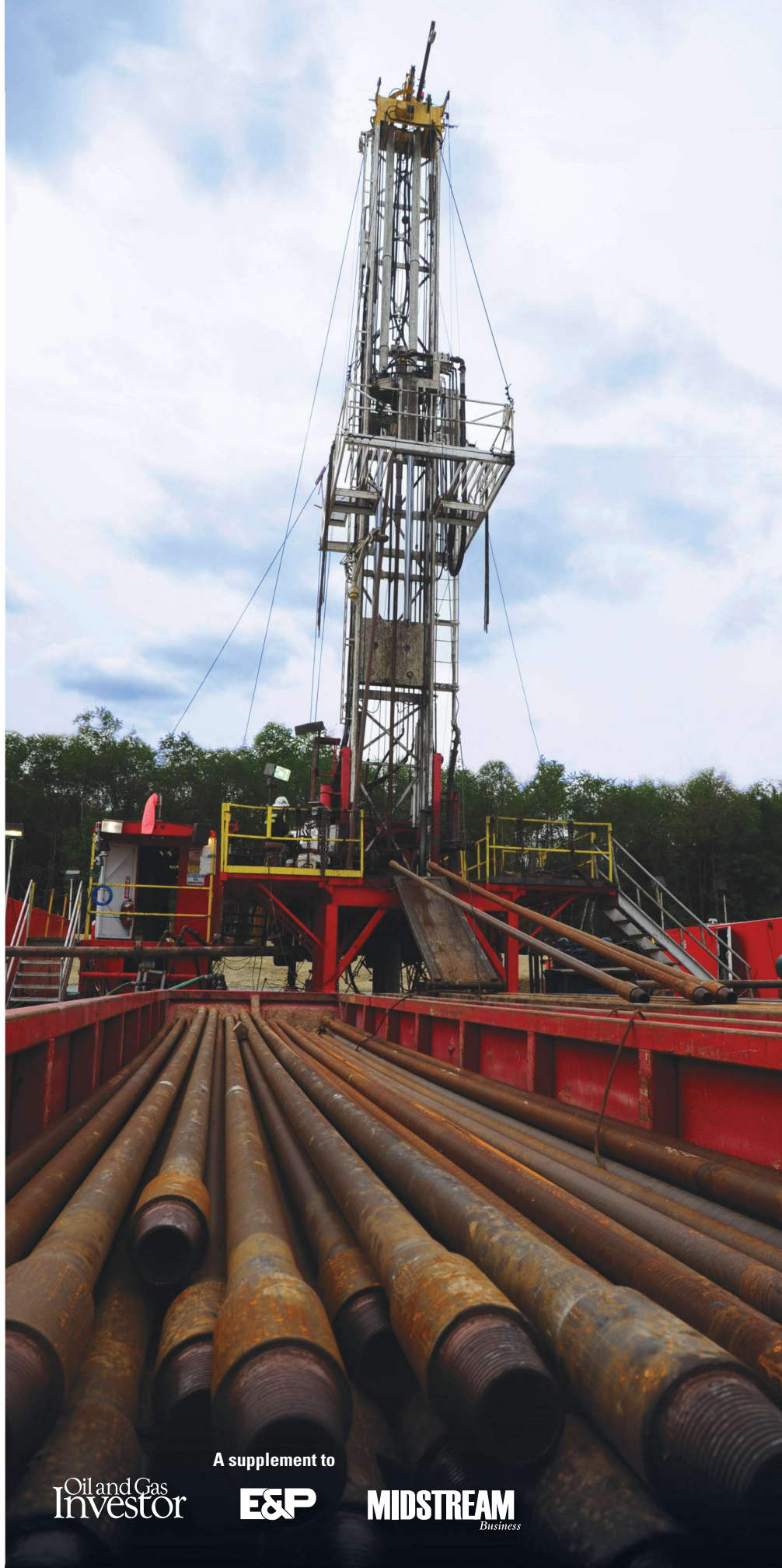


HARTENERGY

# Appalachian Shales

*The 2013 Playbook*



A supplement to

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## Appalachian Shales: *The Playbook*

A supplement to *Oil and Gas Investor, E&P,*  
and *Midstream Business*

### HART ENERGY

1616 S. Voss, Suite 1000 | Houston, Texas 77057  
Tel: +1 (713) 260-6400 | Fax: +1 (713) 840-8585  
[hartenergy.com](http://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*

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For additional copies of this publication,  
contact Customer Service +1 (713) 260-6442.

