in the Mississippi Lime, Hunton, and Woodford Shale.

Alta Mesa has more than 100 potential locations in the Mississippi Lime, Woodford Shale and more than 20 potential locations in the conventional Hunton zone.

At the time of the presentation, the company's first horizontal Mississippi Lime was flowing back hydrocarbons and drilling fluids.

Old vertical Mississippi Lime wells in the company's Lincoln North unit offer estimated ultimate recoveries (EURs) of 20,000 bbl of oil per well, while newer vertical wells come in with EURs of 30,000 b/d of oil. EURs at the company's Lincoln SE unit

wells reach 43,000 bbl of oil, and the East Hennessey unit gives the company EURs of approximately 40,000 bbl of oil.

Alta Mesa plans to develop its properties with horizontal wells with 12-stage fracture treatments. In some cases, it will reenter existing Hunton wells to reach the Mississippi Lime with horizontal laterals.

American Petro-Hunter Inc.

- *Land: More than 2,000 net acres*
- *Working both the Mississippi Lime and Woodford Shale*

American Petro-Hunter Inc., with more than two years of experience in the Mississippi Lime play in Payne County, Okla., landed a cash infusion agreement that will accelerate its drilling and production activities in the county.

The company holds 3,400 gross (2,000 net) acres with working interests from 25% to 50% and an 80% net revenue interest in the Mississippi Lime. It plans wells to 2,800-vertical-ft and 1,600-ft laterals to tap more than 100 ft of Mississippian pay. The land can host a potential 15 horizontal wells, and the company expects production of 100 b/d of oil after fracture treatments. It estimated 1.65 MMbbl of possible reserves.

American Petro-Hunter holds more than 1,400 acres, also in Payne County, with Woodford Shale potential. The company holds 20% to 50% working interests in that property with 75% to 80% net revenue interests. The Woodford in this area is more than 40 ft thick and can support five horizontal and 25 vertical wells, according to American Petro-Hunter's website.

The company controls another 5,300 gross acres of Mississippi Lime properties in its South Oklahoma project.

In March 2013, the company signed a US \$5 million equity enhancement agreement with Magna Group, which allows American Petro-Hunter to sell up to \$5 million in shares to Magna during a 24-month period.

Robert McIntosh, CEO of American Petro-Hunter, said, "This closing provides the company up to \$5 million in additional capital, which will augment our existing financing arrangement when we require operational and drilling funds to be used in

the company's development of the Mississippi Lime and Woodford Shale plays in Payne and Lincoln counties, Okla. We can now plan more effectively as to when and where we will be drilling our first horizontal well under the 2013 development plan."

In July 2012, the company began producing Mississippi Lime to tanks at its SOM-1H well from more than 2,500 ft of lateral.

Apache Corp.

- *Land: 580,000 net acres*
- *Concentrating on the Texas Panhandle and western Oklahoma*

Apache Corp.'s Central region includes nearly 1.9 million gross acres of land with more than 3,500 producing wells. Although those properties include Mississippi Lime potential production, Apache directed its current investment program to 18 rigs drilling in the Granite Wash, oily Tonkawa, Marmaton, Cleveland, Cottage Grove, and Canyon Wash plays.

Concentration on those plays raised regional production by 37% during 2012 as the company drilled or participated in 192 wells.

Apache planned to raise its count in the Central region to 29 rigs in 2013.

In a mid-2012 release, the company said, "Apache has leased more than 580,000 net acres in the Mississippian Lime play in Kansas and Nebraska. The company expects horizontal drilling will be effective in the Mississippian Lime – a good porous limestone – as well as shallower Cherokee and upper Pennsylvanian sections."

Atlas Resource Partners LP

- *Land: 20,000 net acres*
- *Aggressive drilling program*

Atlas Resource Partners LP, an E&P master limited partnership, looks for growth from three regions: the Barnett Shale in Texas, the Appalachian Basin, and the Mississippi Lime in Oklahoma.

In an April 2013 presentation, the company said it paid US \$59.3 million to purchase properties in the Mississippi Lime and Hunton formations from Equal Energy Ltd. Those properties produced 8 MMcf/d of gas equivalent.

The properties lie in Alfalfa, Grant, and Garfield counties in northern Oklahoma and are held by

production from the Hunton Formation. Overall, the 20,000 net acres provides more than 100 drilling locations.

In April 2013, the company had 16 wells in various stages of drilling or completion.

AusTex Oil Ltd.

- *Land: 34,200 net acres*
- *Mississippi Lime produces for Australians*

AusTex Oil Ltd., operating in Oklahoma and Kansas as International Energy Corp., works the Mississippi Lime in both of these states.

Based in Sydney, the company holds a 100% working interest and an 81.25% net revenue interest in some 1,600 net acres of land around Tulsa in Tulsa County, Okla.

The company's most active area is the Snake River project in Kay County, Okla., where it has a 100% working interest with an 81% net revenue interest in 5,500 net acres. It is drilling two wells a month in the Snake River project and had 12 vertical wells online by November 2012. It also participated in two horizontal wells in that area with Range Resources as the operator.

The company plans additional horizontal wells during 2013. In this area, horizontal wells are drilled on 160-acre spacing while vertical wells require only 20-acre spacing. It has the potential to drill more than 25 net horizontal wells on the Snake River project.

The company also controls the Colby project in Thomas County, Kan., with a 70% working interest and a 58.8% net revenue interest in 15,500 net acres of leases. On that project, 3-D seismic data show the presence of Mississippi Lime. The company planned two wells in that project in 1Q 2013 with an estimated ultimate recovery (EUR) of 70,000 boe to give the company an internal rate of return of more than 80% and payout in seven months.

Also in Kansas, the company leases a 53% working interest with a 43.5% net revenue interest in the Cooper project in Sheridan County.

The Cooper project produces through vertical wells aimed at the Toronto, Lansing-Kansas City, and Mississippian formations to 4,700 ft and has a completed well cost of about US \$450,000.

Castle Resources operates the company's Kansas properties.

In its Mississippian wells, the company finds

EURs of 300,000 boe to 500,000 boe on horizontal wells and 60,000 boe to 100,000 boe on vertical wells.

According to IHS Inc., International Energy completed the vertical 21-3 Blubaugh well in southern Kay County and perforated, acidized, and fractured Mississippi Lime zones from 4,267 ft to 4,398 ft and from 4,410 ft to 4,562 ft. That well tested for 332 b/d of oil, 250 Mcf of gas, and 400 b/d of water.

The well is off the northeast flank of Tonkawa Field and west of Ponca City West Field.

Chaparral Energy LLC

- *Land: 260,000 net acres*
- *Ramping up Mississippi Lime*

Chaparral Energy LLC, already the second-largest oil producer in Oklahoma, is counting on the Mississippi Lime in that state to enhance its position.

In an October 2012 presentation, the company said it expanded its overall budget in 2012 to US \$460 million. Of that amount, the company invested \$102 million in drilling, with \$73 million of that drilling budget going to the Mississippi Lime – an amount more than that of any other company operating area and nearly as much as that of any other two areas combined.

It has more acreage than its 48,000 net acres in the Marmaton, its 19,000 net acres in the Bone Spring/Avalon Shale, or its 23,000 net acres in the Anadarko Woodford Shale.

The company's capital investment philosophy is easy to understand. It expects internal rates of return from 35% to 75% from its unconventional holdings.

The company's northern Oklahoma Mississippi Lime property is a key near-term focus area for Chaparral, with wells offering initial potentials between 100 boe/d and 700 boe/d and estimated ultimate recoveries from 100,000 boe to 400,000 boe per well. Horizontal well costs range from \$2.5 million to \$4 million.

Chaparral's core northern Oklahoma Mississippi Lime play includes 93,000 net acres where it expects to produce 210,000 boe per well. The company has room for 378 net risked undrilled wells or 581 net unrisked undrilled wells on 160-acre spacing, and it has a 65% development success. By October 2012, the company had 1.9 MMboe in proved reserves and 77 MMboe in risked unproven resources in

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A rig on the horizon drills to the Mississippi Lime for Chesapeake Energy near Alva, Okla.
(Photo courtesy of Chesapeake Energy Corp.)

that property.

The company had drilled or participated in 37 wells by October 2012 and reached a net production of 3,375 boe/d, with 45% oil. It operated 18 of those wells and planned another one to three wells by the end of 2012. Initial potential production was 600 boe/d.

The company controls another 167,000 net acres in its emerging northern Oklahoma Mississippian play where it has a 33% development success. That portion of the Mississippi Lime yields 160,000 boe per well. It has the potential for 344 net risked undrilled wells or 1,044 net unrisked undrilled wells on 160-acre density. That property has 500,000 boe in proved reserves and 55 MMboe in risked unproven resource.

The company had drilled six wells by October 2012 in the emerging area with initial potential production rates averaging around 200 boe/d. At that time, the wells produced 625 boe/d, with 92% oil.

According to IHS Inc. in May 2013, Chaparral completed a horizontal Mississippi Lime well in

Osage County, Okla. The 2H-11 Big Elk horizontal well came online at 103 b/d of oil and 5,700 b/d of water after acidizing and fracturing an openhole interval from 2,892 ft to 6,140 ft at a true vertical depth of 2,291 ft.

The only other horizontal well in the township was Chaparral's 1H-11 Big Elk, which gave the company an initial pumping potential of 265 b/d of oil with 1,400 b/d of water.

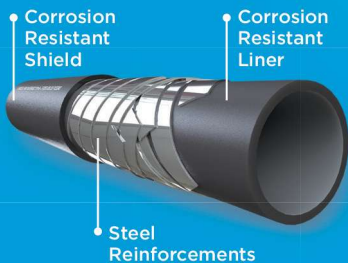
Chesapeake Energy Corp.

- *Land: 950,000 net acres*
- *Closed JV with Sinopec*

Chesapeake Energy Corp., one of the largest landholders in the Mississippi Lime play, found an investment partner in China's Sinopec. The Oklahoma City company had been looking for a partner in the play since late 2011.

Chesapeake is the second largest net gas producer in the US and the 11th largest producer of oil

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and gas liquids. It also is the most active driller of new wells in the nation and holds leading land positions in the Eagle Ford, Utica, Granite Wash, Cleveland, Tonkawa, Mississippi Lime, and Niobrara unconventional liquids plays and in the Marcellus, Haynesville/Bossier, and Barnett unconventional natural gas shale plays.

In a February 2012 release, Chesapeake said it was pursuing joint venture (JV) deals in its Mississippi Lime and Permian Basin plays where it owns 1.8 million and 1.5 million net acres of leasehold, respectively. At that time, the company planned to complete both transactions by the end of 3Q 2012.

The Mississippi Lime deal was delayed for a time. On Feb. 25, 2013, Chesapeake said it signed an agreement with Sinopec International Petroleum E&P Corp. that allowed Sinopec to buy a half interest in 850,000 net acres of Chesapeake's land in the Mississippi Lime in northern Oklahoma for US \$1.02 billion in cash, with 93% received upon closing. Chesapeake announced completion of the JV on

July 1, 2013, and payment of remaining proceeds is subject to customary post-closing contingencies.

In 4Q 2012 before the transaction, Chesapeake produced an average of approximately 34,000 boe/d from those 850,000 net acres. By year-end 2012, the properties contained some 140 MMboe net proved reserves. Chesapeake and Sinopec will share equally in development costs with no drilling carries by Sinopec. Chesapeake will operate the properties, including all leasing, drilling, completions, operations, and marketing activities. Net to Sinopec's interest, production associated with the JV produced approximately 9,600 bbl of liquids and 54 Mcf/d of natural gas during 1Q 2013.

Doug Lawler, Chesapeake's CEO, said, "Chesapeake is pleased to have Sinopec as our partner in the Mississippi Lime play, and we look forward to efficiently developing and growing this asset for many years to come."

GHS Research, in a February 2013 analysis, said Chesapeake produced 24,000 boe/d from the



Oil from the Mississippi Lime in northern Oklahoma joins corn as a significant cash crop for the state.

(Photo courtesy of Chesapeake Energy Corp.)



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Mississippi Lime with 45% oil, 9% gas liquids, and 46% gas.

It said the deal equated to \$60,000 per flowing boe and \$14.57/boe of proved reserves. It amounted to \$2,400 per acre of land, not counting production.

In a May 2013 investor presentation, Chesapeake said it devoted 28% of its 2013 capex to the Greater Anadarko Basin, which included the Tonkawa, Granite Wash, Cleveland, and Hogshooter plays, as well as the Mississippi Lime. Its 1Q net production from all those formations totaled 114,000 boe/d, representing a 30% improvement from the same quarter in 2012. The company was working 28 rigs in the five plays and planned to maintain that level through 2013. It also had nearly completed a water disposal trunk line and water disposal well network to improve efficiency and costs in the Mississippi Lime.

In all the formations, Chesapeake's average peak daily production rate on 90 wells that began producing in 1Q 2013 was approximately 900 boe/d, the company said in its 1Q report to shareholders.

Among notable wells drilled in the quarter, the TDR 12-25-12 1H Mississippi Lime horizontal well in Alfalfa County, Okla., tested at a peak rate of 1,485 boe/d, including 490 b/d of oil, 305 b/d of NGL, and 4.1 MMcf/d of gas.

The 1H Knight 1-28-15 Mississippi Lime well in Woods County, Okla., tested for an initial 990 b/d of oil, 772 Mcf/d of gas, and 892 b/d of water, according to IHS Inc. In the same county, the #1H Herod 3-28-15 produced 1,218 b/d of oil, 754 Mcf/d of gas, and 1,583 b/d of water from an acidized and fractured zone from 5,180 ft to 9,726 ft in the Mississippi Lime at a true vertical depth of 5,056 ft.

Cimarex Energy Co.

- *Land: 120,000 net acres*
- *Strong operator in the Cana Woodford*

Cimarex Energy Inc. entered the Cana Woodford play early, assembling a strong land position and building itself into one of the most active operators in the emerging play. The company began drilling in the play in late 2007.

By mid-2012 the company operated 10 rigs in the Cana Woodford and started an infill drilling program. It averaged 161 MMcf/d of gas equivalent in 1Q 2012, up 56% from the same period the previous year.

In a May 2013 presentation, the company said its infill program was generating good returns, and it was concentrating its midcontinent activity on the Cana Woodford with US \$350 million of its \$450 million midcontinent capex.

Cimarex drilled 167 gross (69 net) wells in 2012 and planned to drill up to 145 gross (55 net) wells in 2013 with a lower capex budget.

By year-end 2012, the company held more than 1.5 Tcf of gas equivalent in proved reserves in the play with 35% of those reserves in liquids.

Cimarex drilled or participated in 532 Cana Woodford wells on its 75,000 net acres in the liquids-rich area and its 45,000 net acres in the gas-rich area. The liquids-rich area contained a Cana Woodford section with 100 ft to 300 ft of gross pay, and nearly all of that area was held by production. Some 22% of the company's properties in the gas-rich area are held by production.

Those properties lie in Dewey, Kingfisher, Blaine, Custer, Canadian, Caddo, and Grady counties in Oklahoma.

During 2013, Cimarex is concentrating its efforts in the liquids-rich core area where it plans 140 gross wells, 100 nonoperated and 40 operated, in 2013. The company had three rigs working the play in 2Q but planned to release one of those rigs by mid-year. Those rigs are working a plan that calls for two well pads per section with nine horizontal wells per section.

Production from the Cana Woodford climbed to 229 MMcf/d of gas equivalent in 1Q 2013, representing a 42% gain from the same quarter in 2012. That production included 3,147 b/d of oil, 11,842 b/d of NGL, and 139 MMcf/d of natural gas. Proved reserves stood at 1.13 Tcf of gas equivalent with 36% of those reserves in liquids.

The company drilled and completed 52 gross (20 net) wells in the midcontinent region in 1Q 2013, nearly of all which were located in the Cana Woodford and completed at producers. At the end of the quarter, 42 gross (15 net) wells were awaiting completion. Cimarex had drilled 33 gross (12 net) wells in the Cana Woodford area in 1Q 2012, according to the company's 1Q report to shareholders.

The company had 3.3 Tcf of gas equivalent in risked potential production from the liquids-rich area and planned to develop those reserves with a play-life-long \$5 billion.

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Continental Resources Inc.

- *Land: 280,610 net acres*
- *Prime mover in the SCOOP play*

Continental Resources Inc., already the powerhouse of the Bakken play in the Williston Basin, built a similar position in the Cana Woodford play in Oklahoma with a particular focus on the South Central Oklahoma Oil Province (SCOOP).

The Bakken has made the company the top oil producer in the Rockies, the Williston Basin, and the Bakken play.

The company called the Woodford Shale “one of the thickest, best-quality resource shale reservoirs in the country.”

According to the company, the SCOOP is the center of Oklahoma oil with three of the state’s top oil-producing counties with 60 reservoirs and 3.2 Bbbl of oil produced. Fields include the giant Sho-Vel-Tum (1.7 Bboe), Golden Trend (1.02 Bboe), Oklahoma City (950 MMboe), and Cement (420 MMboe). The source of oil in the SCOOP is the Woodford Shale, and 70 Bbbl of oil remain in place in that shale.

Much of the shale in the SCOOP is up to 400 ft thick, and Cana zones are more than 200 ft thick. By comparison, shale in the northwest Cana is 50 ft to

100 ft thick, and the SCOOP area has six times the volume of the Cana area. Not only that, but the SCOOP shale also is oil-prone and liquids-rich.

By year-end 2010, Continental held 94,000 net acres in the SCOOP. At 1Q 2013, that number had climbed to 232,000 net acres in the SCOOP alone, and, according to DrillingInfo, the company held 280,610 net acres in Anadarko Basin shales, including the SCOOP and Northwest Cana.

At year-end 2012, the company had 785 MMboe in company-wide proved reserves with 5.7% of those reserves in the northwest Cana and another 8% in the SCOOP. The company’s 1Q production totaled 11 MMboe, with 7% coming from the northwest Cana and 12% from the SCOOP.

In early 2013, Continental held 3,035 net undrilled locations in the SCOOP with an estimated 2 Bboe in net unbooked reserve potential. That unrisks resource was based on 80-acre spacing for wells and an anticipated rate of return from 40% to 70%.

Among the company’s better SCOOP wells in the condensate area, the Knox 1-1H tested for 1,151 boe/d, 26% oil; the Colbert 1-32H for 1,760 boe/d, 30% oil; the Lowrance 1-10H for 1,580 boe/d, 38% oil; and the Cosby 1-13H for 1,761 boe/d, 23% oil. Among wells in the oil fairway, the Elliot 1-035H tested for 633 boe/d, 67% oil, and the Nightengale 1-16H for 523 boe/d, 78% oil.

In early 2013, Continental had drilled or participated in 84 gross (46 net) wells in the SCOOP and derisks more than 600 sq miles of potentially productive properties. The company operated nine rigs in the area and planned to raise its rig count to 12 in 3Q.

The company also described the economics of production in the SCOOP. The condensate area offered wells with an estimated ultimate recovery (EUR) of 1.19 MMboe with 24% oil, 37% condensate, and 39% natural gas. The oil fairway gave up wells with EURs



ECO-Pads lower construction and drilling and completion costs, minimize production footprints, and concentrate collection points of modern drilling operations. *(Photo courtesy of Continental Resources Inc.)*



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A rig drills a deep horizontal well in the SCOOP area of Oklahoma to generate high rates of return.

(Photo courtesy of Continental Resources Inc.)

of 626,000 boe, with 52% oil, 23% NGL, and 25% gas.

A completed horizontal well in the oil-prone area cost US \$9 million to drill but gave the company a 55% rate of return. If the company reaches its target cost of \$8.5 million, it expects a 60% rate of return.

A condensate-area well costs \$9.5 million to complete and yields a 90% rate of return. The company can increase that return to 95% at a cost of \$6/Mcf of gas if it can drive the well cost down to its target cost of \$9 million.

With a gas price of \$4/Mcf, the oil area gives up 44% on a \$9 million well and 50% on an \$8.5 million well. In the condensate area, with the same gas price, the return is 63% on a \$9.5 million well and 68% on a \$9 million well. All those returns assume a \$90/bbl oil price.

While the company's Bakken play gets the bulk of its planned \$3.15 billion in capex for 2013, Continental will direct \$470 million to the SCOOP.

Devon Energy Corp.

- *Land: 700,000 net acres*
- *Cana Woodford ranks as company cornerstone*

Devon Energy Corp. prides itself on its reputation as the only US-based energy company on the Fortune 500, the Fortune World's Most Admired Companies, and the Fortune 100 Best Companies to Work For lists.

Devon started operations in Oklahoma City in 1971 and still claims Oklahoma as its home. The company has three key production areas in the state: the Cana Woodford Shale, the Mississippi Lime, and the Arkoma Woodford Shale. Since the Arkoma Woodford is a gas-producing region, low gas prices have forced the company to concentrate recently on the other two shales for its Oklahoma activities.

In a May 2013 presentation, Devon said it controlled 1.9 million net acres of land in Oklahoma in the Cana Woodford, Mississippi Lime, and Arkoma



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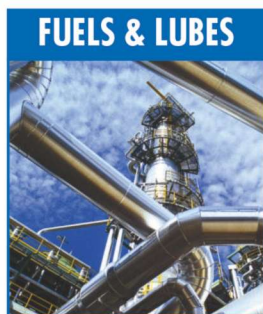
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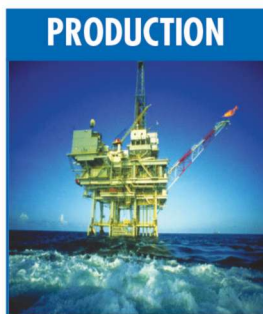
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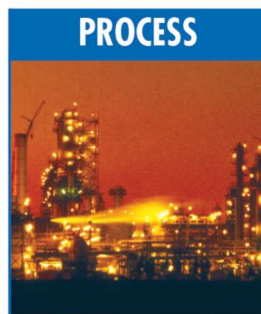
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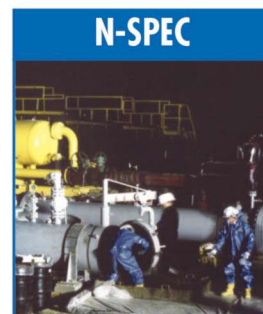
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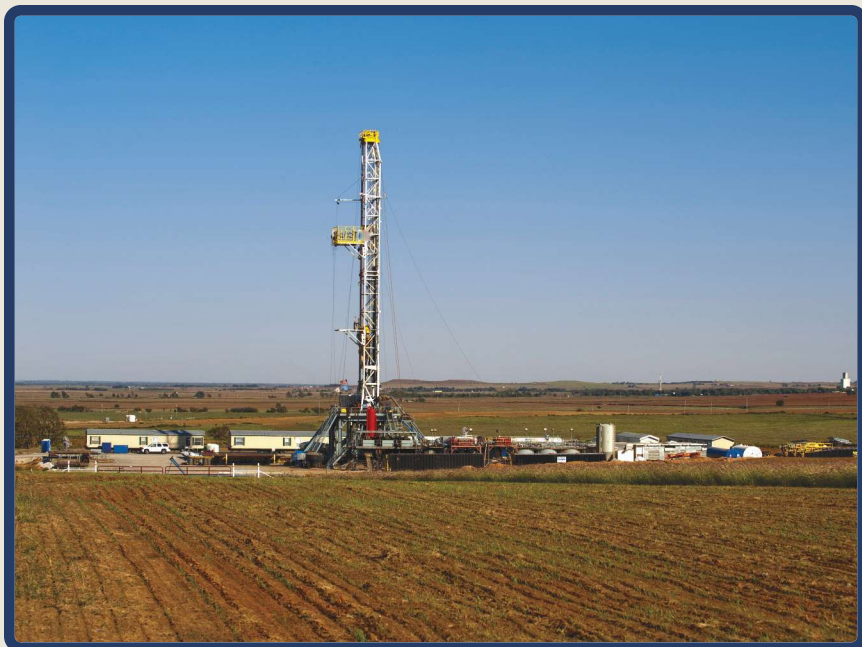
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After overcoming technical challenges during the exploratory phase, the Cana Woodford emerged as a cornerstone asset for Devon. It is the largest producer in the play. *(Photo courtesy of Devon Energy Corp.)*

Woodford. The company had 8,700 wells that produced 316,000 boe/d, 29% liquids, and 46% of the company total in 1Q 2013. Oklahoma also accounted for 2.015 Bboe in reserves, 36% liquids, and 68% of total company reserves.

The Mississippian play still is emerging with strong potential, while the Cana Woodford sets new production records every quarter, according to the company website.

Devon plans to drill about 400 oil wells in the Mississippian in 2013.

Drilling started in the Cana Woodford in 2007, and a Devon engineer gave the play its name after seeing Cana as an abbreviation for Canadian County. Since that time, Devon has drilled more than 500 wells to the formation.

The company holds some 250,000 net acres of land in the area, 200,000 of which are in the liquids-rich area and 50,000 in the dry gas area. It is not developing the dry gas portion. It drilled about 200 Cana Woodford wells in 2012, including the longest horizontal onshore well in company history with a lateral measuring more than 10,000 ft long.

Devon produced 340 MMcf/d of natural gas from the shale in 1Q 2013, representing a 26%

increase from the same quarter in 2012. It built a processing plant to handle 200 MMcf/d of gas in 2010 and will expand that plant to a capacity of 350 MMcf/d of gas in 2013. The company also built a water recycling plant to serve its wells.

Devon produced 23,000 boe/d in oil and NGL, or 41% of its total liquids production.

The company planned approximately 150 Cana Woodford wells in 2013 to reach a net risked resource of 11.4 Tcf of gas equivalent. The play will support some 5,400 risked locations on Devon's property.

According to an April 2013 IHS report, Devon reported production rates from four horizontal Cana Woodford wells drilled from the same pad about three-quarters of a mile west of Mulhall in Logan County, Okla., on the Nemaha Uplift.

Production rates ranged from 150 b/d of oil and 60 Mcf/d of gas with only 2% of the fracture fluids recovered, to 739 b/d

of oil and 550 Mcf/d of gas with about 19% of the frac fluids returned.

Thousands of vertical wells have been drilled into the Mississippi Lime in north-central Oklahoma and south-central Kansas since the formation's first boom in the 1950s. Horizontal drilling and sophisticated fracturing techniques revived the play.

According to the company, this emerging play offers Devon wells with initial potentials of more than 1,000 boe/d, not including high-Btu gas.

By May 2013, the company had approximately 70 wells awaiting completion in the play and planned approximately 400 Mississippian wells during 2013. That play contains more than 800 MMboe in net risked resources and more than 5,000 net risked well locations.

The company holds some 600,000 net acres in the play, and 450,000 of those net acres lie outside of a joint venture area with Sinopec. Sinopec put up US \$900 million in cash and \$1.6 billion in drilling carries for a one-third interest in 1.5 million net acres of Devon properties, including the Mississippi Lime.

Devon was working 15 rigs in the Mississippian in May 2013 and said the area had the potential to support up to 20 rigs by year-end.



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Devon's Cana plant will process up to 350 MMcf/d of gas and 30,000 b/d of NGL when it is completed in 2013. The plant will serve wells throughout west-central Oklahoma. (Photo courtesy of Devon Energy Corp.)

Doxa Energy Ltd.

- *Land: 3,469 net acres*
- *Boosting production through participation*

Doxa Energy Ltd. works the Mississippi Lime as a springboard in its quest for more production and higher profits with the help of partners prominent in the play.

Founded in 2010, the company started its growth path in the Mississippi Lime in 2012 with 16 wells drilled and completed during the year and 16 producing. That was 16 gross (0.52 net) wells.

In January 2013, two more wells (0.05 net) were drilled and awaiting completion, and an additional three wells (0.08 net) were drilling.

In a June 2013 report, the company said it participated in nine new completed Mississippi Lime horizontal wells to increase its interest in the play to 26 gross (0.83 net) wells. It plans to participate in an additional 15 wells during the remainder of the year with interests from 1.67% to 5%. SandRidge will operate most of those wells.

Average production rates for the 23 wells that have been onstream for 30 days or more were 240 boe/d, broken down into 138 b/d of oil and 607 Mcf/d of gas.

Completed well costs declined from an average US \$3.7 million per well for wells completed in 2012 to slightly more than \$3.4 million for the nine wells completed in the first five months of 2013.

Doxa holds a 20% participating interest in 17,347 gross (3,469 net) acres. Its 26 producing wells, drilled at a net cost of \$3 million to Doxa, are generating \$80,000 per month in net revenues after deduction of royalties and taxes.

In the long term, assuming half of the company's acreage will be fully developed, Doxa will participate in more than 200 gross wells at four wells per section with working interests from 3% to 5%.

Based on a SandRidge-type curve on a 409,000 boe well discounted at 25%, those wells could add \$3.75 million in net proved developed potential to Doxa, another \$3.75 million in proved undeveloped value, and a total potential resource worth \$25 million to \$30 million.

Eagle Rock Energy Partners LP

- *Land: 16,000 net acres*
- *Lower costs raise profits in SCOOP*

Eagle Rock Energy Partners LP produces from multiple formations in the South Central Oklahoma Oil Province (SCOOP), but it calls the Woodford Shale its "major driver of future liquids-rich production growth."

In a May 2013 presentation, the company said it held interests in 78 producing wells in the Woodford Cana and Golden Trend area with a 1Q production average of 30.7 MMcf/d of gas equivalent. That was a 31% production gain from the same quarter a year earlier.

As the company worked the learning curve for the play and reduced drilling times and costs for its horizontal Woodford wells in the SCOOP, it expected a rate of return of more than 25% from the play at current New York Mercantile Exchange strip prices. It is operating one drilling rig in the play.

Eagle Rock has interest in nine producing wells in the southeast Cana area with two operated producing wells. The company was drilling a third operated well at the time of the presentation.



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Wells in the SCOOP gave up 25% oil, 38% NGL, and 37% gas. The company's properties gave it 562 nonoperated locations, or 129 operated locations. It held a 43% average working interest in the properties, or a 7% average nonoperated working interest.

Experience with horizontal wells during 2012 showed an average drilling time of 84 days and a drilling and completion cost of US \$12.7 million, but the company expected those numbers to drop in 2013 to 50 days and \$7.9 million.

The company is fairly new to the play, having acquired most of its midcontinent properties from Crow Creek Energy in May 2011.

Encana Corp.

- *Land: 360,00 net acres*
- *Mississippi Lime ranks on emerging play list*

Encana Corp. targets a handful of active plays in the US, establishes strong land positions, and applies a scientific approach to exploitation as it takes those plays from exploration through development. Its activities in the Mississippi Lime remain low-profile at this point since the company ranks it as an emerging play.

In early 2012, the company said it continued to build its position in the Mississippi Lime in Oklahoma and Kansas. At that time, it held leases on some 140,000 net acres and planned six to eight wells during 2012.

By mid-year Encana, had built that land position to 360,000 net acres and planned 15 wells during the year.

According to the Canadian company's website, "In the US division, Encana has amassed a substantial land position in some of North America's most promising oil and liquids-rich plays including the Tuscaloosa Marine Shale straddling the Mississippi and Louisiana border; the Utica/Collingwood formations in Michigan; the Eaglebine play in East Texas; and the Mississippian Lime in Oklahoma and Kansas. The company is seeking partnerships to accelerate the commercialization of approximately 1.2 million net acres within these areas."

By that time the company took a conservative approach to development. It did not mention the Mississippi Lime as a source for liquids growth in 2013, but it still listed the formation as an emerging play.

At that time, the company said it had 81,600 gross acres in the Osage area in Oklahoma with an estimated 2.5 Bboe in place, comprising primarily light oil with associated NGL. It held an 80% net revenue interest in approximately 400 well locations and had drilled 12 wells in 2012 with good results. The company said it had the inventory to support a one- to two-rig program based on its success in the play and planned seven to 12 wells in 2013.

Encana said it planned to establish commerciality on its Osage properties where a well could be drilled and completed for US \$2.6 million to \$3 million. That well would reach estimated ultimate recoveries between 350 Mboe and 400 Mboe with 4,600-ft laterals at a total vertical depth from 2,100 ft to 2,400 ft.

Encana also said it had 218,000 acres in western Kansas, with 92,000 acres in its east Kansas prospect, but results from test wells had not met expectations.

Exxon Mobil Corp.

- *Land: More than 270,000 net acres*
- *Pioneering Woodford Shale in the Ardmore Basin*

Exxon Mobil Corp., working through its XTO Resources arm, established itself as the leader in the Woodford Shale play in the Ardmore and Marietta basins of southern Oklahoma.

By year-end 2011, Exxon Mobil had accumulated 172,000 net acres in the play and had increased its activity by increasing the number of rigs dedicated to the shale from three to seven. That year, it also tripled its gross operated production as it brought 31 new wells online in the Ardmore Basin.

According to the company's website, XTO held 773,000 acres of land in all of Oklahoma in January 2013 and produced approximately 308 Mcf/d of gas and 6,000 b/d of oil as it developed its properties with 13 rigs. It had operations in 25 counties in the state and offices in Ardmore and five other cities, including its midcontinent division headquarters in Oklahoma City.

Among those properties, the company operated in Woods County in northern Oklahoma, where some operators have unconventional production, and in the Ardmore Basin in southern Oklahoma.

During a presentation at the company's annual meeting of shareholders on May 29, 2013, Exxon

Mobil said it operated in five unconventional plays in the US among nine in North America, 11 in the Western Hemisphere, and 16 throughout the world. The Woodford Shale was one of those plays.

In its 2012 financial and operational review, Exxon Mobil said it completed its fifth acquisition in southern Oklahoma since 2010 during the preceding year. That purchase increased its acreage in the Woodford Shale in the Ardmore and Marietta basins to 270,000 net acres.

Both basins were attractive, the company said, because of their high liquids yield and high per-well recoveries. At that time, Exxon Mobil said it had the potential to recover more than 1.5 Bbbl of oil from the play.

After tripling its production in 2011, the company's gross production more than doubled again to approximately 19,000 boe/d in 2012. In 2008, it produced about 1,000 boe/d from the Ardmore Woodford. The company also completed a

117-mile pipeline in 2012 to connect its southern Oklahoma operations to processing facilities in north Texas.

At year-end 2012, the company continued to delineate the Woodford and other shales in the Marietta Basin to the southwest.

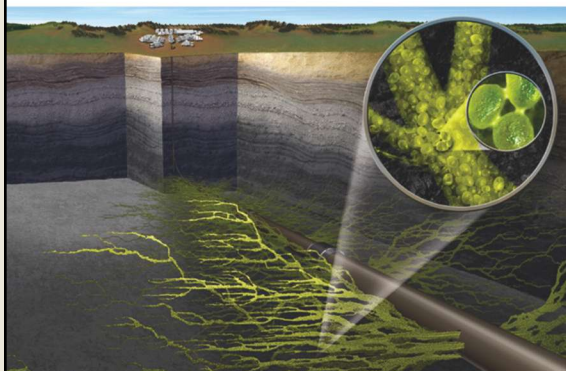
The company said its current development plans could grow its production in the Woodford Shale to more than 150,000 boe/d net. It was Exxon Mobil's most active unconventional area in 2012 with 12 operated rigs in action.

HighMount E&P LLC

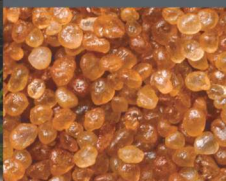
- *Land: 73,000 net acres*
- *Working the Mississippi Lime, looking at the Woodford Shale*

HighMount E&P LLC got its start in August 2007 when Loews Corp. bought assets previously controlled by Dominion Resources, and it has not wasted time since it started operating.

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The company calls the Midcontinent a growth area and maintains a core position in the Mississippi Lime in Noble, Pawnee, and Payne counties in Oklahoma – much of which overlies the Woodford Shale. The company also is expanding operations in the Texas Panhandle. Most of its 73,000 net acres in the Mississippi Lime are contiguous.

Including its Permian Basin operations, the company operates more than 6,133 gross (5,874 net) producing wells and holds more than 1.1 million gross (700,000 net) acres in Oklahoma and Texas and produced some 154 MMcf/d of gas equivalent during 2012.

HighMount plans to spend some US \$270 million on all of its properties in 2013.

During Hart Energy's DUG Midcontinent conference in 2013, Jason Garner, HighMount COO, said water is a significant issue for fracturing in its operations, but supplies are under control. Electricity infrastructure is the most difficult part of the supply equation, he said.

The company is working two rigs in the Mississippi Lime, which Garner called a complex reservoir where understanding of its characteristics is critical. "I think we'll start to delineate the winners from the losers and understand where those opportunities are and where we need to stay away," he said.

The company has 45 producing wells in the Mississippi Lime and is conducting a 3-D seismic survey over its property. It also drilled two wells to the Woodford Shale on its property.

Magnolia Petroleum Plc

- *Land: 78,600 gross acres*
- *Conventional growth with unconventional plays*

Magnolia Petroleum Plc, which started business as a UK company in late 2011, focused its operations on the Bakken/Three Forks, Mississippi Lime, and Woodford/Hunton plays to follow a planned growth path.

The company started with minor land positions and minor participations in a lot of wells and is gradually building both its land holdings and its interests. In November 2012 it spud its first well as an operator.

In a statement at the company's annual meeting

in early June 2013, CEO Steven Snead said Magnolia had acquired approximately 13,000 net mineral acres in proven hydrocarbon formations with more than 600 drilling locations. It held interests in 101 wells by year-end 2012 and 154 wells by June 2013 with 112 of those wells producing.

Production grew 15-fold by year-end 2012 to 122.5 boe/d.

From a participating interest of usually less than 1% in wells, the company is gradually increasing its participation with a high of 12.5% in the Mississippi Lime by June 2013.

Magnolia held approximately 57,600 gross (702 net) acres in the Woodford/Hunton play in 26 counties in central Oklahoma with average working interests of approximately 1.57% and a net revenue interest of approximately 1.18%. It planned to participate in eight wells on the property in 2012.

The company held another 21,000 gross (5,506 net) acres in the Mississippi Lime in northern Oklahoma and identified five prospects. It planned to operate two wells on that acreage with an average working interest of 25%. It anticipated those wells would set up another 22 drilling locations.

The company said its average payout in the Mississippi Lime was less than six months and it participated with Chesapeake Energy on one horizontal well that paid out in three months.

Magnolia started drilling its first well as operator in the Mississippi Lime in Noble County, Okla., in November 2012. The Roger Swartz No. 1 aimed at a total depth of 5,500 ft. The company had not released results from that test by June 2013.

Marathon Oil Corp.

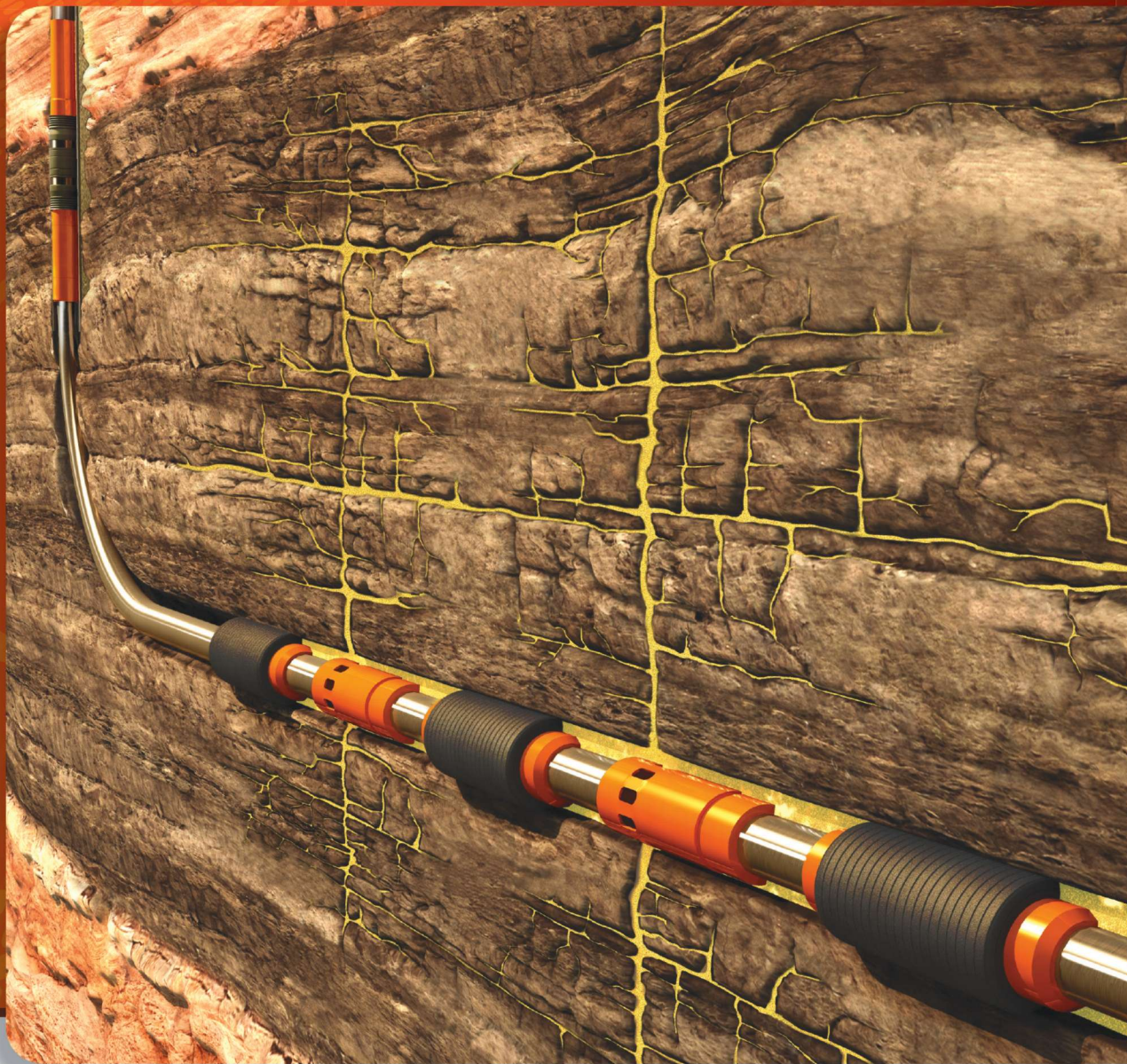
- *Land: Approximately 220,000 net acres in Oklahoma Resource Basins*
- *Building on 70 years of Oklahoma activity*

Marathon Oil Corp. parlayed its experience in Oklahoma to establish operations in some of the strongest plays in the area.