Vice President - Publishing **RUSSELL LAAS**  
Vice President - Publishing **SHELLEY LAMB**  
Group Publisher  
*Midstream Business* **DAVID PARKER**  
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On the cover: The Whipstock Natural Gas Rig #22 drills topoles on Consol's Gaut pad that will feature three strings of protective casing between the wellbore and the water table. (Photo courtesy of Peter C. Piazza)





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The play is simply the 'single biggest element' in the gas market, analysis states.

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A frac crew at the Hulk well site works in winter weather. (Photo courtesy of Rice Energy LLC)

# Operators Enjoy Copious Gas and Some Liquids Too

Huge wells deliver world-class pay, world-class profits.

**By Don Lyle**  
Contributing Editor

**T**he Appalachian basin rang in first for US oil production and shale production, and it is flexing its muscles with at least two of the premier shale producing zones in the country.

The Marcellus set its banner as the second largest gas field in the world, second only to North field offshore Qatar in the Persian Gulf, according to some analysts. The Utica waves its pennant as one of the biggest liquids shale plays in the US behind the Bakken in North Dakota and Montana and the Eagle Ford in South Texas. The Upper Devonian shales, often overlying those formations, wave a small flag now as operators evaluate a profit potential that looks good, if early wells are accurate indicators.

First to arrive on the geologic scene, the Middle Ordovician Utica shale feeds the deeper Point Pleasant reservoir in the sweet spot of the play in Ohio and western Pennsylvania. Following Silurian deposition, the popular Devonian shales, including the Middle Devonian Marcellus, took the spotlight followed by the stacked Upper Devonian shales that have seen production for more than a century.

## Utica

According to the Ohio Department of Natural Resources, “At the end of the Trenton deposition time the Point Pleasant was deposited within a restricted-circulation sub-basin, surrounded by carbonate platforms. As waters deepened, seas over-

rode the platforms, depositing the Utica shale on top of the entire area.”

The Utica is immature in west-central and western Ohio, oily in east-central and most of eastern Ohio, and contains wet gas along the Ohio border with Pennsylvania and into western Pennsylvania and north into Quebec. It furnishes dry gas in West Virginia and in a band through western Pennsylvania and New York. The formation is overmature farther east.

The sweet spot is the wet gas area with up to 4% total organic carbon (TOC).