Those plays include the Anadarko Woodford Shale, Mississippi Lime, Granite Wash, Tonkawa, Cleveland, and Marmaton. The company's 2012 Oklahoma activities, both conventional and unconventional, gave it an average 5,000 b/d of liquids and 80 MMcf/d of natural gas, or 5% of the company's

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total US liquids production and 22% of its domestic gas sales.

At year-end 2012, Marathon held approximately 163,000 net acres in the Anadarko Woodford resource play with an approximate 55% working interest in its operated assets, another 46,000 net acres in the Mississippi Lime, and 60,000 net acres in the Granite Wash, Cleveland, Tonkawa, and Marathon formations. These totals exclude Marathon's acreage position in conventional plays.

According to the company website, Marathon ramped up its Woodford program in 2012 targeting the liquids-rich condensate and oil windows in the East Knox and Knox fields. Successful development of the play could give the company more than 980 drilling locations on 80-acre spacing and approximately 600 MMboe in proved and probable net resources.

The Anadarko Woodford averaged net sales of 8,000 boe/d in 2012 and the company recorded an exit rate of production of approximately 10,000

boe/d. Marathon continues to evaluate this acreage and could increase rig count when more favorable gas prices are available.

In a March 2013 presentation, Marathon said it had two rigs working the Woodford, Cana, and Knox shales.

For 2013, the company planned to drill 42 to 50 gross (15 to 19 net) wells in its Oklahoma resource plays with a capital program of approximately US \$150 million. Marathon planned to spend another \$25 million on four test wells, including two in the Mississippi Lime.

Marathon expects to average 730 b/d of condensate on initial 30-day potential on its Cana wells. Those wells offered a gross estimated ultimate recovery of 908,000 bbl of condensate with 45% of the volume and approximately 62% of revenues from liquids.

Estimated gross well costs are \$9 million including facilities. Currently, the company is drilling on 160-acre spacing and receiving a 12% internal rate of

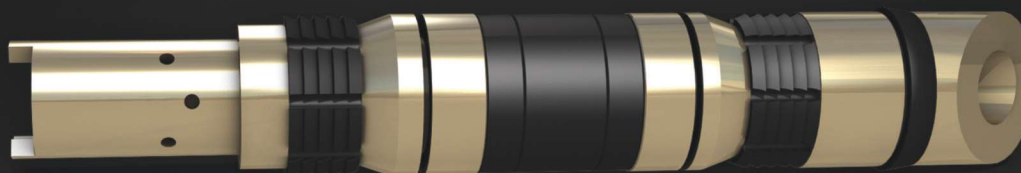


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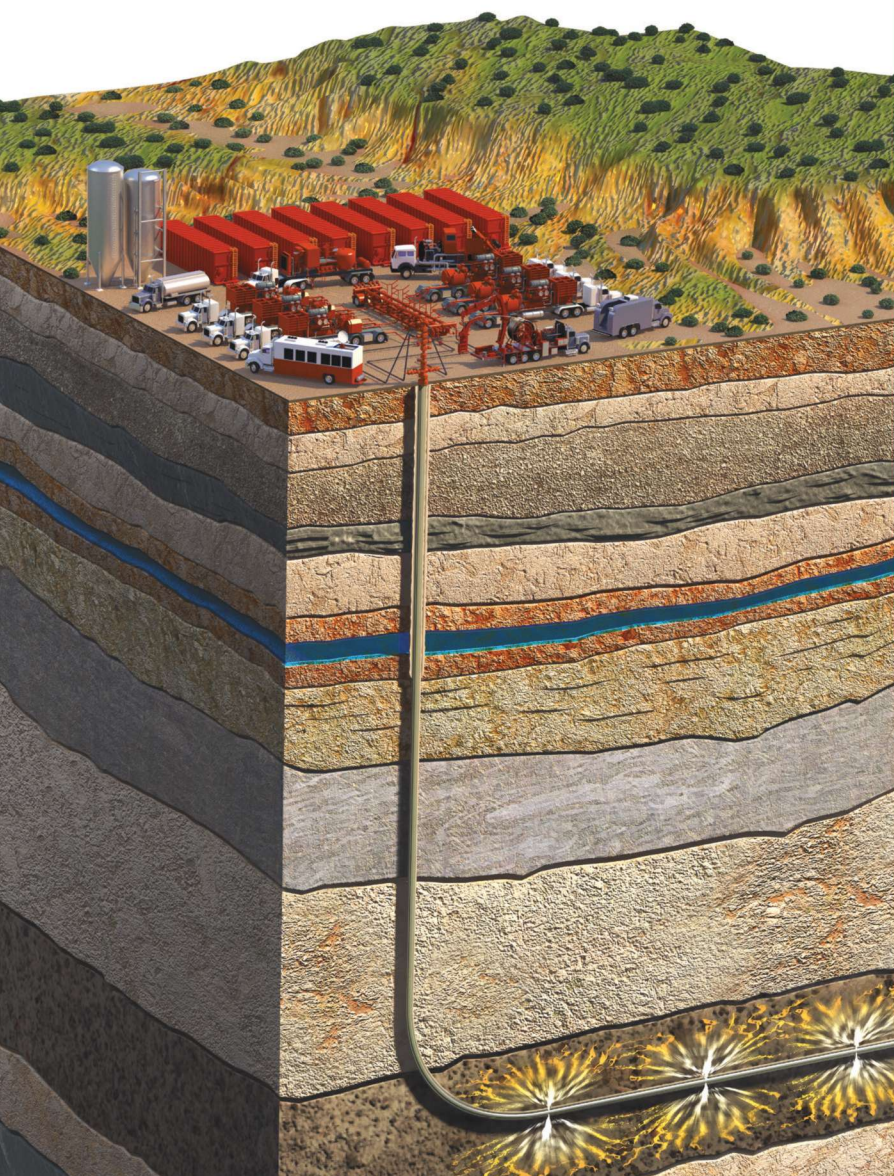
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Marathon taps the Woodford Cana and Mississippi Lime formations as part of its unconventional program in Oklahoma. *(Photo courtesy of Marathon Oil Corp.)*

return with a before-tax net present value, discounted at 10%, of \$700,000. The undiscounted payout per well is approximately 6.8 years. This estimate assumes flat commodity prices at \$85/bbl of oil, \$3.45/Mcf of gas, and \$27.80/bbl of NGL.

In contrast, Marathon's Knox Shale wells offer the company a 28% internal rate of return before taxes with an undiscounted payout of approximately 3.9 years.

Midstates Petroleum Co. Inc.

- *Land: 77,400 net acres*
- *Newcomer that is drilling aggressively*

Midstates Petroleum Co. Inc. bought into the Mississippi Lime play in Oklahoma with the purchase of land from Eagle Energy in October 2012.

The company immediately assumed operations of the properties in Woods and Alfalfa counties, which offered 7,207 boe/d of production in 4Q 2012, according to the company's presentation at Hart Energy's DUG Midcontinent conference in April 2013.

The company operates 90% of its producing wells and obtains hydrocarbons containing 38% oil and 22% NGL. The property also contains potential for production from the deeper Woodford Shale.

By the time of the presentation, Midstates had 70 wells producing from the Mississippi Lime with 90% of its wells produced with an electric submersible pump.

The company put 19 wells online since acquiring the Eagle properties, and 17 of those wells produced for more than 30 days with a 30-day average of 638 boe/d with 65% liquids.

The company has 600 potential future drilling locations with three wells per section and 800 potential wells with spacing at four wells per section.

Showing its enthusiasm for the Mississippi Lime, Midstates put five rigs to work in the play for 2013, with four of them working on development and the fifth to hold land by production.

The company plans to drill 60 to 70 operated wells in 2013 with an average 70% working interest and a 56% net revenue interest. It will drill another three saltwater disposal wells.

By March 2013, Midstates had 69 wells that had been on production for at least 30 days with an average 30-day initial potential of 586 boe/d. Thirty-six of those wells showed initial 30-day production rates of more than 500 boe/d, and 11 offered 30-day rates of more than 1,000 boe/d.

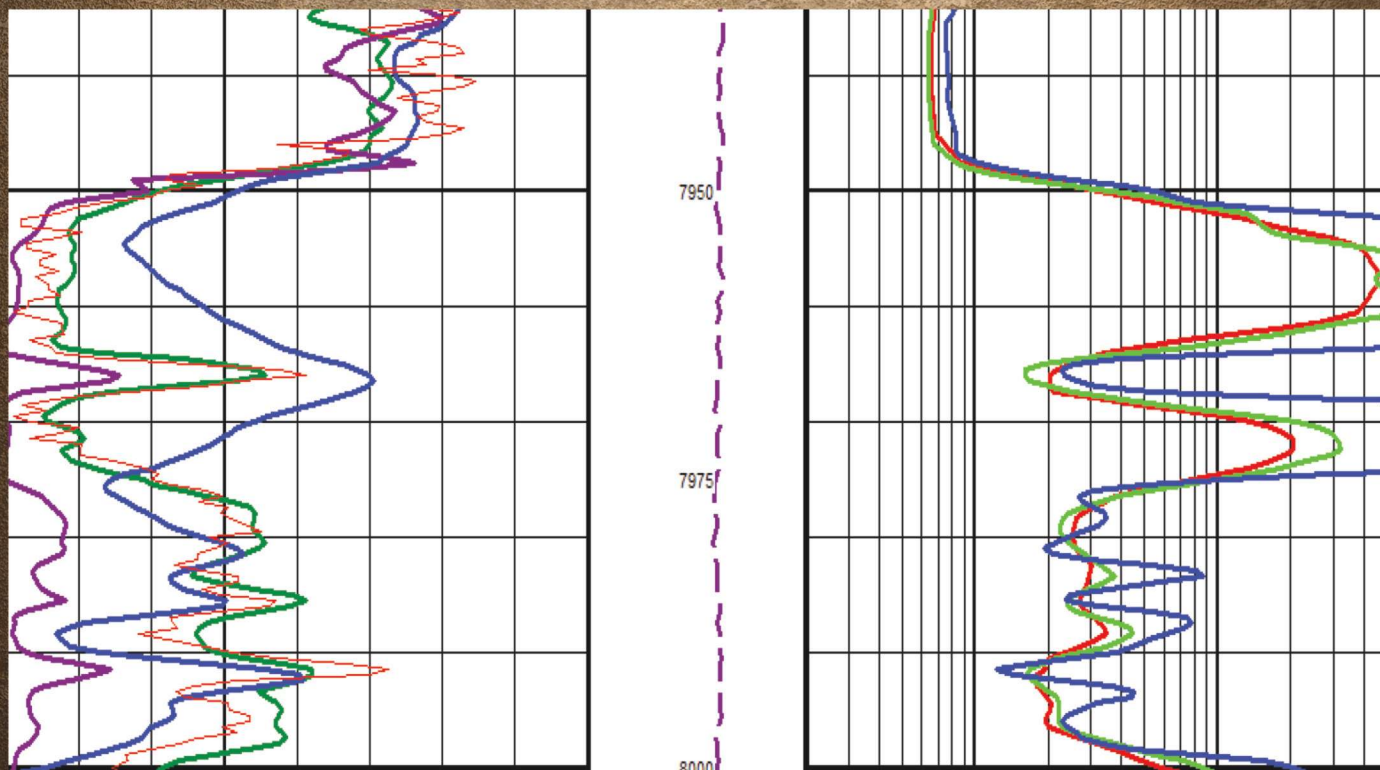
The company's average well cost US \$3.6 million to complete with a 4,600-ft lateral and 10 frac stages, but Midstates currently is reducing drilling and completion costs. The company also is reducing spud-to-first-sales time by using pad drilling on 70% of its 2013 wells.

Nemaha Oil & Gas LLC

- *Land: Undisclosed*
- *Less than two years old and growing*

Nemaha Oil & Gas LLC received an initial investment from Pine Brook Road Partners LLC in October 2011, and it took that investment to the Mississippi Lime.

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Little public information is available about the privately held company, but a September 2012 article in the *Tulsa World* said the E&P company set its sights on the Mississippi Lime in southern Kansas. At the time, Nemaha planned to add 75 jobs at its corporate headquarters in Tulsa, and that investment could entitle it to US \$3.9 million in payroll tax incentives.

IHS Inc. provided data that shows Nemaha is an active company. It contracted Horizon Energy Services Rig No. 4 to spud the DJK 1A-16-32-9 well in Chataqua, Kan., and started drilling on Dec. 30, 2011. Nemaha drilled into the Mississippi Lime with a 2,422-ft horizontal leg at a total vertical depth of 2,424 ft and perforated the Mississippian in 16 intervals from 2,545 ft to 4,423 ft. It acidized and fractured the horizontal leg in five stages.

Nemaha completed the well on March 10, 2012, as a producer but did not report initial production rates. IHS called the well a new field discovery.

Newfield Exploration Co.

- *Land: 125,000 net acres*
- *Expanding activity in Cana Woodford*

Newfield Exploration Co. pins a substantial amount of its growth promise on the Cana Woodford play, which it ranks as the second most important in terms of capex.

Fully a fourth of the company's US \$1.4 billion to \$1.5 billion in 2013 capex will go into the Oklahoma play, exceeded only by the 26% share directed at its Uinta Basin properties in Utah among domestic projects.

The company produced 14,400 boe/d from the Cana Woodford in 1Q 2013, up from 10,100 boe/d in 4Q 2012, and expected to produce 15,000 boe/d from the formation in 2Q 2013. The company estimated production of 100,000 boe/d from US sources in 2015 and anticipated producing 40,000 boe/d of that from the Cana Woodford.

By May 2013, Newfield had operated in the formation for a decade and had drilled more than 400 horizontal wells. It converted more than a third of its Cana acreage to development within a year.

With the help of long lateral legs on its wells, the company increased its rate of return from the wells to more than 50%.

Between 2013 and 2015, Newfield expects to operate six to eight rigs continuously with a focus on development.

The company also initiated pilot programs testing five, six, and eight wells per section.

During 2013, Newfield expects to work its 28,500 net acres in the south area with the Cana Woodford at 12,000 ft to 18,000 ft where it has 375 gross locations and 125 MMboe to 150 MMboe in net unrisks resource.

The south area produced 2,200 b/d of oil, 3,200 b/d of NGL, and 4,700 b/d of gas equivalent in 4Q 2012 and grew to 3,500 b/d of oil, 4,600 b/d of NGL, and 6,300 b/d of gas equivalent in 1Q 2013. The company planned to produce 26,000 boe/d from the area by year-end 2013.

In the same period, Newfield increased lateral lengths by approximately 40% to an average 8,761 ft, more than double the length of its peer companies in the play.

The company also will operate in its 19,000 net acres in the north area, where the Cana Woodford lies at shallower depths but offers lower estimated ultimate recoveries. Those properties hold some 50 MMboe in net unrisks resource.



A drilling rig aimed at the Cana Woodford in Oklahoma stands out against a flat horizon. Companies working with the play claim high profit margins from the oily shale. (Photo courtesy of Newfield Exploration Co.)

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Activity will expand to the company's full 77,500 net acres in 2014 where it has 985 gross drilling locations and more than 200 MMboe in net unrisked resource.

Among the company's better recent wells, the Casados well in the south wet-gas area tested for 2,127 boe/d of initial potential, a 1,795 boe/d 30-day average, and an 1,875 boe/d 60-day average from a 6,698-ft gross perforated interval.

Newfield's Tina well in the south oil area showed an initial potential of 1,855 boe/d, a 30-day average of 1,305 boe/d, and a 60-day average of 1,508 boe/d from a 10,153-ft gross perforated interval.

In the north oil area, the Klade well offered an initial potential of 1,000 boe/d, a 30-day average of 657 boe/d, and a 60-day average of 521 boe/d from a 10,292 gross perforated interval.

Throughout the Anadarko Cana, Newfield had 24 MMboe in proved reserves at year-end 2012 with an incremental unrisked net resource of 407 MMboe on 125,000 net acres and 1,500 gross potential drilling locations.

The company's rates of return ranged from more than 50% in the south wet-gas and oil areas to more than 40% in the north area with a \$90/bbl price for oil and a \$3.50 MMBtu price for gas.

In May 2012, Newfield operated five rigs in the Cana Woodford and planned to add two more rigs later in the year.

Osage Exploration & Development Inc.

- *Land: 15,782 net acres*
- *Partners push aggressive drilling effort*

Osage Exploration & Development Inc. set the stage for a drilling program highlighting the Mississippi Lime when it bought leases in the play in Logan County, Okla., at a bargain price.

The company paid US \$1.5 million for 10,000 net acres, or \$150/acre, and later sold 75% of the properties to its operating partner, Slawson Exploration, for \$650/acre. Now, Slawson holds 45% of the parcel, US Energy Development 30%, and Osage 25%, or 7,950 net acres in the expanded venture property position.

Also in Oklahoma, Osage controls 100% of 3,579 net acres in Pawnee County prospective for the Mississippi Lime and 4,253 net acres in Coal County prospec-

tive for the Woodford Shale, Osage said in a May 2013 presentation. The Woodford is present under the company's Logan and Coal county properties, as well.

By that time, Osage had participated in 28 Logan County wells, most operated by Slawson. Devon Energy operated another well, and Stephens Production Co. operated multiple wells.

In late June 2013, Osage said it had participated in spudding 10 wells in 2Q 2013, including nine horizontal Mississippian wells and one horizontal Woodward test. Those wells raise the company's participatory well count to 19 in the first half of 2013, up from 10 wells for all of 2012.

Slawson, US Energy Development, and Osage plan one well per section on their properties over the next three years to hold more than 115 sections by production.

The first and best well, the Wolf 1-29H, came online in March 2012 with an initial potential of 1,388 boe/d. By the end of March 2013, it had produced a cumulative 95,926 boe, with 72% of that production in oil.

The companies' average initial potential for the first seven wells in the program was 541 boe/d with 78% in oil. Estimated ultimate recoveries averaged 278,031 boe with 60% oil, and the companies expect first 30-day production averages of 456 boe/d. They have 387 gross drilling locations.

Production, net to Osage, was 240 boe/d in 1Q 2013.

Osage still was in leasing mode on the Pawnee project in 1Q 2013 but planned to start drilling in the second half of the year. It planned to continue leasing through 2013 on the Coal County Woodford project.

PEDEVCO Corp.

- *Land: 6,763 net acres*
- *Mounting operations in the Mississippi Lime*

PEDEVCO Corp., doing business as Pacific Energy Development, was founded in January 2011 with a public offering in July 2012 and began operations with a strategic goal of acquiring and developing high-growth energy projects.

That led to an attraction for developing proven and producing oil and gas plays in the US and plans to find and develop prospective shale oil and gas opportunities in countries on the Pacific Rim.

The company closed its acquisition of 7,006 gross (6,763 net) acres of properties prospective for the

Mississippi Lime in Comanche, Harper, Barber, and Kiowa counties in Kansas in March 2013 and held an option to acquire another 7,880 gross (7,034 net) acres.

It has analyzed 3-D seismic data on the property and planned to drill its first well in 2Q 2013. The company planned four wells by year-end 2013.

Petrodyne Resources Ltd.

- *Land: Undisclosed*
- *Focused on northwestern Oklahoma*

Petrodyne Resources Ltd. picked the Mississippi Lime as its play of choice and is looking for partners to work development deals.

The company plans to “aggressively acquire, explore, develop, and produce oil properties onshore in the US with a primary focus on Oklahoma and Kansas,” according to its website.

Currently the company has a position in the Tier 1 Core of the Mississippi Lime, primarily through nonoperated working interests and overriding roy-

alty interests in Alfalfa, Grant, and Garfield counties in northwestern Oklahoma.

Petrodyne planned to participate in drilling at least 10 horizontal wells on acquired acreage by year-end 2012 with support from operating partners such as SandRidge E&P, Chesapeake Energy, Eagle Energy, and Panther Energy.

Petrodyne said its total proved undeveloped reserves reached 465,630 boe on 60 proved undeveloped locations in the three Oklahoma counties.

The company said it was forming new ventures for its Mississippi Lime properties.

Petro River Oil Corp.

- *Land: 95,000 net acres*
- *Focused on eastern Kansas*

Petro River Oil Corp., supported by 70 sq miles of proprietary 3-D seismic and a substantial land position, is looking for profits from the Mississippi Lime in southeastern Kansas.



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The company has potential for more than 2,400 vertical locations and 600 horizontal locations on its properties in Marion, Cowley, Butler, and Harvey counties.

According to an April 2013 press release, Petro River, previously known as Gravis Oil, acquired Petro River Oil LLC and its 115,000 gross (85,000 net) acres in the Mississippi Lime to add to its existing acreage. Petro River also has properties in Missouri, Kentucky, and Montana.

The company also acquired working interests in leases in the Mississippi Lime from Mega Partners I for 15.5 million shares of stock.

Primexx Energy Partners Ltd.

- *Land: Undisclosed*
- *Plans 10 Mississippi Lime wells in 2013*

Primexx Energy Partners Ltd., working through its Primexx Operating Corp. arm, directs its primary activities in the Wolfbone play in Reeves County, Texas; a waterflood in Borden County, Texas, where it also has Cline Shale potential; and its Mississippi Lime properties in Oklahoma and Kansas.

The company's growth point in the Mississippi Lime lies in Grant County, Kan., where it plans on vertical well development on its existing acreage and horizontal upper-Mississippian wells.

In mid-2013, Primexx had four producing horizontal wells on its contiguous block of properties in that county, all with initial potential production rates of more than 320 boe/d.

Primexx planned to drill another six horizontal wells during the year.

The company also received approval to drill the Boor No. 4-1 wildcat to the Mississippi Lime in Harper County, Kan.

QEP Resources Inc.

- *Land: 73,000 net acres*
- *Focus on panhandles, Anadarko Basin*

Denver-based QEP Resources Inc. concentrates the bulk of its funds and operations on the Rocky Mountains and Williston Basin, but its liquids plays in the Texas Panhandle and Oklahoma contribute to the company's bottom line.

At year-end 2012, QEP had company-wide proved reserves of 3.94 Tcf of gas equivalent and produced 800 MMcf/d of gas equivalent, with 27% of that production coming from oil and NGL.

In a June 2013 presentation, QEP claimed 73,000 net acres of leases in the Cana Woodford with 337 Bcf of gas equivalent in proved reserves in 156 proved undeveloped locations and 3,236 additional potential locations. Those locations include 1,872 in the Tier 1 area of the Cana Woodford, where the company has a 20% average working interest.

The company's Tier 1 property included 31,700 net acres in Canadian County, Okla., while Tier 2 consisted of 43,300 net acres. Only 30% of its total Cana Woodford acreage lies in the dry gas area.

In June 2013, the company had one rig drilling in the Tier 1 area where it had a 75% interest in wells. It had completed four wells with a 100% working interest.

Approximately 17% of QEP's 2013 capex of US \$1.68 billion will go into its Cana Woodford, Granite Wash, Tonkawa, and Marmaton activities with a combined 530 Bcf of gas equivalent of proved reserves. It directed more than half of that budget to the Williston Basin.

According to the company, a Cana Woodford well costs an average of \$8 million to drill and complete, and QEP planned to drill 12 new operated wells in the first half of 2013. Estimated ultimate recoveries ranged from 6 Bcf to 8 Bcf of gas equivalent with a yield of 25 bbl to 130 bbl of NGL/MMcf.

The company's wells cost \$1.64/Mcf of gas equivalent, and it generated a 10% before-tax rate of return with a price of \$2.54/Mcf of gas equivalent.

In a November 2011 presentation, QEP said that its Cana Woodford properties lay immediately east of and slightly overlapped its Tonkawa properties in western Oklahoma and the Texas Panhandle. Its Cana Woodford production grew from approximately 5 MMcf/d of gas equivalent in 2009 to nearly 20 MMcf/d of gas equivalent in late 2011.

Range Resources Corp.

- *Land: Approximately 200,000 net acres*
- *Seeking Mississippi Lime and Cana Woodford pay*

Range Resources Corp. has the potential to drill more than 2,000 wells on its leases in the Mississippi Lime play, a number that could mean almost 1 Bboe of net production for the company.

By the time the company put together a presentation in May 2012, more than 4,500 total wells

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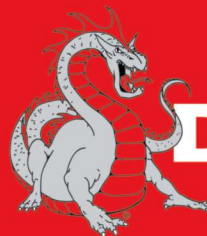
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had “defined productive limits” in the Mississippi Lime, and the highest cumulative production from vertical wells has come from Kay County, Okla. Cowley and Sumner counties in Kansas also have produced high-producing wells.

Range reviewed economics of the play based on 25 horizontal wells drilled between 2009 and 2012. Those wells average estimated ultimate recoveries (EURs) of 485,000 boe, but 2012 wells offered EURs of 600,000 boe. The wells cost US \$3.4 million to drill and complete, giving the company a finding and development cost of \$8.91/boe for the pre-2012 wells and \$7.27/boe for more recent wells.

Those numbers resulted in a 91% internal rate of return on the earlier wells based on the 10-year strip price on March 28, 2013, and a 133% internal rate of return on the later wells. That strip price was \$86.86/bbl of oil and \$4.79/Mcf of gas.

The company’s 1Q 2013 report said Range’s midcontinent division focused on the Mississippian with 17 gross (16.7 net) wells with average lateral lengths of 3,616 ft and 19 frac stages, turned to sales. Average seven-day production rates on those wells were 480 gross (382 net) boe/d with 78% liquids. The company’s Tyr 24-3N gave up 1,024 gross (827 net) boe/d with 80% liquids from a 3,403-ft lateral after 20 frac stages.

The Balder No. 1-30N, completed in 2012, has produced more than 68,000 bbl of oil in its first 11 months on production with an average 562 gross (388 net) boe/d of production with 74% liquids. That well paid out in less than six months.

Originally, Range planned to drilled 51 gross (42 net) wells in 2013, but it cut that gross number back to 41 to 43 wells. At the same time, the company increased average working interests in wells, so it should drill 40 to 42 net wells during the year.

The company has reduced spud-to-spud cycle times by 30% for its horizontal wells to a current 25 days. Drilling fewer gross wells with increased drilling efficiency will let Range complete its 2013 development plan with fewer rigs and fewer saltwater disposal wells.

Range expected to run five rigs in the Mississippi Lime in 2013, 10 rigs in 2014, and 15 rigs in 2015. That drilling rate should hold nearly all of its currently leased acreage by production.

The company’s midcontinent division also drills horizontal Woodford Shale wells in the Ardmore Basin in southern Oklahoma and has more than 40,000 net acres of leases in the Cana Woodford play in the Anadarko Basin in western Oklahoma.

Royal Dutch Shell Plc

- *Land: Approximately 700,000 net acres*
- *Works the Mississippi Lime in Kansas*

Royal Dutch Shell Plc, through its Shell Gulf of Mexico Inc. arm, has established itself as one of the dominant players in the Mississippi Lime after SandRidge Exploration and Chesapeake Energy.

It started slowly with the acquisition of 30,000 net acres in Harper County and 5,000 net acres in Sumner County, both in Kansas. The company picked up some of its acreage from Woolsey Energy.

In addition to those counties, the company’s other Kansas properties lie in Barber, Kingman, Pratt, Reno, Rice, and Sedgwick counties. Shell also established an operating and land office in Harper County.

The company planned to have three rigs working the Mississippi Lime by year-end 2012.

It opened another office in Anthony, Kan., about 10 miles east of the first well it drilled into the Mississippi Lime in October 2011.

According to Kansas Geological Survey records, Shell completed 10 Mississippian wells in 2011 and produced 27,700 bbl of oil and 38.7 MMcf of natural gas. The following year, the company completed 23 wells and produced a cumulative 131,280 bbl of oil and 616.4 MMcf of gas.

By April 2013, Shell had completed 24 wells and produced a cumulative 174,180 bbl of oil and 829.48 MMcf of natural gas.

A December 2012 report by IHS Inc. described Shell’s plans for Rice County, Kan. The company planned to drill two horizontal wildcat wells to the Mississippian and one saltwater disposal well in the county. It planned to drill the wells on a single pad on the eastern flank of the Central Kansas Uplift, nearly 9 miles northwest of the town of Hutchinson.

The company scheduled the 19-2H Hedrick with a south lateral to a measured depth of 6,440 ft and a true vertical depth of 3,557 ft. The 19-1H Hedrick, about 55 ft to the west, will drill north from the same vertical depth to a measured depth of 7,532 ft.

Shell staked its first Rice County horizontal Mississippian test in September 2012, IHS said. No activity was reported at the site of the 30-1H Mizel, but that well is within 1.5 miles south and southwest of Pennsylvanian and Mississippian production in Bull Creek Field.

Most of the Mississippi Lime horizontal production in Kansas is 75 miles to 90 miles generally south of the proposed Shell wells. The main activity is along the Kansas-Oklahoma border.

Shell previously said it would spend some US \$6 billion developing shale prospects around the world in 2012, and most of that amount would go into the US and Canada.

Shell has heavily invested in the Eagle Ford and Pearsall shales in Texas, the Utica in Ohio, the Marcellus in Pennsylvania, and the Niobrara in Colorado and Wyoming.

The company also has shale operations in the Neuquén Basin of Argentina, the Western Canada

Sedimentary Basin, the Sichuan Basin in China, the Middle Magdalena Basin in Colombia, the Bashenov Shale in Russia, the Karoo Basin in South Africa, and the Dnieper-Donets Basin in the Ukraine.

Samson Resources Co.

- *Land: Less than 70,000 net acres*
- *Increasing Mississippi Lime activity*

Samson Resources Co., one of the top 20 US E&P companies, took an early look at Mississippi Lime potential on its Anadarko Basin properties, liked what it saw, and made plans to further delineate the play.

Company-wide, Samson holds interests in 7,640 gross (3,380 net) wells on nearly 3 million net acres of land in the Rocky Mountains, Midcontinent region, and East Texas.

The company has not publicly released information specific to the Mississippi Lime, but it lumps it together with other midcontinent operations, which include the Hogshooter, Cottage Grove, and



A SandRidge well site in the hot spot of the Mississippi Lime play makes little impact on the surrounding farming country. (Photo courtesy of SandRidge Energy Inc.)

Marmaton plays on 70,000 net acres in the Anadarko Basin. Two of its four rigs in the area are drilling to Marmaton targets.

By May 2013, the company completed two Mississippi Lime wells “which exceeded expectation” and planned to continue work in the play. Samson demands an internal rate of return of at least 20% on its active plays. In April 2013, it had one rig in the Mississippi Lime.

In May 2013, IHS Energy said Samson completed a horizontal well, the 3-4H Dietz, in the Mississippi Lime for 535 b/d of oil, 265 Mcf/d of gas, and 783 b/d of water after acidizing and a multistage frac treatment.

The Oakdale Field well was ¼-mile offset to the 2-4 Dietz horizontal well, the first horizontal Mississippian producer in Woods County. That well was completed by Samson Gas Production Co. in 1991 for 111 b/d of oil, 75 Mcf/d of gas, and 301 b/d of water after a small fracture treatment. The well, still operated by Samson, had produced a cumulative 109,300 bbl of oil and 655 MMcf of gas through September 2012.

SandRidge Energy Inc.

- *Land: 1.85 million net acres*
- *Top Mississippi Lime operator*

SandRidge Energy Inc. built its position in the Mississippi Lime in northern Oklahoma and western Kansas into the most active in the industry because, according to the company’s website, “We believe this area generates the highest rate of return for horizontal drilling in the US today.”

The company’s property will support more than 11,000 potential horizontal well locations at four wells per section, and SandRidge had 25 rigs at work in the play in late 2012 to prove its potential and raised that number to 31 in 1Q 2013. That is the highest rig count of any operator.

Since the Woodford Shale sources hydrocarbons for the Mississippi Lime, the company also has potential in that play, but it is not currently working that play.

In a June 2013 presentation, the company said its horizontal wells in the play cost an industry-low US \$3.1 million. It has completed three Mississippi Lime wells with 30-day initial potentials (IPs) of more than 1,000 boe/d. Currently, 90% of its drilling activity is in its focus area where it has predictable results and can high-grade the formation for higher

capital efficiency and rates of return.

It will dedicate \$1.1 billion, or 80% of its overall capex of \$1.45 billion for 2013, to the Mississippi Lime, and it will invest \$1.04 billion of that in its main Mississippi program in its focus areas to drill 425 gross (292 net) wells.

Another \$70 million will go into 44 gross (25 net) wells outside the focus areas.

It expects that investment to result in 60% growth in total Mississippi Lime production and 64% growth in Mississippi Lime oil production.

It produced 4.77 MMbbl of oil and 33 Bcf of gas, or 10.1 MMboe, from the formation in 2012 and expects to produce 7.6 MMbbl of oil and 51.3 Bcf of gas, or 16.2 MMboe, in 2013. The company plans to produce 44,400 boe/d during 2013.

Overall, its Mississippi Lime appraisal area covers a rough jelly bean-shaped area from Sherman and Thomas counties in Kansas to the northwest to Garfield and Kay counties in Oklahoma to the southeast, and SandRidge has some land in most of the counties within that area.

The company’s focus area lies within some 2.8 million total acres spanning 130 miles in Comanche, Barber, and Harper counties in Kansas and Woods, Alfalfa, and Grant counties in Oklahoma.

It used that focus area to produce an industry-leading 39,500 boe/d in 1Q 2013, up from 19,300 boe/d in 1Q 2012. The company has drilled an industry-leading 725 producing wells and 118 salt-water disposal wells.

Although oil makes up only 45% of average production, it accounts for 80% of Mississippi cash flow.

SandRidge’s confidence in the play shows in its drilling activity. It drilled 37 wells to the formation in 2010, 167 in 2011, and 396 in 2012, and expects 425 in 2013.

In its presentation, the company offered a look at its economics on a horizontal well with a 369,000 boe estimated ultimate recovery (EUR). That well would produce an oil EUR of 107,000 bbl of oil with a 30-day IP of 140 b/d and an initial decline of 76%.

The same well would yield a natural gas EUR of 1.387 Bcf, a 30-day gas IP of 790 Mcf/d, and an initial decline of 62%. And, the well would give up an EUR of 60 Mbbbl of NGLs with a 30-day IP of 34 b/d and a yield of 43.4 bbl/MMcf.

From that production, SandRidge expects an approximate 40% return at current New York Mercantile Exchange strip prices, a 38% return with \$90/bbl oil and \$4.50/MMBtu gas, and a 50% return with \$100 oil and \$5 gas.

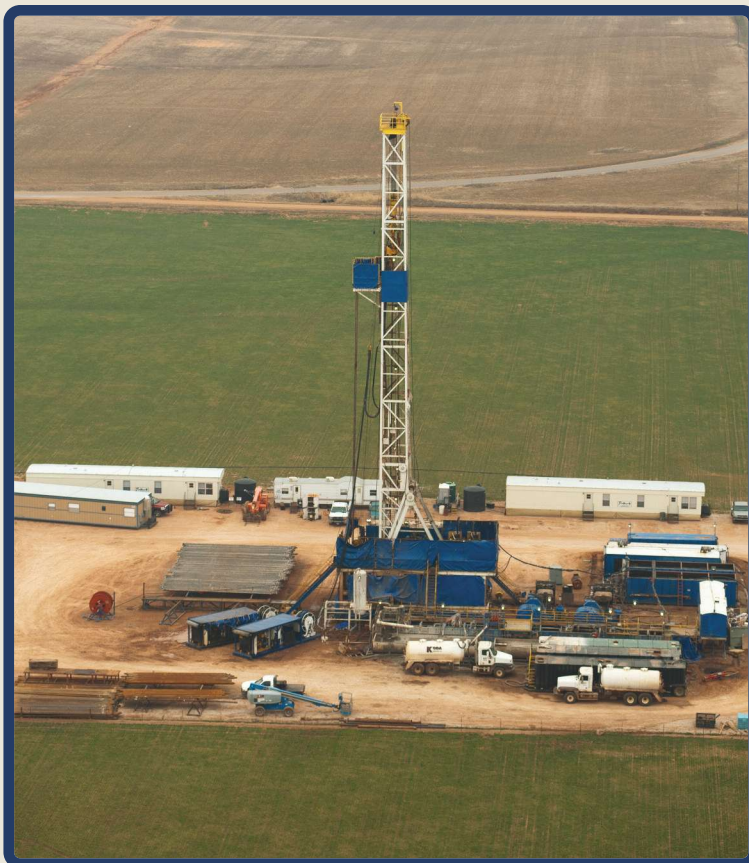
As the company increases production, experience and economies of scale also help it lower production costs. It decreased drilling and completion costs by \$500,000 between 1Q 2012 and the same quarter in 2013 to a low of \$3.1 million, and it targeted a cost of \$3 million by year-end 2013. At the same time, the company cut spud-to-spud cycle times by 16% to 22.7 days, including rig mobilization. It has a best-in-class spud-to-first-sales cycle time.

In addition to the SandRidge properties, the SandRidge Mississippian Trust I has 41,900 net acres in an area of mutual interest with the operating company. That land has 37 producing wells with a 90% interest for the trust, 123 development wells with a 50% interest, and 6.3 undrilled development wells.

Its SandRidge Mississippian Trust II covers 52,200 net acres in an area of mutual interest with an 80% interest in 67 producing wells, a 70% interest in 206 development wells, and 87.3 undrilled development wells.

A May 2013 report from IHS Inc. credited SandRidge with the highest initial oil production rate to that time for a Mississippian horizontal completion in Grant County, Okla. Its 4-30H Kretchmar 2705 flowed 1,315 b/d of oil, 2.8 MMcf/d of gas, and 1.06 Mb/d of water after acidizing and fracturing an interval from 5,300 ft to 9,265 ft.

That well wiped out the previous SandRidge record of 1,235 b/d of oil, 2.57 MMcf/d of gas, and 1,940 b/d of water on the 3-30H Noemi 2705, 1 mile west of the new record holder.



A drilling rig, one of 31 operated by SandRidge in the area, drills to the Mississippi Lime for the most active operator in the growing play. *(Photo courtesy of SandRidge Energy Inc.)*

Meanwhile, SandRidge management dealt with possible conflicts. TPG-Axon Capital, a 7% SandRidge shareholder, said that SandRidge CEO Tom Ward set up WCT Resources to benefit his children, according to a Rigzone special report.

SandRidge directors supported the management activities and said the TPG-Axon nominees did not have the necessary background to complement the company's operations.

In June 2013, SandRidge said Ward resigned his position with the company, taking a going-away award of \$5.35 million and 6.33 million shares of restricted stock. James Bennett, former CFO, took over as president and CEO of SandRidge, and an independent director would assume the position of nonexecutive chairman.

Bennett has been the company's CFO for the past two-and-a-half years and was named president in March 2013.

Sinopec Group

- *Land: 425,000 net acres*
- *Bought into Chesapeake Energy's position*

The Sinopec International Petroleum E&P arm of China's Sinopec Group bought a half interest in 850,000 acres of Chesapeake Energy land in the Mississippi Lime play for US \$1.02 billion in cash. The companies anticipated closing the agreement in 2Q 2013.

That transaction marked the highest proportion of equity investment ever made by a Chinese company in a US asset.

In many previous cases Chesapeake has taken in partners for some upfront cash and drilling carries. In this case, Sinopec put up 93% of the cash on signing.

Chesapeake will operate the properties, including leasing, drilling, completion, operations, and marketing for the venture.

Before signing the agreement, Chesapeake produced an average 24,000 boe/d in 4Q 2012 from a total of 140 MMboe of net proved reserves on the properties. That production averaged 45% oil and 9% NGL.

Some 425,000 of the acres acquired by Sinopec are undeveloped. The deal breaks down to \$2,400/acre, not counting production.

Slawson Exploration Co. Inc.

- *Land: More than 14,310 net acres*
- *Working Oklahoma acreage with independents*

Veteran shale explorer Slawson Exploration Co. Inc. aligned its exploration and drilling talents with partners with lands and funds to build a thriving business in the Mississippi Lime with prospects in the Woodford Shale source rock.

Although the privately held company releases little specific information about its activities, it has drilled more than 3,500 wells in 10 states. The company has drilled hundreds of lateral legs on horizontal wells to 14 formations in seven basins.

Specific information is available from Slawson's industry partners. One of those partners, Osage Exploration & Development, is a 30% joint venture (JV) partner on Mississippi Lime properties in Logan County, Okla. Slawson is the operator with a 45% interest, and US Energy holds the remaining 25%.

According to an Osage release, the Slawson-operated Davis Farms 2-5H Mississippi Lime well produced at 600 boe/d in May 2012.

After resolving "operational challenges," Slawson brought the Krittenbrink 2-36H well on line with a submersible pump at a rate of 250 boe/d.

The companies began running two drilling rigs on the project in September 2012 and planned to drill their first Woodford test in the first half of 2013.

In another JV formed in September 2012, Newkumet Exploration Inc. and Slawson also are developing leases in Logan County. The companies planned for horizontal Mississippian wells on two pad sites in 4Q 2012 with Slawson operating.

Sundance Energy Corp.

- *Land: 41,000 net acres*
- *Oklahoma represents largest resource land position*

Sundance Energy Corp. hangs success on a number of US resource plays, but its land position in the Mississippi Lime and Woodford Shale in Oklahoma is larger than all its other resource plays combined. Those other resource plays include the Niobrara, Eagle Ford, and Bakken/Three Forks.

The company logs 24.7 MMboe in proved, probable, and possible reserves.

For 2013, Sundance plans to drill between 8.2 and 13.5 net operated wells at a cost of US \$35.1 million and to participate in two or three nonoperated wells for \$10.7 million. For perspective, the company plans to drill 36.2 to 51.2 net wells for \$225.5 million in all of its prospect areas during 2013. The Mississippi Lime represents its second highest investment after the Eagle Ford.