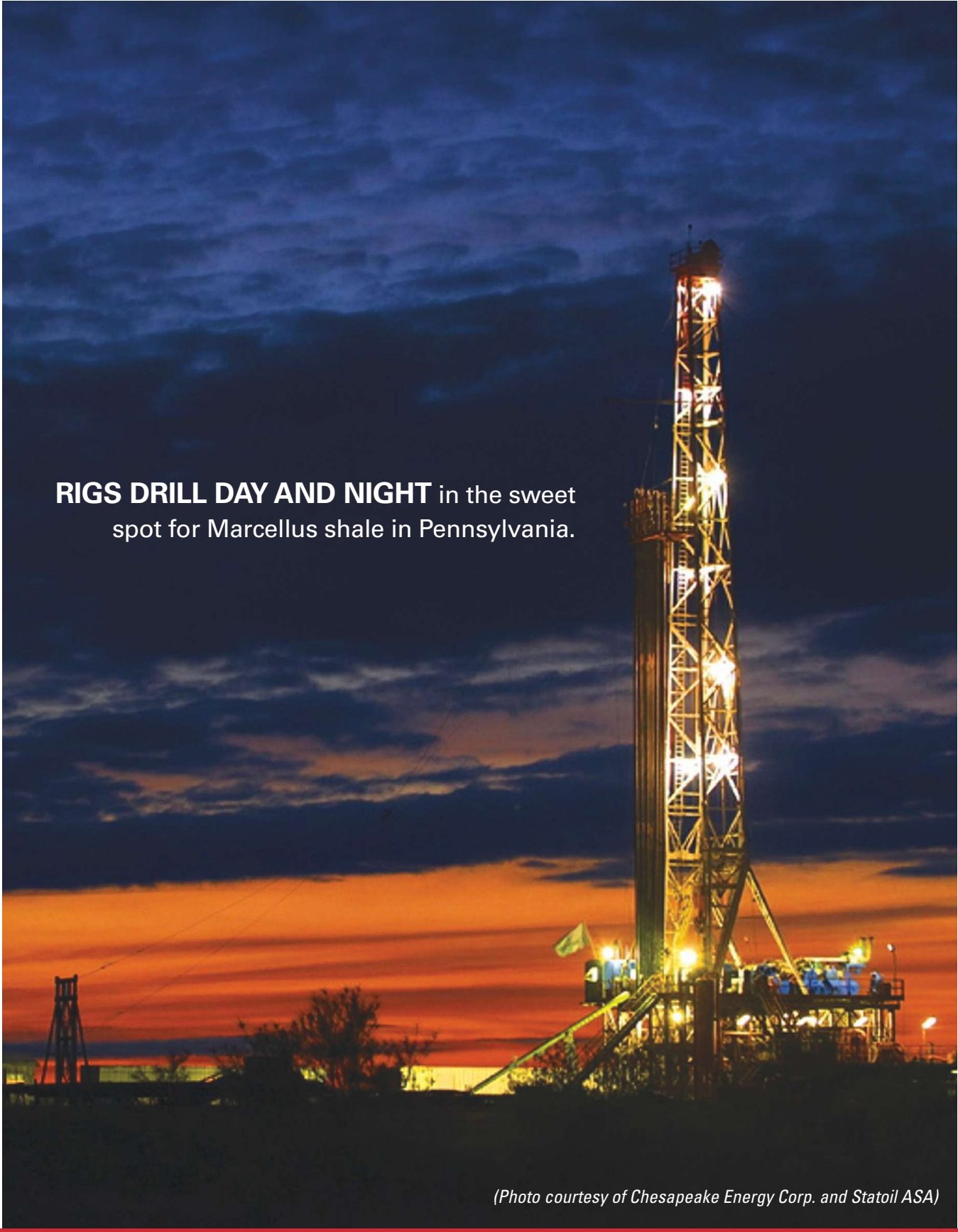
People in the industry compare the Utica with the Eagle Ford in Texas. Where the Eagle Ford covers some 20,000 sq miles, the Utica/Point Pleasant has a range of some 17,000 sq miles.

According to Rex Energy, the Utica shale is a 300-ft-thick section (on its land) of calcareous shale lithologically similar to the Eagle Ford. The formation lies some 4,000 ft below the Marcellus shale.

As the Utica reaches Rex acreage in Butler County, Pa., it’s too deep to exploit economically at 3Q 2013 prices. The formation dips deeper as it moves east across Ohio into Pennsylvania. Rex has some expertise in the play. It brought in the 2H Guernsey in Guernsey County, Ohio, for 3,111 boe/d with 43% gas, 18% condensate, and 39% NGL.

Chesapeake, in an October 2011 press release, claimed credit for the first production from the Utica/Point Pleasant with the 8H Buell in Harrison