The company's properties in Logan and Garfield counties in Oklahoma give it 100 net locations on 210-acre spacing in the Mississippi Lime or 150 net locations on 160-acre spacing.

Sundance said that a typical horizontal well costs between \$3.2 million and \$4.2 million to complete with an estimated ultimate recovery of 200,000 boe to 275,000 boe and an initial potential between 125 boe/d and 350 boe/d. That well offered a liquids content between 50% and 70%.

The company's working interests in wells ranged from 87% to 100% on operated wells. Its best well by 2Q

2013 was the Branson 17-4-23-1HM with a 24-hour initial potential (IP) of 652 boe/d, a 30-day IP of 476 boe/d, a 60-day IP of 376 boe/d, and a 90-day IP of 307 boe/d. That was the first horizontal Mississippian well drilled in that township in western Logan County.

Among nonoperated wells, the company had a 14% share of a Devon well that tested for 503 boe/d and a 20% interest in a Slawson Woodford well that tested for 251 boe/d.

Triple Diamond Energy Corp.

- *Land: Undisclosed*
- *Growing through preferred partner funds*

With a goal of becoming one of the largest independent producers in the country, Triple Diamond Energy Corp. focused on Oklahoma to drive its growth and the Mississippi Lime as one of the plays to fuel the growth engine.

The company finances its operations through preferred partner funds and plans to use its experi-

ence in Oklahoma for longer term expansion. To that end, it is evaluating sites in North and South Dakota, Wyoming, and Colorado.

The company completed the Hofmeister 21-1H well in late June 2012 in Kay County, Okla., flowing naturally at a high test rate.

The well produced more than 500 b/d of oil and more than 1 MMcf/d of gas in early testing.

Tug Hill Operating LLC

- *Land: More than 800,000 acres*
- *One of the largest private companies working the Mississippi Lime*

Tug Hill Operating LLC, an independent, privately held company with powerful backers, has worked itself into one of the largest landholders in the Mississippi Lime play in Kansas.

The company established itself in 2011, although it had been conducting operations before that time, and now has operations in more than 18 states and

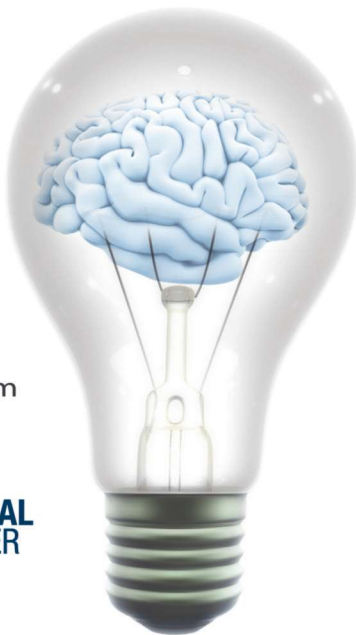
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Partners in the company include Chief Capital Oil & Gas, PEC Energy, Arad Energy, and BP Capital Management, led by Boone Pickens.

Early in 2010, a consortium of partners led by Tug Hill started picking up leases in Kansas, both as Tug Hill Kansas and as Cheyenne Exploration. It now has more than 800,000 acres of land prospective for the Mississippi Lime and continues to lease property.

Tug Hill Operating is the active manager of the Cheyenne properties in Kansas and drilled its first well in early 2012.

Existing properties run from Sheridan, Gove, and Trego counties in the northwest to Clark, Comanche, Barber, Harper, Sumner, and Cowley counties along the Oklahoma border, to Elk and Greenwood counties in the east.

The company's 1-7H Bearden Trust established Annamae Northeast Field in Comanche County.

Production and potential production is high enough that Tug Hill dedicated production from some 600,000 acres of its leases to the new JP Energy Development pipeline.

In a late 2012 report, Independent Oil & Gas Service said Tug Hill Operating had completed the 1-7H Bearden Trust and that well was the first of 28 planned horizontal wells. The company completed the well for a gas-lift potential of 43 b/d of oil, 1.03 MMcf/d of gas, and 1,933 b/d of water from perforations between 5,550 ft and 9,595 ft.

Unit Corp.

- *Land: 110,000 net acres*
- *Mississippi Lime is one of four key focus areas*

Unit Corp. wants a 15% risk-adjusted rate of return on its new wells, and it carefully chose its key plays to meet that goal.

The company chose the Granite Wash and Marmaton in the Panhandle area of Texas, the Wilcox in south Texas, and the Mississippi Lime in Kansas. Those choices also follow the liquids-focused strategy the company started in 2008.

In a June 2013 presentation, Unit said 5% of its Mississippian land is held by production, and it has approximately 300 locations in the play on 320-acre spacing.

The company's average well depth is 8,000 ft, including a 4,000-ft lateral, and the pay zone is 50 ft thick vertically. Unit estimated reserves at 125,000 boe to 180,000 boe per well with 92% liquids.

That combination offers the company a 40% to 66% rate of return with US \$90/bbl of oil, \$30/bbl of NGL, and \$3.25/MMBtu of gas with a drilling and completion cost of \$3 million.

The company drilled four Mississippi Lime wells in 2012, completing the first in May and the second in December. Its average 30-day initial potential was 240 boe/d with 89% liquids.

The company planned three more wells in 1Q 2013 but will hold off on completion until a pipeline is completed in 3Q. At that point, Unit will resume drilling with one rig assigned to the play and will add a second rig in 4Q.

The company plans first sales on 13 gross wells by year-end 2013 after spending a net \$40 million on the play.

The company's midstream operations supplement its drilling. It already has some 875,000 net acres of wells in the Mississippi Lime area dedicated to its seven processing plants. Those plants have a processing capacity of 168 MMcf/d of gas. It also includes 477 miles of gathering line.

Unit plans to enhance its midstream operations with a \$34.5 million capital budget in 2013.

US Energy Development Corp.

- *Land: 9,560 net acres*
- *Part of a Mississippi Lime JV*

US Energy Development Corp., cited by Inc. Magazine as one of the nation's fastest growing private companies in each of the past four years, brought expertise from the Marcellus Shale to Logan County, Okla.

The company is a 30% joint venture (JV) partner with Slawson Exploration and Osage Exploration & Development in the Mississippi Lime.

Since 2003, the company has invested more than US \$700 million and currently claims more than \$1 billion in oil and gas reserves and assets. It has participated in more than 3,000 wells in 12 states and operates 2,000 wells.

US Energy Development is one of the top 50 independent oil and gas drillers in the US and one of the largest operators in New York and Pennsylvania. The company has expanded its operations

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from the Marcellus into the Bakken, Barnett, Wolfberry, Eagle Ford, Hunton, and Mississippi. The Mississippi Lime is one of the smaller holdings in its 300,000-plus acres of leases.

Among the JV's recent wells, Osage's Davis Farms 2-5H was producing approximately 600 boe/d with 84% to 90% oil in late 2012.

The partners ran two rigs in the play in September 2012 and planned to drill their first Woodford well in the first half of 2013.

WCT Resources LLC

- *Land: 475,000 net acres*
- *Close ties to SandRidge Energy top executive*

Operating quietly, WCT Resources LLC established itself as one of the top acreage holders in the Mississippi Lime play, but the company recently found itself involved in controversy.

The company's properties, in many cases, lie next to properties controlled by SandRidge. Trusts set up by Tom Ward, former president and CEO of SandRidge, for his children own WCT, according to TPG-Axon Capital, a 7% shareholder in SandRidge. Those properties make the privately held company the fifth biggest landholder in the play following SandRidge, Chesapeake, Royal Dutch Shell, and Devon Energy.

TPG-Axon, in February 2013, put up its own proposed board of directors to replace existing SandRidge directors claiming the land position of WCT represented a conflict of interest for Ward and that the SandRidge directors should not have allowed him to set up those trusts.

Since SandRidge holds some 1.85 million acres of land in the play, the directors said, it would be difficult for any operator not to hold land adjacent to SandRidge land. They also said the TPG-Axon board nominees were not qualified to run the company most efficiently.

At least one analyst said he did not see a conflict, since SandRidge acquired as much land as it could afford to buy and there was no indication that the WCT purchases damaged SandRidge shareholders.

Following the accusations of conflicts, SandRidge allowed TPG-Axon to put four of its nominees on the board of directors and the board hired an independent firm to determine whether Ward should be terminated.

That investigation was scheduled for completion on June 15, and the directors were scheduled to make their decision about letting Ward go by the end of the month.

Less than a week after the completion of the investigation, SandRidge named James Bennett president and CEO, and an independent director took over as interim nonexecutive chairman. The company also said Ward is leaving the company.

The SandRidge board's audit committee, following an independent investigation by Mayer Brown LLP, attorneys, said nonemployee members of the board unanimously found the investigation did not merit termination of Ward for cause.

That determination allows Ward to get a severance package that includes 6.33 million shares of restricted stock and US \$53.5 million in cash.

The leadership fracas in SandRidge should not have an impact on WCT.

Woolsey Energy Corp.

- *Land: 80,000 net acres*
- *Worked southern Kansas for more than 30 years*

Wayne Woolsey, president and CEO of Woolsey Energy Corp., earned a place in the Kansas Oil and Gas Museum Foundation Hall of Fame, largely because of his contributions to and confidence in the Kansas oil patch.

Woolsey formed one of the state's largest domestic oil and gas companies with a focus in southern Kansas, as he built a position of some 280,000 net acres. He sold most of that acreage to Royal Dutch Shell as the major company sought a way to enter the Mississippi Lime play.

Before the Shell deal, Woolsey's was one of the first companies in Kansas to drill horizontal wells and use multistage fracturing.

Woolsey still drills on his land in Barber County, and in early 2013 he ran one rig drilling vertical wells and another drilling horizontal wells.

According to a December 2012 article in the Kansas City Star, Woolsey drilled three failures in the Mississippi Lime before the fourth came in at 30 boe/hr. It later dropped off to 350 b/d to 400 b/d of oil and 1 MMcf/d of gas.

Woolsey's fifth well could pay for itself in two years, and the sixth well looked good, according to an interview with him. ■

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A New-Age Boom in an Old-Age Play

Drilling and completing the complex Mississippi Lime and Woodford plays require the latest technologies and involve numerous challenges.

By Glenn R. Meyers
Contributing Editor

Many people once considered that the vast formations of the Midcontinent belonged to old chapters in the history books of oil and gas plays. That notion was “once upon a time,” though. Today, a new breed of hydrocarbon booms are taking place on some considerably different plays, from the Mississippi Lime to the Cana Woodford and the Woodford SCOOP (South Central Oklahoma Oil Province), thanks in part to the introduction of horizontal drilling and advanced fracturing methods.

Starting with the Mississippi Lime, about six months ago, Kansas political leaders were projecting what might turn out to become an oil boom rebirth. Their reasoning was based on the belief that a treasure trove of hydrocarbon riches was ready to be gathered from the oil fields of the Mississippi Lime.

This massive formation, created 330 million years ago, is a limestone layer stretching approximately 17 million acres in northern Oklahoma, much of Kansas, and a small corner of Nebraska. In Kansas, the limestone is up to 1,700 ft thick at a depth of roughly 3,500 ft to 6,000 ft.

Various well metrics showed appealing economics to potential players, coupled with reduced production costs. This has led to increased rig count and growing interest in the region.

However, there are plenty of challenges, ranging from water management issues to basic water availability. Infrastructure issues also exist, which include everything from calls for various pipeline networks to access to electricity, if it is available. Add to this list the broad-based goal of reducing drilling costs.

Operators and service companies are traversing a learning curve on the best methods of drilling and recovering assets from the Mississippi Lime and the varied parts of the Woodford. One thing is clear, as most people will affirm, there is no “one size fits all” solution to be found.

Continental Resources operates in the SCOOP but not in the Mississippi Lime. Some of its operations take place not far from the Healdton Field, which began production 100 years ago. As Rick Muncrief, senior vice president of operations, puts it, “A century later, we’re back applying new technologies in old oil fields and having some real nice results.”

While the availability of a solid infrastructure is not a given in many Mississippi Lime locations, it is more than likely in place for most of the Woodford, Muncrief said.

Indeed, the Midcontinent can vary significantly from southern Oklahoma, westward near the Colorado border, and northward into Kansas. Michael Samuelson, Schlumberger senior production stimulation engineer, provided perspective about the complex Mississippi Lime play spread over two states. “One of the biggest challenges in this play because of the extensive variability – it is a naturally fractured carbonate – is to try to pull all of the reservoir information together into one place to make the best completion and stimulation decisions,” Samuelson said.

There is sparse homogeneity in the “midcon” formations, added Luke Kuwertz, eastern division operations manager for PathFinder, a Schlumberger

company. “One thing I’ve noticed is you can drill a well, move a few miles away, and it’s almost like being in a different country.”

“That’s kind of the nature of the Mississippi,” added Ken Lake, Baker Hughes sales manager for pressure pumping. “You can drill an offset well, everything looks the same, but they respond completely different.”

Even though there is little play homogeneity, cost-efficiency remains a prevalent theme for all. Like the Bakken to the north, a quick glance reveals a familiar increase in pad drilling – anything capable of killing the proverbial “two birds with one stone.” A range of new or advanced tools and technologies are being used in the Midcontinent by service companies and operators, including Continental Resources, now operating a SCOOP water

A range of new or advanced tools and technologies are being used in the Midcontinent...

recycling plant (the Garvin County Water Recycling Facility) with more planned; Baker Hughes’ friction reducer technologies (ClearStar guar alternative hydraulic fracturing system) and artificial lifts (Centrilift FLEX ESP system); a QA/QC process from Packers Plus; pipeline and process applications from Halliburton (the ClearStream service and Clean-Wave frac flowback system); Schlumberger’s horizontal surface pump system (REDA HPS G3), software platform (Petrel E&P), and stimulation design software (Mangrove).

Infill drilling

According to the Kansas Geological Survey (KGS), renewed interest in the Mississippi Lime in southern Kansas emerged in 2010, even though production from vertical wells continued declining.

Horizontal wells, which can more precisely target potential pay zones, have rekindled widespread activity across the entire reaches of the Midcontinent.

Samuelson said for larger operators there is a fair amount of infill drilling currently going on. “As you get into that level of development in a play like this, it becomes important to help determine

how much of an impact the infill drilling is having in regards to completion as well as production impact,” he said.

Understanding the area around a specific well is but one of the criteria for developing a completion and stimulation design. For Samuelson, it is critical “to make sure that we’re best characterizing the multiple layers that exist in the play and getting a very good idea of where we think the fracture stimulation is located, and ultimately, coupling that with the highest reservoir quality.”

Among other hurdles, reports the KGS, poor drainage in hydrocarbon production of Mississippian limestone reservoirs has long been an obstacle in oilfield development here. Rocks in the play might often have good porosity due to numerous and large pores, yet they have poor permeability. This results in isolated or poorly connected pores and poor hydrocarbon recovery with traditional methods.

Drilling efficiency continues to be an important oilfield consideration. “The fact of the matter is everybody wants to drill these wells as efficiently as possible,” said PathFinder’s Kuwertz. “If you’re having to trip for an MWD or a motor, that removes a lot of your savings very early on.”

Recycling water gains favor

Usable and disposable water places high on most lists when it comes to drilling and completion challenges. “As everybody knows, fresh water is a scarce resource,” said Lake, from Baker Hughes. “So the first problem is finding water, and enough of it, especially in drought years. It takes a lot of water to treat and stimulate Mississippi Lime wells. Now you’re seeing a lot of people going to recycled and refined water, and using produced water as a water source for treatment,” he said.

Today Continental Resources operates its own water recycling plant in Lindsay, Okla. The Garvin County Water Recycling Facility helps with pre-planning of work. Muncrief added that Continental Resources will probably have more recycling facilities as it moves forward, “especially as we go through the first phase, which would be drilling to hold our acreage. Then, once you begin full-scale development, recycling becomes a lot easier,” he said. “But even with that we’re trying to get ahead and do as

much recycling as we can. There are some economic benefits, but the main benefit is it's just the right thing to do."

Frac flowback, produced water treatment

Halliburton's H2OForward service also allows customers to negate the use of fresh water through the recycling of produced and flowback water. Key products within H2OForward are CleanWave frac flowback and produced water treatment, CleanStream service, and High TDS (totally dissolved solids) frac fluids. For every barrel of oil produced, approximately three barrels of water are produced. And, between 10% and 40% of the fluid volume used in fracturing operations flows back during the subsequent cleanup.

The CleanWave service features a mobile electrocoagulation component that uses electricity to treat flowback and produced water at rates of up to 26,000 bbl/day while using minimal power.

The CleanWave system destabilizes and coagulates the suspended colloidal matter in water. Heavier coagulants sink to the bottom, creating a clean brine. Halliburton's approach is to treat the water enough so that productive wells are made but not to over treat the water as that only adds costs and creates large waste streams.

Thus, Halliburton has developed high TDS slick-water and X link frac systems that enable operators to use their available waste streams at a very low price point to make stable completion fluids. With



The CleanWave service features a mobile electrocoagulation component that uses electricity to treat flowback and produced water at rates of up to 26,000 b/d while using minimal power. *(Image courtesy of Halliburton)*

a scarcity of fresh water, especially in times of drought like last year, the interest for using produced or recycled water has grown significantly.

Managing bacteria with ultraviolet light

Halliburton's CleanStream service uses ultraviolet light to disinfect all of the water used in the completion process. This technology, which has been proven to control microbial populations in municipal drinking water, hospitals, and other industries, is applied directly in front of the blender to control microbial populations and ensure reservoir and fluid integrity occurs. Halliburton has treated more than 1 billion gal of water with CleanStream service and removed more than 250,000 gal of biocide from the process.

Ultraviolet light is an alternative to traditional chemical methods of controlling bacteria. The disinfection process can be used either discretely or in conjunction with reduced concentrations of traditional chemical treatments.

Bacteria have the potential to cause production damage to formations as well as risk fluid integrity for frac fluids. One anaerobic form of bacteria is sulfate-reducing bacteria. These particular bacteria reduce sulfate ion to sulfide, which can lead to the accelerated corrosion of metal components through the formation of hydrogen sulfide (H_2S). In addition to its potential health hazards, even in small concentrations, transport and processing of H_2S -containing fluids through pipelines and facilities not specifically designed to be H_2S -resistant can lead to excessive corrosion or even catastrophic failure.

Disinfection of water occurs with a single pass through the CleanStream service unit at rates up to 19 m³/min (120 bbl/min). It also eliminates the issues associated with the handling of biocides and minimizes the need to manage chemical-containing fluids following commissioning operations.

Water cuts vary in the Mississippi Lime

Great amounts of water are typically produced in the large portions of the Mississippi Lime, although the totals vary from southern Oklahoma in the Kingfisher and Garfield area, which can contain fairly high oil cuts (30+%). But this is atypical for a larger extent of the Mississippi Lime, said Samuelson. "Certainly, when you get up into northern Okla-

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homa and southern Kansas by and large, 5% to 10% oil cuts are much more common. The big challenge farther to the north and west in Kansas has been that, unfortunately, those wells may produce predominantly water – you can have almost a 99% water cut,” Samuelson said. With this in mind, it is important to ensure that players characterize the rock to the point of understanding what is being targeted regarding oil content and that laterals are properly targeted.

According to Samuelson, the Mississippi Lime geology consists of multiple productive reservoir facies (cherts, limestones, dolomites) in highly variable depositional environments.

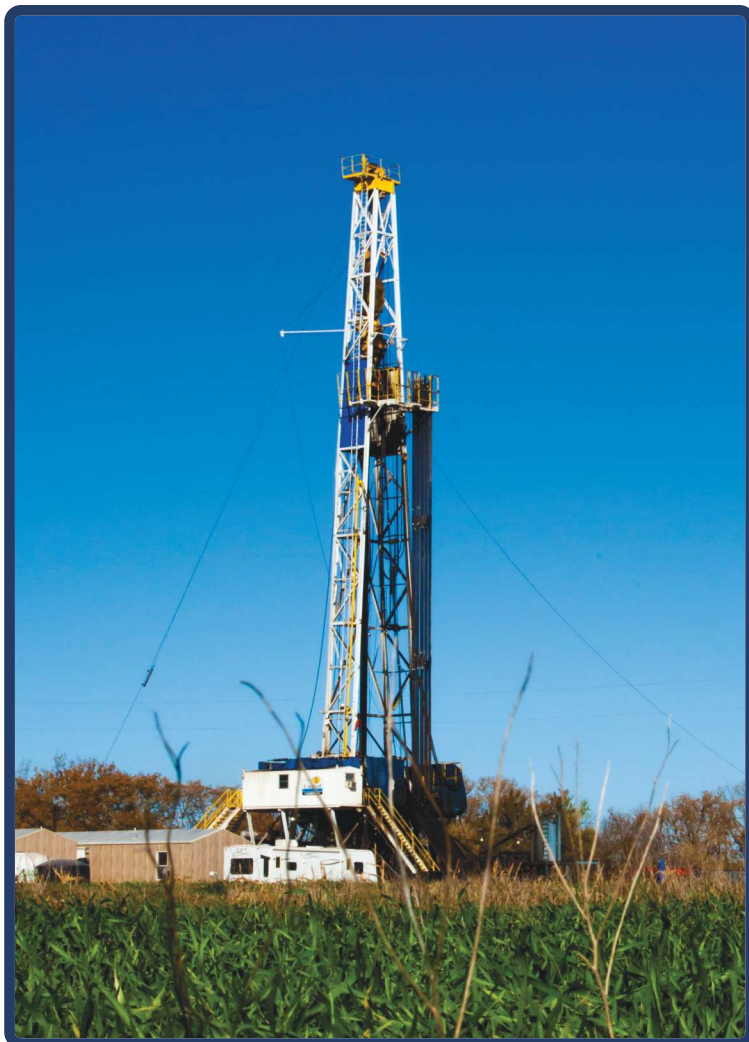
“It’s a matter of adequate characterization to try to minimize your water [and] maximize your oil,” he added.

Drilling efficiencies remain high on the operator list

Continental Resources has targeted some improvements in its bit selection that are creating better penetration rates, according to the company. “When that drives you to less days on the well, it helps from a cost standpoint,” said Continental’s Muncrief.

He added his company is seeing quite a bit of competition between service providers for stimulation work. This provides a significant positive on the cost side of the equation, he said. “We think we’re getting very effective at completions, so it’s really the best of both worlds.”

Continental Resources uses the plug and perf (PNP) method for completions, cementing its casing strings. According to Muncrief, the company’s frac designs have evolved over the past few years, starting back in the Arkoma Woodford, going to the northwest Cana area, and evident today in the



A drilling rig on a Continental Resources well site in the SCOOP play. *(Image courtesy of Continental Resources)*

SCOOP area. A typical job for one lateral is a 14-stage endeavor pumping approximately 3½ million lbs using resin-coated sand for proppant.

Average lateral lengths are running from 4,500 ft to 5,000 ft. “However, we are going to be drilling longer laterals of up to 10,000 ft,” Muncrief said, citing efficiency and economics as drivers.

Starting with a correct foundation

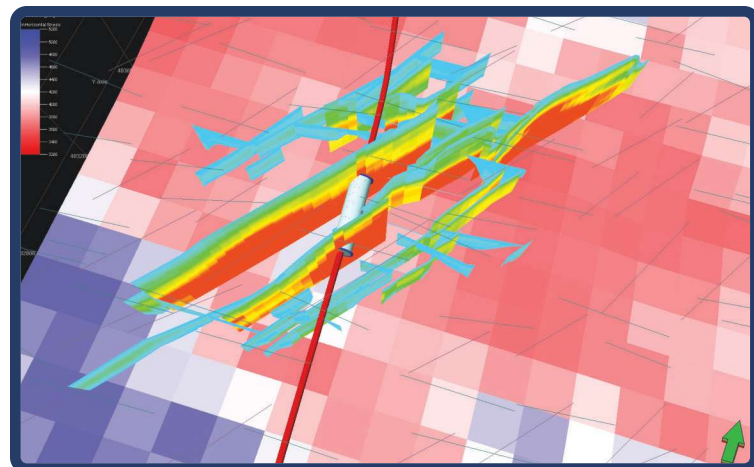
PathFinder’s Kuwertz is steadfast about the need for building the correct foundation, with reliable MWD and building on top of that with integrated solutions. “Obviously our clients want to drill the well and get out of the hole as fast as possible,” he said. “To do this, there are a number of challenges within the Midcon,

especially within southern Oklahoma; we see a lot of vertical control issues. Drilling challenges may involve dipping formation beds anywhere from 20° to 60°.”

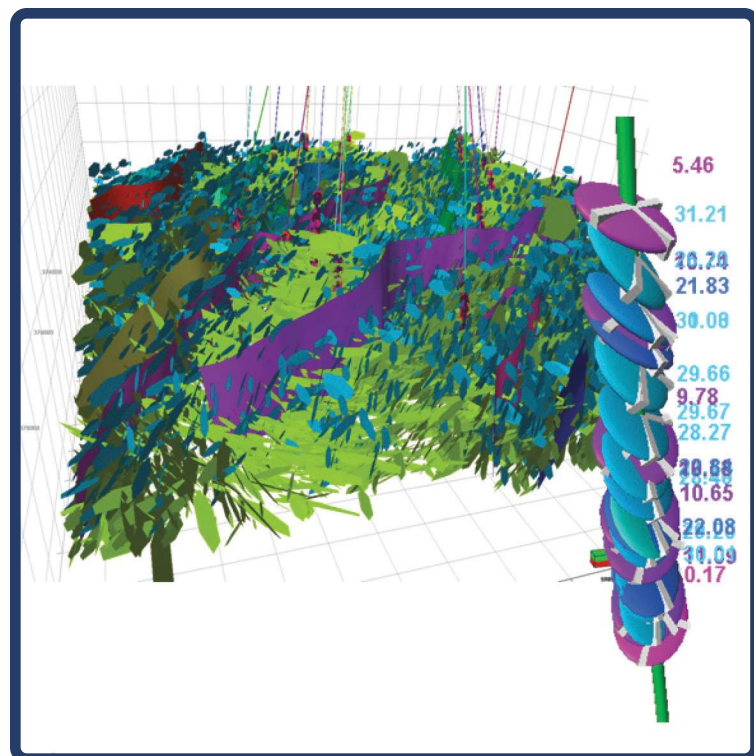
Steerable system enhances ROP

Kuwertz uses the PathFinder PowerV vertical drilling system to maintain well trajectory as close underneath as possible. “Then they can drill down

to the casing point as fast as possible,” he said. “Once you’ve got a nice, clean vertical well, then you can use the PowerDrive Archer high-build rate rotary steerable system to optimize your ROP down through the curve.” He added that his PathFinder team can drill 4,800 ft to 100,000 ft laterals in about half the time as it takes to move the motor. “This has made a big impact, especially in the Cana Woodford and the Mississippian,” he said.



Complex hydraulic fracture with stress values in the background. The fractures are showing fracture width. (Images courtesy of Schlumberger)



Discrete Fracture Network illustrates natural fissures.

Demand for solid characterization

When asked about significant characterization issues in the Mississippi Lime, Samuelson listed porosity and water saturation as key information he tries to couple with lithology and minimum horizontal stress. “These are all critical to determining the quality of what you’re into, trying to minimize the connection into higher water zones,” Samuelson said. “Trying to minimize to some extent; you’re not going to eliminate it. You’re just trying to keep those ratios economic.”

Natural fracture characterization makes up part of this completion amalgam. Samuelson believes image log data is critical in the Mississippi Lime to best characterize the natural fracturing, because that is what can help connect to the reservoir rock. His conclusions? “If you’ve got a high density of natural fractures in a highly hydrocarbon-saturated zone, you want to try and target that,” he said.

Having good lateral information is key

According to Samuelson, because there is so much horizontal development taking place that calls for multistage transverse fracturing, accurately placing fractures along

the laterals depends on having the most accurate information.

The Petrel E&P software platform was developed to help geophysicists, geologists, and reservoir engineers in developing collaborative workflows to increase reservoir performance.

The Mangrove software has been designed to link reservoir characterization, stimulation, and production to optimize completion designs in conventional and unconventional reservoirs. The software models both planar and nonplanar complex fractures and allows integration using a single seismic-to-stimulation platform.

Samuelson believes these platforms help considerably in the drive to put the most cost-effective procedures in place, targeting the best zones. Regarding the completion adviser, which is part of the Mangrove platform he said, “We’re using the lateral log information to determine what staging, what perf cluster, [and] what positioning is needed,” he said. “That is a big part of trying to make sure that we’re targeting the best reservoir with the stimulation, and not overstimulating or understimulating, but making sure that we’re applying the fracturing to the best rock.”

Fracturing products emerge

Less than a year ago, Reuters reported oil and gas companies were racing to find a new substitute for India’s guar bean, a key ingredient used in hydraulic fracturing.

The extract from guar produces a gel in fracturing fluid that delivers proppant to hold open cracks in shale when fractured. Baker Hughes, among others, set out to develop a guar replacement, or friction-reducer technologies. “Guar gel became a scarce commodity last year, with guar bean prices in

India,” said Baker Hughes’ Lake. “So Baker Hughes developed a high-molecular-weight polymer as a guar replacement.” He added that the company has combined this new polymer with delayed crosslinking chemistry and breaker technology.

That replacement product, the ClearStar system, was released in July. “ClearStar is going to be a premium fracturing fluid that helps deliver superior regained conductivity, which is closely tied to production,” said Scott Nelson, Baker Hughes director, US land pressure pumping engineering.

The Baker Hughes ClearStar guar-alternative



Baker Hughes’ ClearStar fracturing fluid system was designed to improve reservoir performance. (Images courtesy of Baker Hughes)



The ClearStar system uses a premium cellulose-based polymer that leaves behind little, if any, residue in the fracture.

hydraulic fracturing fluid system uses a premium cellulose-based polymer and specialized breaker technology. With customized delay times based on lateral length and pump rates, ClearStar fluids enhance sand transport through the wellbore and ensure proper placement within the fractures.

The fluid then breaks cleanly and completely, minimizing the risk of formation or proppant pack damage. Its controllable viscosity performs well at varying downhole pressures, across a broad range of temperatures –150°F (66°C) to 275°F (135°C) – in both conventional and unconventional reservoirs.

In the laboratory, ClearStar fluids deliver high regained permeability (94% to 100%). In the field, wells stimulated using these fluids showed faster cleanup compared to offsets treated with conventional systems. On these wells, fluid load recoveries averaged approximately 35% within five days as compared to recoveries ranging from 15% to 20% for the offsets.

This alternative hydraulic fracturing fluid system is considered safe and reliable when using all common fracture fluid additives. In addition to boosting production, the ClearStar system improves economic performance because its high molecular weight requires less polymer, resulting in improved friction properties, thus minimizing horsepower demands.

Case study: the ClearStar system

Recently, an operator in northern Colorado tested ClearStar against a premium derivative guar fluid to identify which system offered the best operational and production performance.

The systems were tested on a pad in the central Wattenberg Field. Pump schedules and treated zones were held constant for all wells on the pad, so the fluid system was the only change.

The J Sand, Codell, and Niobrara formations of the Wattenberg Field were treated in each well, and all wells were flowed back similarly. Treatment pressures were higher than normal because of a higher polymer loading and nondelayed crosslinker in the old system. All wells in the dataset flowed up the casing for more than 60 days without assistance.

Fluid recovery after the fracturing operation was better in the ClearStar wells than in those with the premium guar system. On average, the ClearStar

wells produced 10% more cumulative oil after 300 days of production, yielding a very healthy ROI, according to Baker Hughes.

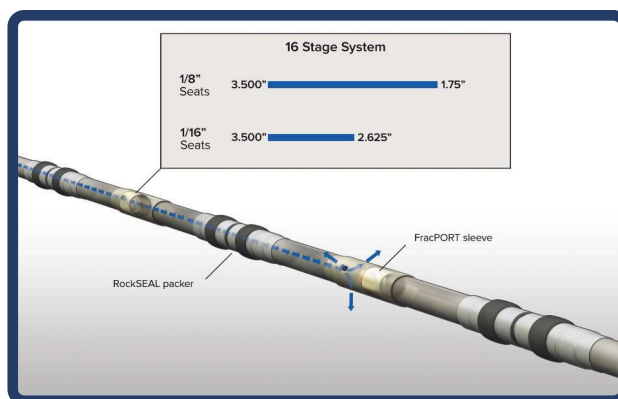
Alternative completion methods fit many new plays

Packers Plus brings a different approach to completions in the Mississippi Lime, said D.J. Snyder, the company's sales representative for the Oklahoma region. The Packers Plus method calls for continuous pumping, dropping balls to isolated stages while continuously conducting fracturing operations. "It's extremely efficient," said Snyder.

Not all operators are comfortable with such a technology, preferring to continue with PNP – a technology that has existed for some 60 years. "Some operators just love it, and they go with it, and that's all they use," he said, "whereas other operators – it's a little bit harder changing their thought process."

Like the palette of formations below, operators come with different expectation for their completions. "We have operators that have been looking at completing wells at 80 bbl/min, and then we have companies that look at 120 bbl/min," said Snyder. "And how do we together design and engineer the system? What does our pre-job planning look like? And is that system design appropriate for the application?"

Snyder points out that Packers Plus has recently received some good feedback involving 20- and 22-stage jobs.



Using 1/16-in. FracPORT sleeve seat increments allows the Packers Plus StackFRAC system to be designed with larger ball seat sizes, reducing friction and enabling more stages to be run with higher treating rates. *(Image courtesy of Packers Plus)*

Case study: the StackFRAC HD system

The Mississippian Formation has been developed using vertical drilling for years, but the majority of development today has been focused on horizontal wells, either through new-drills or by re-entering existing vertical wells.

Packers Plus has been successfully completing wells in the Mississippian Formation since 2007, working with operators to provide completion technology advancements to better exploit their reserves. Operators stimulate these wells at very high rates, up to 120 bpm. In addition to boosting their rates, operators have also been increasing the total stage count in their wells, according to Packer Plus. As such, effective drilling and completion strategies must maximize production.

The StackFRAC system, an openhole, multistage ball-drop completion system, uses hydraulically set, mechanical RockSEAL packers to isolate sections of the wellbore and FracPORT sleeves to create openings in between the packers for fracture treatment.

To allow for more stages, the StackFRAC HD system was used, doubling the stage capability of the original system. To mitigate concerns regarding the effect of pumping proppant at high rates, all FracPORT ball seats are made with a resistant material. The FracPORT sleeves, in combination with a field-proven suite of actuation balls, allowed operators to stimulate their wells faster and more efficiently.

One operator working in the Mississippian used a 16-stage StackFRAC HD system with 1/8-in. ball seat increments to complete an openhole horizontal well. Prior to installation, a reamer was used to prepare the wellbore for the completion string, gauging the wellbore to ensure the system would reach the desired depth. The system was successfully installed with the SF Liner Hanger Packer set in the lateral at 90°, just above the intermediate shoe, to allow production equipment to be set deeper in the well.

The RockSEAL packers were spaced out on the liner with an average stage length of 250 ft. During the fracture stimulation, 15% HCl was pumped followed by a slickwater fracture treatment using 30/50 white and 16/30 resin-coated proppants. The stimulation was pumped at an average 115 bpm to a maximum of 123 bpm with an average total proppant/stage of 200,000 lb.

As of June 2013, 34 StackFRAC systems had been

run in the Mississippian throughout Oklahoma and Kansas. The wells were completed with 12 to 20 stages. All have been successfully completed with no operational issues. Moving forward, the operator will be using 1/16-in. seat increments in higher density wells. This allows the systems to be designed with larger ball seat sizes, reducing friction and enabling more stages to be run with higher treating rates.

Pumping efficiency

As Ken Lake from Baker Hughes puts it, from a pressure pumping perspective in the Cana Woodford, some of the leading cost-effective measures taking place include multiple wells per pad. “You’re seeing a lot of operators drilling more than one well per pad – three, four, sometimes five wells per pad,” he said. As a result, a frac fleet may pump multiple wells without leaving the site. “You develop some efficiencies by eliminating downtime and moving from one well to the next. Sometimes you’ll never move a fleet; you’ll just run lines from each wellhead, so you’ll just basically sit in one place, get all the required sand, acid, and water delivered to one central location so you can complete multiple wells from one location,” he said.

On the subject of pumps, Lake said most of the fracturing pumps Baker Hughes uses now are 5-in. or 6-in. plungers. “You get a lot higher rate and move more volume with less equipment,” he said. Bottom line, the company is trying to get less equipment on location, creating a smaller footprint while delivering the same exceptional treatment, according to Lake.

Electrical submersible pumps

Baker Hughes has installed more than 1,000 electrical submersible pumps (ESP) since 2007. One ESP especially designed to handle high gas and increase production at lower pump intake pressure is the Baker Hughes 400FLEX10 pump.

Case study: Increasing ESP production

A Bakken operator’s well in North Dakota experienced too much downtime and lost production using an existing ESP system. The ESP system also maintained a high fluid level, causing undesirable drawdown and productivity.

Using Baker Hughes’ artificial lift systems, the oper-

ator chose an ESP system that could operate through the gas-related shutdowns, while increasing the drawdown and production rate.

Baker Hughes' engineers installed a 400FLEX10 pump designed to improve gas handling and increase ESP uptime. For this application, this ESP system included a Centrilift Multiphase Pump (MVP), which has been designed to handle excessive free gas and gas slug-ging. The 400FLEX10 pump worked along with the MVP pump and handled more free gas for improved fluid level drawdown.

After installation of the FLEX ESP system, oil production increased 42%, according to Baker Hughes. Proprietary variable speed drive software was another key technology that assisted with ESP system ride-through during gas slugs and kept the system continuously operational.

Using a coordinate measuring machine for QA/QC

Using a coordinate measuring machine (CMM), Packers Plus has a fully integrated quality assurance and quality control (QA/QC) process that starts at the design stage and follows each tool through manufacturing, assembly, testing, shipping, and installation.

"We QA/QC 100% of our balls, 100% of our ball seats," Snyder said. "I think that's how we're able to do what we're doing today." The CMM is an optical sensor used in the design, development, and manufacture of tools and systems.

Snyder also elaborated on the Packers Plus manufacturing group. "We have sensors that look for seat angles, for concentricity. They'll look for squareness and are able to look at 1/10,000 in. (1/20 the size of a human hair). It's what NASA used to QA/QC the Mars Rover," Snyder said.

The Zeiss CMM produces maximum precision during high-speed scanning. Its multipoint measuring capability of the machine allows it to adjust to the distinct dimensions of every tool stored in the electronic database and provides a clear picture of each tool in a 3-D environment.



The Baker Hughes Centrilift FLEX series electrical submersible pumps (ESP) are designed for wide operating ranges. *(Image courtesy of Baker Hughes)*

2-D bar coding

As part of overall QA/QC standards, all Packers Plus tools and individual components receive a 2-D bar code. All of the tool and component information, including Raw Material Certificates, production order and testing/torquing data, are tracked via these 2-D bar codes. This information is captured electronically through an internal wireless data-logging system. The 2-D bar code system also allows for tracking of all relevant information on each tool assembly, including any ancillary items that have been made up to the tool, such as pup joints, collars, and centralizers.

All Packers Plus tools are labeled with a serial number, providing the ability to track from assembly through installation down to the position it was run in the well.

Infrastructure issues surface

For some companies setting up operations in Kansas and Oklahoma, the required electric, transportation, and pipeline infrastructure is nonexistent. According to Baker Hughes' Lake, some green operators are basically building their own pipeline structure as they go, because there is nothing in place. "The electric grids have similar challenges," Lake said. "There's really no electricity to operate submersible pumps or disposal pumps, so they have to build as they go."

In fact, one operator found it necessary to hire an electrical engineer in order to run an electric grid.

"They [the operator] said they never dreamed 10 years ago of having an electrical engineer on staff," said Lake. "That's what's required these days to manage their own electricity and everything."

Elsewhere in Oklahoma, most of the infrastructure is already in place. Companies close to Cushing benefit from existing transportation networks.

Infrastructure continues to improve in the Mississippi Lime formation with numerous expansion projects taking place.

Even so, Midcontinent plays, such as the Mississippi Lime, offer an appealing amount of existing oil and natural gas infrastructure and assets – all which can drive efficiency.

Lake elaborated on the importance of efficiency today in the oilfield: “For us, we prefer 24-hour round-the-clock operations as opposed to what’s considered daylight operations, because operators have to shut down and start up again in the morning. So, they lose eight, ten, twelve hours of productive time.” Lake also added that, “two of the most important things for us that drive efficiency are to implement round-the-clock operations and

our FracPoint multistage fracturing system.”

From the perspective of Continental Resources, south central Oklahoma has higher liquid content, higher hard condensates, and higher oil volumes. According to Muncrief, the existing infrastructure here is threefold. The region has more gas-gathering lines, even though it is in an older province. “You do have to go in and revamp some of your gathering systems to handle the increased gas volumes,” Muncrief said.

He added that the company is also looking at oil-gathering infrastructure, similar to what is taking place in the Bakken. “When you have that much oil growth, you’d like to take as many trucks off the road as you can for oil gathering,” he said. You also have existing rail infrastructure in the SCOOP area, which could have additional benefits.

Finally, Muncrief cites the importance of water infrastructure: “We think that we’re going to have more water infrastructure lines installed. It helps with recycling, it helps with disposal, [and] once again, taking trucks off the road. It helps not just from a cost and economic standpoint, but also overall efficiency.”

Summing up the Midcontinent

With production only expected to increase from the Mississippi Lime, Granite Wash, Cana Woodford, and other booming plays in the region, it is clear that significant infrastructure investments – both new and updated – will be required.

“It’s going to be a matter of trying to best characterize the reservoir, as well as looking at alternate fracturing technologies to minimize water and to try to better target stimulation placement. This is an extensive and complex geologic environment. As we increase our understanding, our approaches continue to evolve. There are lots of challenges here and certainly lots of opportunities for ongoing development as well,” said Samuelson.