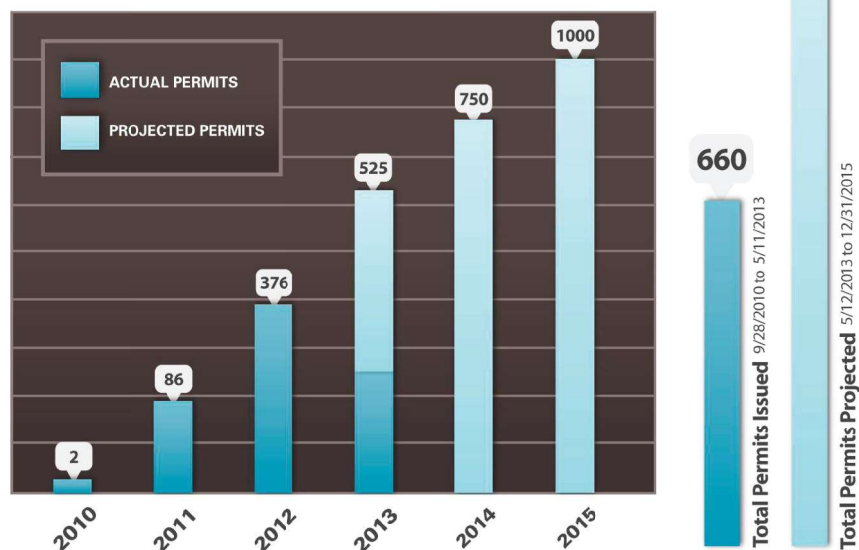




**RIGS DRILL DAY AND NIGHT** in the sweet spot for Marcellus shale in Pennsylvania.

*(Photo courtesy of Chesapeake Energy Corp. and Statoil ASA)*

## Horizontal Utica Well Permits



Projections call for more than 2,900 Utica wells in Ohio through year-end 2015. (Source: Ohio Department of Natural Resources, courtesy of EV Energy Partners LP)

County, Ohio, posting an initial potential of 9.5 MMcf/d of gas and 1.425 b/d of condensate, or 3,008 boe/d. That well still ranked as the fourth most prolific in the formation at the end of June 2013.

The top producer at that time was Gulfport Energy's 1-12 Shugert at 28.5 MMcf/d of gas and 300 b/d of condensate, or 5,050 boe/d. Gulfport also hit the second best well, the 1H Wagner Unit, a well that tested for 17.1 MMcf/d of gas and 432 b/d of condensate. Both wells were in Harrison County, Ohio.

That kind of production drew bidders with big wallets. A *Pittsburgh Post Gazette* article based on PricewaterhouseCoopers' research said the Utica drew no acquisitions for more than US \$50 million in 2010. The following year, the formation generated \$5.864 billion for six deals. That figure dropped to four deals for \$1.278 billion in 2012 when many deals focused on pipelines and processing rather than drilling and land acquisitions.

In 1Q 2013 two Utica shale deals took place for \$283 million, a gain from the \$112 million generated in 1Q 2012.

The research report said the Utica ranked third in deal value in 1Q 2013 behind the Eagle Ford and Marcellus but ahead of the Bakken.

An EnerVest presentation quoted Ohio Department of Natural Resources figures to June 20, 2013. That state had permitted 747 Utica/Point Pleasant wells. Of those, 359 had been drilled and 102 wells were producing.

That state also had high hopes for the future of the Utica. It said it issued two permits in 2010, 86 in 2011, and 376 in 2012. It estimated it would finish 2013 with 525 permits issued, and that number would climb to 750 permits in 2014 and 1,000 in 2015. It projected it would issue 2,242 permits between May

12, 2013, and year-end 2015.

That activity aims at ambitious goals. The Ohio Department of Natural Resources calculates the Utica, with a 3% recovery rate, has generated 13.26 Bboe to conventional reservoirs throughout Appalachia.

With a 5% recovery rate and TOC of 2.5%, some 8.2 Bboe are recoverable in Ohio. That breaks down to one-third gas, or 15.7 Tcf, and two-thirds oil, or 5.5 boe. The agency emphasized that's an educated guess.

## Marcellus

Approximately 365 million years ago, in an area that would later become the eastern US, mud and plankton drifted gradually to the seafloor. The massive amounts of organic matter cooked under high pressure into low-permeability shale during the early part of the Middle Devonian.

Over the next 65 million years, gases formed by decay started creating natural fractures. About 280 million years ago, the earth's crust buckled causing the valley and ridge system in eastern Pennsylvania and further fracturing the lower Middle Devonian Marcellus.