Continental Resources’ Muncrief, for one, is excited about the exploration opportunities that exist down the road. “We’re going to find some other things,” he said. “So when you get one formation – the Woodford – driving some great economics and then you get a free look at other intervals on the way down, that’s the best of both worlds.” ■



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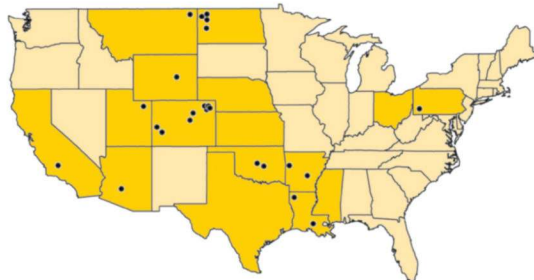


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Can't Touch This

Current projects will make the Midcontinent's good infrastructure even better.

By Paul Hart

Editor, *Midstream Business*



JP Energy Partners' truck rack at Cherokee, Okla., serves a steady stream of rigs hauling in production from Mississippi Lime wells. *(Photo courtesy of JP Energy Partners LP)*

Rapper MC Hammer recorded a hit with his single "Can't Touch This." That catchy tune's title might describe the midstream infrastructure in place to serve E&P firms active in the Midcontinent.

The bustling midcontinent shale plays enjoy a significant edge when compared to the other North American unconventional prospects that have emerged during the last five years.

Like the Permian Basin in West Texas and New Mexico with its own developing unconventional plays, the Midcontinent has extensive legacy infrastructure to support gathering, processing, storage,

and transportation. Unlike the Permian, downstream markets lie comparatively close at hand. Oklahoma has a fair amount of refining and petrochemical capacity. The sizeable natural gas markets of Oklahoma City, Tulsa, and Wichita also are right next door.

The midcontinent shale plays literally wrap around the sprawling Cushing, Okla., crude oil trading hub with its vast storage and pipeline connections – systems that can move crude to just about anywhere in the nation, as well as to tidewater and beyond.

To the north of Cushing, the big Phillips 66 Co. refinery at Ponca City, Okla., provides an unbeatable, close-at-hand customer. The plant has a capacity of 187,000 b/d and easily can handle light shale crudes, although it does have fluid catalytic cracking and hydrodesulfurization capacity for the heavier crudes that came north for a number of years through what is now the southbound Seaway Pipeline. Ditto for Holly Frontier's 125,000 b/d Tulsa refinery farther east, also built to process light sweet crude.

But what is in place does not always exactly match the location of the drilling and production action. There is considerable midstream activity to tweak the midcontinent midstream as well as some merger and acquisition (M&A) activity that matches some of the horse trading under way by the region's upstream operators for top prospects.

'Well-piped'

Rick Wilkerson, president and CEO of Velocity Midstream Partners LLC, calls the region "well-piped." Velocity specializes in engineering, acquiring, owning, and operating gas-gathering and transportation pipelines, compression, and treating. Ironically, despite its Tulsa base, Wilkerson says the company has no midcontinent operations yet.

"Historically, the wellhead was trucked to pipe or to a refinery. The Midcontinent is fairly well-piped, so the focus should be on gathering, intermediate pipes, and other transport options to reduce trucking costs, which can be exorbitant," Wilkerson said. "The economics work beautifully as long as there are the proper IPs [initial productions], EURs [estimated ultimate recoveries], and such."

If the highly successful Bakken far to the north has a little brother, it is the Mississippi Lime. The up-and-coming play has been a hot topic among midstream players this year.

Stretching across northern Oklahoma and southern Kansas, the Mississippi Lime was proven out vertically years ago. More recently, new horizontal technology began allowing for the extraction of much more significant volumes. Plenty of definitive well data already exists in the area, which increases producers' ability to best plan activities there.

As the buildup in the region intensifies, 2013 has proven to be a big year with several key projects

set to come online. The Mississippi Lime's magnetism has lured several big midstream players to the area, and those companies are pumping billions of dollars into the region as they work to bring the young basin to life.

Predominately a crude oil play, the Mississippi Lime also produces natural gas and NGL in abundance. Put it all together – comparatively shallow depth, well control, and midstream-in-place – it boasts some of the greatest economics around for shale plays. Well completion costs are among the cheapest in the country at between US \$3.5 million to \$4 million per well. Paired with the play's latest production rates, it is turning out to be a profitable place to do business.

"I think the Mississippian is a hard basin to beat right now. It's one of the better return oil plays in North America at this point," J. Patrick Barley, chief executive of JP Energy Partners LP, told Hart Energy.

"The economics are very attractive, because you can drill through lower commodity price environments," Barley added. "From a midstream perspective, you want assets in plays that when you encounter lower economic environments, producers will still drill. This is one of those plays where we feel pretty confident that producers will drill at a lower price environment."

Bill Ward, vice president of gas supply and business development for Superior Pipeline Co., spoke positively of the Mississippi Lime and Cana Woodford plays. "In these regions, you do need to spend capital," said Ward. "But unlike Montana or North Dakota where you are in isolated areas, you do have some infrastructure to work with."

Ward added Oklahoma and Kansas are pro-oil and -gas states that provide a supportive working environment for the industry. Community support can mean a lot.

Off the rails

The Mississippi Lime often is compared to the Bakken. However, it is at an earlier developmental stage than the Bakken. Up north, the industry has a good indication of the Bakken play's decline rates and anticipated oil and gas volumes. Mississippi Lime, however, remains a bit more hit-and-miss at this point. The industry still is working to determine what it will shake out to be.

But the Bakken is less developed relative to midstream infrastructure compared to the Mississippi Lime.

“This has been addressed in the Bakken through rail,” said JP Energy’s Barley. “You don’t see as many rail opportunities in Kansas and Oklahoma because of the infrastructure already in place.”

The morning sun glints off the recovery tower above SemGroup’s new 125 MMcf/d gas-processing plant at Hopeton, Okla., which started up in 2Q 2013. (Photo courtesy of SemGroup)

Not nowadays – at one time rail lines crisscrossed the Midcontinent, laid down when conventional production boomed. Railroads such as the Midland Valley, Fort Smith & Western, St. Louis-San Francisco (Frisco), and Missouri-Kansas-Texas (Katy) built in and were big oil-focused operators during the conventional production boom that started before World War I and slowly waned in the mid-20th century. They have long since disappeared. Around 20 years ago the Union Pacific Railroad

pulled up its Cushing branch line, once part of the Katy, due to a lack of business.

EOG Resources Inc. at year-end 2009 opened a new crude rail terminal at nearby Stroud, Okla., on Watco’s Stillwater Central shortline – connected to the Cushing complex via a 17-mile pipeline. BNSF has major north-south and east-west routes that cross at Perry, Okla. It says it’s developing 11 crude-by-rail service points in the Midcontinent.

One of the best pipeline networks anywhere replaced all those railroads – which is why the New York Mercantile Exchange made Cushing its West Texas Intermediate futures contract delivery point in 1983.

For Ward and Superior, a challenge is keeping costs down, since the Mississippi Lime does spread into areas outside northern Oklahoma and southern Kansas where existing infrastructure is more limited.

“In an area that has characteristics like the Bakken’s, with the early drilling development of small groups of wells coming on with low volumes and in areas that have limited gathering and processing infrastructure for gas this rich, you have to hope you’ve got enough gas liquids to justify laying the pipelines and installing processing plants,” said Ward. “That is the challenge: to make sure these wells have enough reserves to justify the economics to provide midstream services.

“I would say the Mississippi Lime is somewhat unpredictable in North-Central Oklahoma and Kansas, so far, with initial volumes and decline rates. This is an oil-driven play. It is still a science project how far the Mississippi Lime extends north into Kansas and how far it extends east in Oklahoma.”

Accommodating growth

JP Energy has made major investments in the region since 2012. It completed its acquisition of Parnon Storage LLC and Parnon Gathering LLC. With the acquisition of Parnon Gathering, a crude oil midstream company, came 215 miles of pipelines. This includes the Great Salt Plains Pipeline, which runs from Cherokee, Okla., straight to Cushing. It was the first new-build pipeline to target the Mississippi Lime specifically and has an operating capacity of 45,000 b/d.

The firm announced in early 2013 that it will construct a second area pipeline, the Kansas Express, which will transport crude from the Mississippi Lime



in southern Kansas to Cushing. It signed a 15-year agreement with Tug Hill Operating on the project. The line will ensure crude gets to market quickly and efficiently, said Barley, who added that takeaway capacity is currently an issue faced in the region.

“As production ramps up it becomes a bigger and bigger problem,” he said. “That’s where we’ve seen producers like Tug Hill step up and make a commitment to facilitate the build out of infrastructure to meet their forecasted production rate.”

Meanwhile, Caballo Energy LLC, financially backed by EnCap Flatrock Midstream, completed its Carmen, Okla., cryogenic gas processing plant to serve the Mississippi Lime and Cana Woodford plays in mid-2013. The Carmen plant has capacity to process 60 MMcf/d, bringing the firm’s total regional processing capacity to 100 MMcf/d. Caballo delivers processed gas to ONEOK Gas Transportation and Panhandle Eastern Pipe Line. Gas liquids go to ONEOK NGL Pipeline.

With room to spare on a 160-acre site at Carmen, Caballo is evaluating the addition of a second cryogenic plant, which could give the location a capacity of 220 MMcf/d by mid-2014, the company said.

The Carmen plant and Caballo’s existing Eagle Chief plant in Alfalfa County, Okla., serve the company’s Eagle Chief system, which includes more than 600 miles of natural gas-gathering pipelines and compression facilities located in Alfalfa, Blaine, Garfield, Major, and Woods counties. Caballo also has 600 miles of gas-gathering pipeline and a 30 MMcf/d of refrigeration capacity serving Mississippi Lime and Cana Woodford producers.

However, additional infrastructure is still needed. Caballo’s board of directors recently instructed company executives to start looking into the timing and size of a third cryogenic plant, which would have a capacity of up to 200 MMcf/d and likely will be needed to keep up with growing volumes.

Carmen was full when it went online and “that means we’ll need to bring on additional capacity to serve our customers and the high level of activity we’re seeing in the area,” said Glenn Powell, Caballo’s chief commercial officer. “It is a challenge for all of the midstream companies in the play to get infrastructure in place quickly enough. Drilling activity is picking up and we’re all behind the curve.”

Catching up

“To catch up, the industry must first resolve its NGL and residue takeaway issue. DCP’s Southern Hills Pipeline will help resolve the liquids takeaway issue and that will help,” said Powell. Although there are existing gas pipelines, more ultimately will be needed to accommodate growth in the play, he added.

Southern Hills, a billion-dollar repurposing of an existing 800-mile petroleum products line, moves Y-grade (mixed) gas liquids to the midstream NGL hub at Mont Belvieu, Texas, for both DCP and third parties.

“We’re trying to get ahead of the curve by building new processing plants and laying lines out to new wells, but as you move farther down the pipeline, there’s going to have to be some natural gas pipelines expanded or looped in order to take residue gas to market,” Powell added.

Other midstream companies are helping alleviate some of those problems with a series of projects. Plains All American Pipeline LP recently announced a 55-mile extension of its previously announced Mississippian Lime pipeline. The expansion, which is expected to be in-service during 4Q 2013, will provide 75,000 b/d of crude throughput capacity from Coldwater in Comanche County in Kansas, to Byron in Alfalfa County, Okla.. The oil will then flow from Bryon via Plains’ Mississippian Lime Pipeline to – where else? – Cushing.

DCP’s Southern Hills line started moving product in mid-2013. The 800-mile common carrier pipeline has a target capacity of 175,000 b/d following completion of additional pump stations.

“As production increases in the Mississippi Lime, DCP will have an NGL outlet to meet the needs of the producers,” Gregory K. Smith, DCP’s president of the midcontinent and Permian business units, told Hart Energy.

The big midstream operator sees a “sweet spot” in the Midcontinent. It currently accounts for more than 100,000 b/d day of NGL production in the region, where it currently owns 30,000 miles of pipelines and 13 gas plants that process 2 Bcf/d. Additionally, DCP is building out its assets on the western side of the Mississippi Lime, where it ultimately will be able to gather and process 75 MMcf/d. The company recently converted an NGL

pipeline to dry gas to serve Oklahoma producers on the eastern side of the Mississippi Lime. Together, these projects are likely to ease the strain of increasing Mississippi Lime volumes, said Smith.

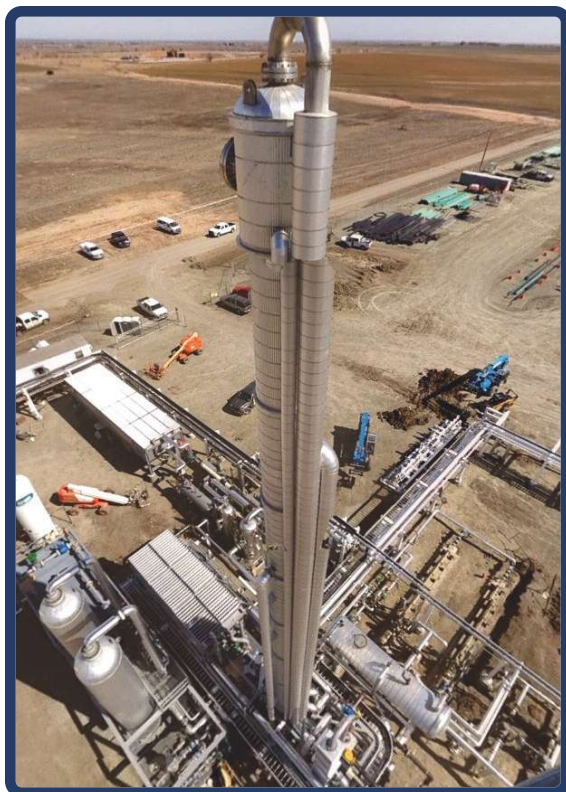
“That’s certainly been one of the biggest challenges,” he said. “The Mississippi Lime as a whole is a pretty young play. We think our projects will provide much-needed midstream infrastructure, allowing producers to flow their gas and continue to drill exploratory wells.”

Bellmon System

Superior Pipeline is among the midstream companies expanding their presence in the Mississippi Lime. By fall 2013, Superior expects to have 90 MMcf/d of cryogenic processing capacity in North-Central Oklahoma through expansion of its Bellmon System in Noble and Kay counties outside Ponca City.

At midyear, the Bellmon System had 20 MMcf/d of refrigeration processing and 85 miles of pipeline. The addition of a new, 30 MMcf/d cryogenic plant, which started up in March, provides a total of 50 MMcf/d of combined processing capacity. The company plans to move in 60 MMcf/d of cryogenic capacity in late 2013 and idle existing refrigeration trains.

Superior Pipeline’s Bellmon plant went onstream in mid-2013, serving gas producers in north central Oklahoma. (Photo courtesy of Superior Pipeline Co.)



Named for popular, late Oklahoma Governor and US Senator Henry Bellmon, whose family wheat farm was in the area, the Bellmon System has been connected to the existing Remington System via 26 miles of new pipeline that will enable Superior to provide cryogenic processing services to Osage County, Okla., producers. The company also completed an NGL pipeline from Bellmon to ONEOK Hydrocarbon LP’s Medford fractionation facilities in Grant County, Okla.

“Approximately 40% of my capital budget last year was spent in the Mississippi Lime, and we see a substantial percent of this year’s budget being deployed to the Mississippi Lime in Oklahoma and Kansas,” said Ward.

Ward said the company’s assets are geographically well-situated in the region to keep up with the ever-evolving Mississippi Lime.

“It keeps on getting better as we go,” he said. “We feel in the Bellmon area, with the amount of acreage we have dedicated, that we will be able to keep up with the growth in that area. The same thing applies in Kansas, where we are starting the process of building enough gathering and processing capacity to accommodate the future growth in this area. I feel we should be able to stay up with the curve.”

Ward does not expect the increase in liquids output to put a strain on take away lines anytime soon. He said the pinch might be felt, however, when it comes to residue gas takeaway capabilities, which could be expanded if required to meet future growth. Some major interstate pipelines also serve the area.

To ensure the movement of liquids there are some major growth projects under way, such as ONEOK’s Sterling expansion. “I think we’re probably in pretty good shape in terms of the capability of moving liquids out of the region,” said Ward. Moving forward, he added that his company’s long-term vision is to continue providing low-pressure gas gathering and processing services.

Earlier in 2013, SemGroup Corp. announced a US \$300 million acquisition of the equity interests of Mid-America Midstream Gas Services LLC, a wholly-owned subsidiary of Chesapeake Energy Corp., which owns gas gathering and processing assets in the Mississippi Lime. The transaction was expected to close in the

TO THE SOUTH AND EAST, the Cana Woodford and South Cana Woodford shale plays typically produce drier gas than the liquids-rich Mississippi Lime. These unconventional prospects overlie a combination of three well-known conventional plays in Oklahoma: the Anadarko, Arkoma, and Ardmore basins.

second half of 2013, subject to certain regulatory approvals and closing conditions. SemGroup management also announced completion of a 125 MMcf/d expansion of Mississippi Lime gas processing capacity by its SemGas subsidiary.

Cana Woodford

To the south and east, the Cana Woodford and South Cana Woodford shale plays typically produce drier gas than the liquids-rich Mississippi Lime. These unconventional prospects overlie a combination of three well-known conventional plays in Oklahoma: the Anadarko, Arkoma, and Ardmore basins.

That once again means midstream infrastructure is in place and more is to come. In the South Cana play, DCP has added more than 100 miles of gathering capacity in recent months, according to Smith.

ONEOK Partners LP is one of midstream's biggest Cana Woodford players with an extensive legacy of gas gathering and processing system. It announced plans in 2012 to invest as much as \$360 million through early 2014 in additional gas gathering assets, plus the new Canadian Valley processing plant – its largest in Oklahoma. Capacity will be 200 MMcf/d.

ONEOK also plans to invest \$160 million for expansions and upgrades of its existing operations in the area. When finished, ONEOK projects to have 390 MMcf/d onstream to serve Cana Woodford producers.

Enogex is another major midstream operator in the Cana Woodford, offering gathering, processing, storage, and transmission services. It has 2,200 miles of gathering and transmission intrastate pipelines that serve 15 gas-fired power plants in the Sooner state. It also has 11 gas processing plants with a combined capacity of 1.5 Bcf/d and 24 Bcf of working storage capacity.

Crossing the middle of Oklahoma from west to east, CenterPoint Energy offers gas gathering, processing, storage, and transmission services to Cana Woodford producers with 500 MMcf/d of gathering and 400 MMcf/d of treating capacity.

Those two systems combined in mid-2013 – another example of the M&A asset shuffle typical nearly everywhere in the midstream nowadays. The Enogex parent, OGE Energy Corp., CenterPoint, and ArcLight Capital Partners LLC closed on the formation of a new midstream master limited partnership. The new operation includes CenterPoint Energy's interstate pipelines and field services businesses and the midstream business of Enogex LLC. The partnership will be managed by a general partner whose governance will be shared by CenterPoint Energy and OGE on a 50/50 basis.

The Woodford midstream has seen other M&A activity in 2013. During 2Q 2013, Kinder Morgan Energy Partners closed its \$3.2 billion stock-for-stock acquisition of Copano Energy LLC. This purchase expanded Kinder Morgan's infrastructure asset base by nearly 7,000 miles of gas pipelines in Oklahoma, Texas, and Wyoming.

Of course, the effects of reviving and building out the midcontinent midstream are having long-term impacts on the region's economy, pointed out Superior's Ward. Drilling rigs and their crews come and go but pipelines, compressor stations, tank batteries and gas plants hang around awhile. Once-dead main streets laid out a hundred years ago look perky again and new subdivisions are going in at the edge of towns.

"There has been life brought back into areas of Oklahoma and Kansas that we haven't seen in years," added Ward. "It has put money back into the local economy, has provided employment, and will continue to be a great area of opportunity for producers and pipelines for the coming years."

You can't touch that. ■

Liquids-rich Production Booming in the Midcontinent

By **Narmadha Navaneethan**

Research Analyst, Hart Energy

Oily and liquids-rich plays in the midcontinent region continue to attract operators.

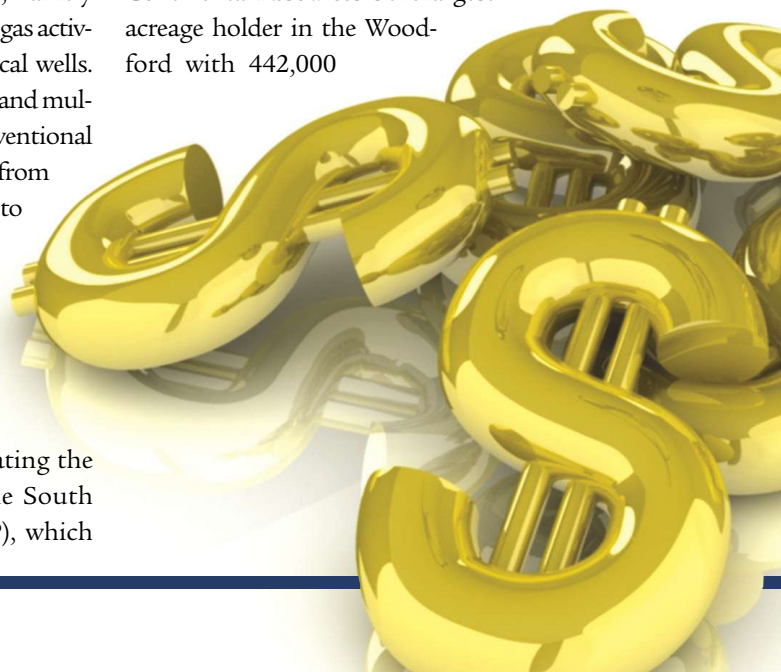
The rapid growth of unconventional production from the shale plays has transformed the US from being a net importer to preparing the stage for exporting natural gas. The midcontinent region is a hot spot for operators focusing their assets on oil, condensate, and NGLs. There is a spectrum of development in the midcontinent liquids plays, such as the Mississippi Lime, Cana Woodford, Ardmore Woodford, and Panhandle. When the Henry Hub natural gas price dropped below US \$2/MMBtu in 2012 due to oversupply from unconventional plays, high oil prices helped operators maintain margins and continue drilling in the liquids-rich and oilier portions of their acreage.