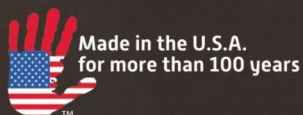


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Technically, it is the lowest member of the Hamilton Group, which includes the Moscow, Ludlowville, and Skaneateles shales in western New York and the Mahatango formation in western Maryland, western Pennsylvania, West Virginia, and northern Virginia.

That combination of events created a vast shale play spreading through southern New York, northern and western Pennsylvania, eastern Ohio, western Maryland, most of West Virginia, and extreme western Virginia.

It also exists in western New Jersey, Kentucky, and Tennessee and stretches into southern Ontario in Canada, but those portions aren't considered ripe for development.

In all, the Marcellus covers some 95,000 sq miles with the potentially productive section lying at 4,000 ft to 8,000 ft in thicknesses from 50 ft to 200 ft.

boundary makes them separate fields.

Arjun Sreekumar with The Motley Fool noted the surge in US natural gas production and the resultant drop in prices to around \$3.60/Mcf in late September 2013.

By September 2012, the Marcellus moved into first place in production among US conventional and unconventional fields as it overtook the Haynesville shale. The Marcellus produced 7.81 Bcf/d of gas in January 2013, up 51% from January 2011. That total gave it 12% of all US gas production, according to the EIA.

Sreekumar said, "At the risk of oversimplifying, it really comes down to a single, highly prolific shale gas play – the Marcellus. Even as production from other US shale fields has fallen, output from the Marcellus continues to grow. According to Bentek Energy, an energy market analytics firm, Marcellus production from Pennsylvania and



**BY SEPTEMBER 2012, the Marcellus moved into first place in production among US conventional and unconventional fields as it overtook the Haynesville shale.**

The sweet spot of the play lies in southwestern Pennsylvania, an area rich in gas liquids. It's considered a dry gas play in northeastern Pennsylvania, and operators generally drill in this area to hold their land positions. Northern West Virginia also produces liquids-rich gas and is the only area outside of Pennsylvania under development.

Some people have called the Marcellus the world's second largest gas field with an estimated 410 Tcf of gas in place and 141 Tcf technically recoverable, according to the US Energy Information Administration (EIA). The US Geological Survey came up with an 88 Tcf recoverable figure. The world ranking depends on the definition of a field. Clearly, Qatar's North Dome field is the leader with an estimated 900 Tcf of recoverable gas. Iran's South Pars field is part of that same supergiant field and adds another 360 Tcf of recoverable gas. Only a political

West Virginia has jumped 50% year over year. By comparison, output from the Haynesville shale of Louisiana and Texas has fallen 21%."

Companies continue to drill in spite of low gas prices, he added, because the Marcellus offers superior economics and high NGL content. He paraphrased a Standard & Poor's study in 2012 that said the Marcellus was "easily the most economical shale gas play in the country. With natural gas prices of \$3.50/MMBtu, Marcellus dry gas wells generate an internal rate of return [IRR] of around 12%, while Marcellus wet gas wells generate an IRR of close to 30% due to the higher revenues associated with NGL."

Statistics back up that line of reasoning. Production from the Marcellus was negligible in early 2008. The Aug. 13 issue of *Gas and Power Kaleidoscope* from Barclays Capital said gas consumption