The Woodford Shale is located in Oklahoma and the Texas Panhandle region in three basins, namely the Anadarko, Ardmore, and Arkoma. Oil and gas activity started in this area as conventional vertical wells. Today, operators are using horizontal drilling and multistage fracturing techniques to drill unconventional wells. The Woodford's production mix ranges from the gassy Arkoma Basin in eastern Oklahoma to the condensate-prone Anadarko Basin to the west and oily Ardmore Basin to the south. With lower natural gas prices, operators began redeploying their rigs from the Arkoma to the liquids-rich part of the Cana Woodford and Ardmore.

Now the operators have started delineating the Woodford shale formation known as the South Central Oklahoma Oil Province (SCOOP), which

has greater oil and liquid components than the Cana Woodford. SCOOP is located in Grady, Garvin, Stephens, McClain, Carter, and Love counties. Continental Resources started promoting this play as premium Woodford, and many operators are testing wells due to the oilier nature of the play. According to Continental Resources, SCOOP has six times more reservoir volume than the Cana field. Continental Resources, Newfield Exploration Co., Marathon Oil Corp., and Eagle Rock Energy Partners LP, are the top operators in the SCOOP region.

Figure 1 lists the top acreage holders in Woodford. Continental Resources is the largest acreage holder in the Woodford with 442,000



net acres, out of which 232,000 acres are in the SCOOP area. Exxon Mobil Corp. has around 399,000 net acres and is focused on the Woodford Ardmore play.

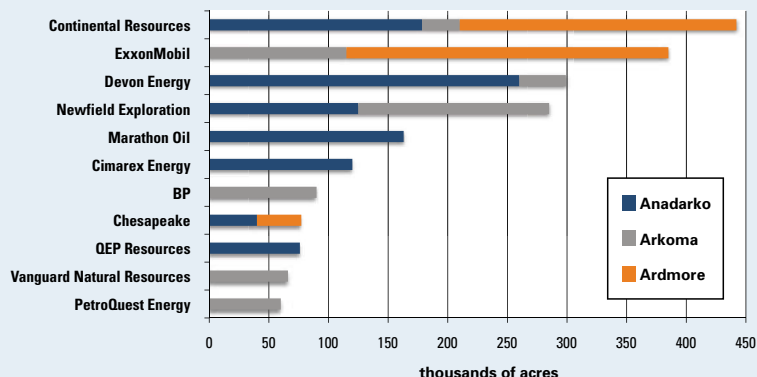
The Mississippi Lime is another major play extending from Kansas to Oklahoma. The Mississippi play is a conventional one that is being revived with horizontal drilling technology. The Mississippi Lime is a shallower formation, hence the average Mississippi Lime well costs around \$3 million, which is less than deeper formations like the Bakken and Granite Wash. But the high water adds costs by increasing the need to handle the water via infrastructure and disposal facilities. Leasing acreages in the midcontinent region is relatively less expensive than in plays like the Bakken.

Figure 2 lists the top acreage holders in the Mississippi Lime. The closure of Sinopec's joint venture (JV) deal with Chesapeake Energy Corp. has pushed SandRidge Energy to first place among acreage holders with 1.85 million acres. It is followed by Chesapeake Energy with 1.675 million acres and Devon Energy Corp. with 603,000 acres.

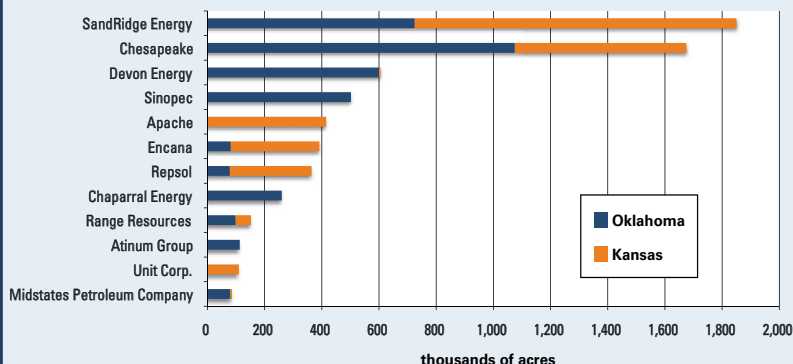
Production in the Midcontinent

Midcontinent production is growing every year with operators increasing their investments in the liquids-rich part of the region. Figure 3 shows the Mississippi Lime production for top operators as forecasted in the 2Q 2013 North American Shale Quarterly (NASQ) report. According to the NASQ forecast, the Mississippi Lime production will reach a peak of 557 Mboe/d by 2019. SandRidge Energy cut 2013 capex by one-third to \$1.45 billion in comparison with its 2012 expenditures. With the revised capex, the company is planning to reduce the rig count and optimize its saltwater disposal systems. Devon and

Woodford Acreage



Mississippi Lime Acreage

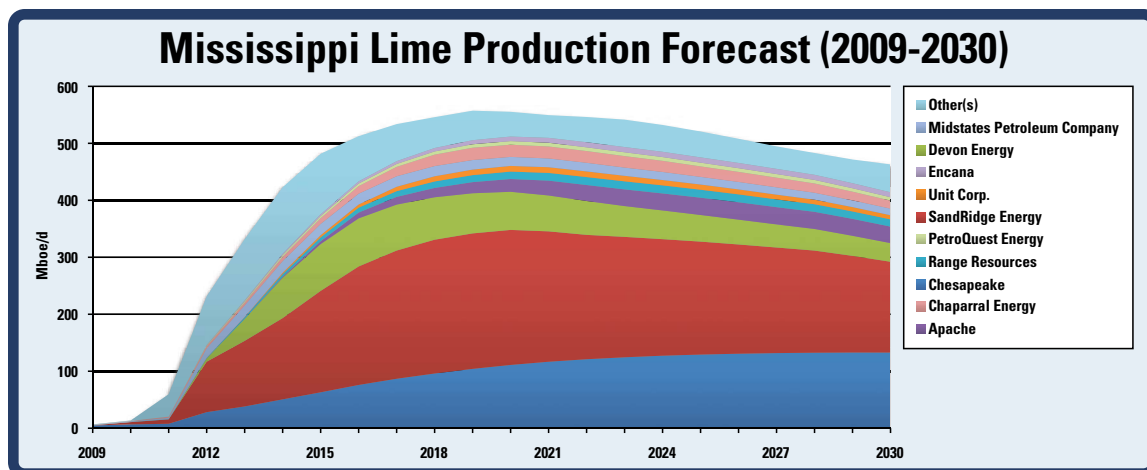


Sinopec plan to invest \$1.2 billion in the play through their JV with the goal of drilling 400 wells. Roughly two-thirds of the drilling will focus in the JV acreage with the balance being deployed to derisk acreage in the north and northwest. Midstates Petroleum Co. plans to invest \$70 million to \$80 million to drill 16 to 18 wells in 2Q 2013. Chesapeake is using 3-D seismic across its core development areas to help it efficiently develop the Chesapeake/Sinopec JV acreage. Overall, the operators are derisking more acreage and increasing their well count and production substantially in the short term.

In the Woodford, many operators are planning to increase their operations in the SCOOP and liquids-rich Cana regions. Continental Resources said it will increase operated rig count in the SCOOP faster than originally planned. This accelerated rig deployment involves no increase in capex. The company will invest \$470 million in its SCOOP operations. The company plans to reduce completion costs by \$500,000 per operating well by year-end 2013. Continental does not

Figure 1 (top): Net acreage of top acreage holders by basin in the Woodford. Figure 2 (bottom): Net acreage of top acreage holders by state in the Mississippi Lime. (Source: Hart Energy's North American Shale Quarterly)

Figure 3:
Mississippi Lime
production forecast
for top operators
(Source: Hart
Energy)



plan to drill in the Northwest Cana or Arkoma plays in 2013 due to depressed natural gas prices. Overall, the 2Q 2013 NASQ report forecasts that Woodford production will reach a peak of 3.83 Bcfe/d by 2025.

Significant transactions

A number of significant acquisition and divestiture transactions occurred in the midcontinent region. Although many operators are seeking interest in the play, Chesapeake sold part of its Mississippi Lime assets as the company focuses on core properties. On June 28, 2013, Chesapeake closed a JV agreement in which Sinopec purchased a 50% undivided interest in 850,000 acres of Chesapeake's net oil and natural gas leasehold acres in northern Oklahoma for \$1.02 billion. Production from these assets (including the Mississippi Lime and other formations), net to Chesapeake's interest and prior to Sinopec's purchase, averaged about 34,000 boe/d in 4Q 2012 and, as of year-end 2012, there were approximately 140 MMboe of net proved reserves associated with the assets. All future exploration and development costs in the JV will be shared proportionately between the parties with no drilling carries involved. Chesapeake is the operator and will conduct all leasing, drilling, completion, operations, and marketing activities for the JV. In November 2012, Sinopec also picked up a 33% working interest in 250,000 gross acres in the play as part of a deal with Devon.

In the Woodford, BNK Petroleum Inc. closed its sale of Tishomingo Field, Okla., assets (other than the Caney and upper Sycamore formations) to Exxon Mobil subsidiary XTO Energy Inc. for \$147 million

in April 2013. The company is currently drilling Caney/Upper Sycamore wells, where it has 12,500 net acres. The net proceeds of this transaction also will be invested in drilling the Caney formation.

Gravis Oil acquired emerging oil and gas producer Petro River Oil LLC on April 19, 2013, to become Petro River Oil Corp., with significant acreage in the Southeast Kansas region of the Mississippi Lime formation. The acquisition added 115,000 gross (85,000 net) acres to the newly-merged company's portfolio, comprising 60,105 gross (40,951 net) acres in Missouri, Kentucky, and Montana.

A few midstream transactions in the region are worthy of mention. SemGroup Corp. executed a definitive agreement to acquire the equity interests of Chesapeake Energy subsidiary Mid-America Midstream Gas Services LLC, the owner of gas gathering and processing assets in the Mississippi Lime play. The \$300 million cash transaction is expected to close by 3Q 2013 and is subject to approvals and closing conditions. The assets include 200 miles of gathering pipeline, Rose Valley I plant, and Rose Valley II plant.

Another midstream transaction includes the May 2013 completion of Kinder Morgan Energy Partners' acquisition of Copano Energy LLC in an all-stock deal worth \$3.2 billion. This purchase increases Kinder Morgan's current infrastructure by adding almost 7,000 miles of natural gas pipelines in Texas, Oklahoma, and Wyoming.

In late 1Q 2013, OGE Energy Corp. and CenterPoint Energy Inc. announced the formation of a multi-billion dollar partnership intended to combine midstream assets owned by the partners and

ArcLight Capital Partners LLC. The new partnership will own and operate 8,400 miles of interstate pipelines with nearly 9 Bcf/d of transport capacity and nearly 2,300 miles of intrastate pipelines. It will also have more than 11,000 miles of gathering lines, which in 2012 moved nearly 4 Bcf/d of natural gas. Additionally, it will have more than 90 Bcf of natural gas storage capacity and 11 major processing plants with nearly 2 Bcf/d of inlet capacity.

Well costs and break-even price

Hart Energy estimates the break-even gas and oil price for the midcontinent plays. The half-cycle break-even gas price for an Anadarko Woodford well is somewhere between \$2.8/Mcf and \$3.9/Mcf. Although the break-even price for liquids-rich Cana Woodford is competitive when compared with natural gas plays, sustained low natural gas prices have caused operators to move to oily regions of the play like SCOOP where the break-even price is lower. The break-even oil price for a Mississippi Lime well averages \$49.31/bbl in the play. These half-cycle break-even prices do not include transportation or leasing costs.

Figure 4 lists the break-even pricing from the 2Q NASQ report. Break-even prices are calculated assuming price of \$4/Mcf for natural gas, \$37.80/bbl for NGL, and \$80/bbl for oil.

Woodford wells in liquids-rich and oilier parts of the play cost around \$8 million to \$9.5 million. Continental Resources reports that the SCOOP Condensate fairway has a well cost of \$9 million to \$9.5 million whereas SCOOP oil fairway costs \$8.5 million to \$9 million. Newfield Exploration splits its operations in the Cana Woodford into north oil, south oil, and south wet-gas regions. The development costs of wells

in the north oil region are approximately \$9 million to \$10 million while costs are almost \$2 million higher in the south oil region due to increasing depth. Exxon Mobil's well cost in the Ardmore formation is around \$5.5 million. The Mississippi Lime play well costs \$3 million to \$3.5 million since the formation is shallower compared with the SCOOP. Companies are working towards reducing the drilling and completion costs to increase rates of return by optimizing completion techniques and produced water utilization.

Tumbling NGL pricing in the Midcontinent

When natural gas prices began to decline, operators started redeploying rigs to liquids-rich regions. But now with abundant NGL supply from these plays, the NGL supply and demand balance has been disrupted. Ethane and propane prices started falling in 2012 with very high NGL supply from the midcontinent region. With low ethane prices, there also is a high level of ethane rejection in the Midcontinent. ONEOK Partners reported in 1Q 2013 that about 90,000 b/d of ethane were rejected from its systems. Propane also has seen low prices due to increased supply, but cold winter and exports provided some relief on propane inventories and pricing. In the long term, we believe ethane demand will keep pace with the supply. The ethane price will increase again with petrochemical facilities and ethane crackers coming online in 2017, offsetting increasing supply. Propane prices also will see relief with exports and petrochemical demand.

Figure 5 shows the NGL pricing at Mont Belvieu and Conway markets. In 2013, Conway and Mont Belvieu NGL prices continued to approach parity. Heavy NGLs were seeing higher price differentials between the two hubs because of a stronger refining market at the Gulf Coast.

Figure 4: Break-even prices for selected wells in Mississippi Lime and Woodford plays.
(Source: Hart Energy's North American Shale Quarterly)

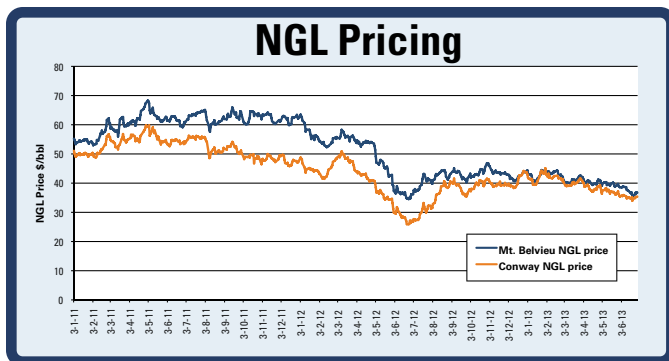
Mississippi Lime Economic Analysis

| Well and Acreage Parameters | | | | Product Splits | | | Type Well NPV | | Breakeven Oil Price | | Breakeven Gas Price | |
|-------------------------------|--------------------------|-----------------------|-----------------|----------------|------------|------------|-------------------|---------------------|---------------------|-----------------------|---------------------|-----------------------|
| Case Name | IP at 30 days (boe/d) | 30 Year EUR (Mboe) | CAPEX (\$mm) | Gas (%) | NGL (%) | Oil (%) | Pre-Tax (\$mm) | After-Tax (\$mm) | Pre-Tax (\$/bbl) | After-Tax (\$/bbl) | Pre-Tax (\$/Mcf) | After-Tax (\$/Mcf) |
| Chesapeake (Alfalfa) | 352.63 | 777.36 | 3.5 | 50% | 21% | 28% | \$6.06 | \$2.32 | \$26.30 | \$45.90 | - | - |
| SandRidge Energy (Woods) | 488.52 | 657.41 | 3.1 | 49% | 17% | 34% | \$7.18 | \$3.32 | \$21.25 | \$36.39 | - | - |
| Midstates Petroleum (Alfalfa) | 627.51 | 312.32 | 3.6 | 38% | 16% | 46% | \$3.33 | \$1.34 | \$42.92 | \$58.14 | - | - |
| Range Resources (Kay) | 327.62 | 612.41 | 3.4 | 48% | 27% | 25% | \$4.06 | \$1.25 | \$34.23 | \$56.79 | - | - |

Woodford Economic Analysis

| Well and Acreage Parameters | | | | Product Splits | | | Type Well NPV | | Breakeven Oil Price | | Breakeven Gas Price | |
|-------------------------------|----------------------------|-----------------------|-----------------|----------------|------------|------------|-------------------|---------------------|---------------------|-----------------------|---------------------|-----------------------|
| Case Name | IP at 30 days (MMcfe/d) | 30 Year EUR (Bcfe) | CAPEX (\$mm) | Gas (%) | NGL (%) | Oil (%) | Pre-Tax (\$mm) | After-Tax (\$mm) | Pre-Tax (\$/bbl) | After-Tax (\$/bbl) | Pre-Tax (\$/Mcf) | After-Tax (\$/Mcf) |
| QEP Resources (Canadian) | 3.06 | 6.59 | 8 | 61% | 26% | 13% | \$4.22 | \$0.12 | - | - | \$1.31 | \$3.88 |
| Continental Resources (Grady) | 2.87 | 6.18 | 9 | 42% | 29% | 29% | \$5.66 | \$0.66 | \$45.70 | \$73.40 | - | - |

Figure 5: NGL pricing in Conway and Mt. Belvieu hubs (Source: Hart Energy's Midstream Monitor)



Since the Midcontinent has been producing from conventional formations for decades, there is well established infrastructure in the region. As companies are increasing their liquids-rich production in the play, midstream companies are also expanding their NGL systems to access various markets. NGL growth in the Midcontinent will see an increase with the new Southern Hills NGL pipeline that came online in June 2013. ONEOK Partners' Sterling III NGL pipeline is

expected to come online in late 2013, providing additional capacities benefiting the midcontinent plays. ONEOK Partners have announced \$1.7 billion to \$2 billion in investments in NGL infrastructure in the Midcontinent and Gulf Coast and \$615 million to \$635 million in the Cana Woodford and Granite Wash areas. The additional pipelines, processing, and fractionation facilities will help reduce the glut in Conway and provide access to the

Gulf Coast market. This also will help to reduce the price differentials between the midcontinent and Gulf Coast markets.

Operators might start drilling for natural gas in the Midcontinent when their economics look positive with a sustained period of natural gas price increases and build-out of LNG facilities. The liquids-rich midcontinent plays will continue to attract operators and logistics investments. ■

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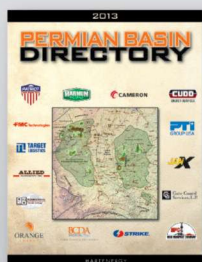
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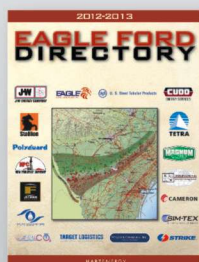


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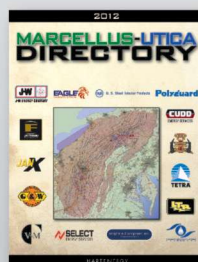
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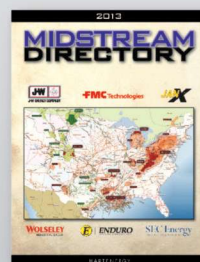
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6,000+ key personnel listed



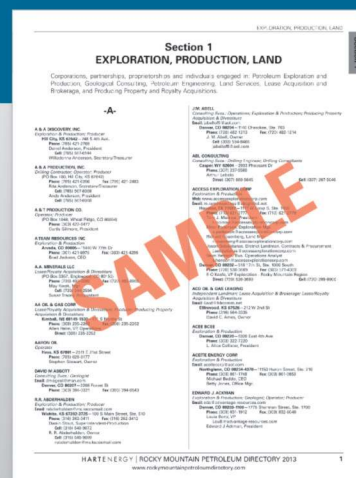
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2,000+ companies profiled
12,000+ key personnel listed



3,000+ companies profiled
7,000+ key personnel listed



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For more details on the Mississippi Lime and Woodford, consult the selected sources below.

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Senior Editor, *E&P*

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A black and white photograph of a middle-aged man with short hair, wearing a light-colored button-down shirt with the United Rentals logo on the chest. He is standing with his arms crossed in front of an industrial facility with tall smokestacks and scaffolding. The background is slightly blurred, emphasizing the man and the large text overlay.

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