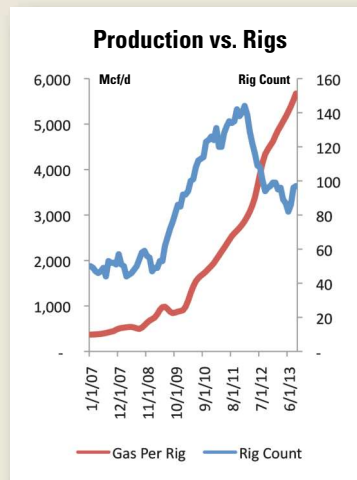


# Marcellus Metrics

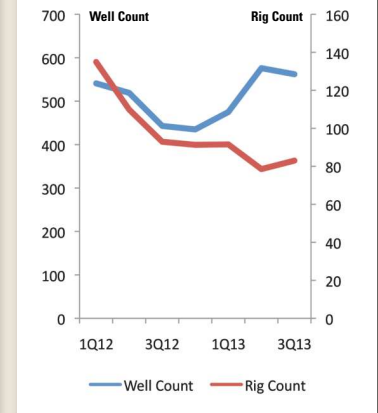
The Marcellus shale is entering the resource harvest phase in the unconventional exploitation cycle. That phase features economies of scale as operators turn to batch drilling and completions to capture hydrocarbons in an economically efficient manner. The trend is evident in metrics that show rising well count despite fewer active rigs and in cost reductions associated with pad drilling. The Marcellus compares favorably from an expenditure basis with oil-focused tight formation plays in the Bakken and Eagle Ford.

**Figure 1 (near right). Production vs. Rigs**

Marcellus rig count fell in late 2011 with the decline in natural gas prices. However, the volume of new natural gas added per rig increased to 6 MMcf/d as operators high-graded their drilling. (Source: US EIA)



**Wells vs. Rigs**

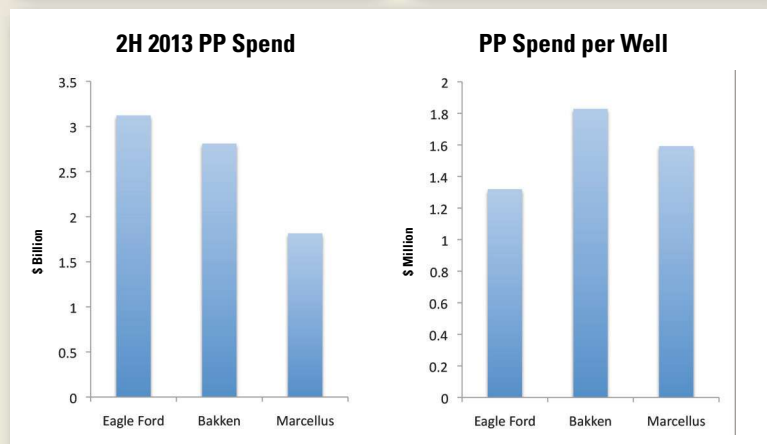


**Figure 2 (far right). Wells vs. Rigs**

Although rig count has dropped in the Marcellus shale, well count has moved higher because of drilling efficiencies accompanying the move to pad drilling. That effort picked up momentum in 2013. (Source: Baker Hughes)

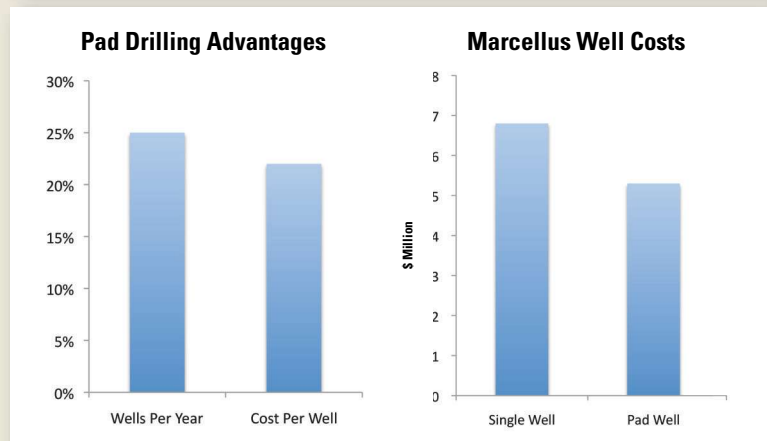
**Figure 3. Marcellus Spend**

Estimated industry expenditures for well stimulation in the Marcellus shale (left) lag spending in the tight oil shales, though stimulation spending for individual wells in the Marcellus is roughly midway between the Eagle Ford and Bakken. (Source: Hart Energy)



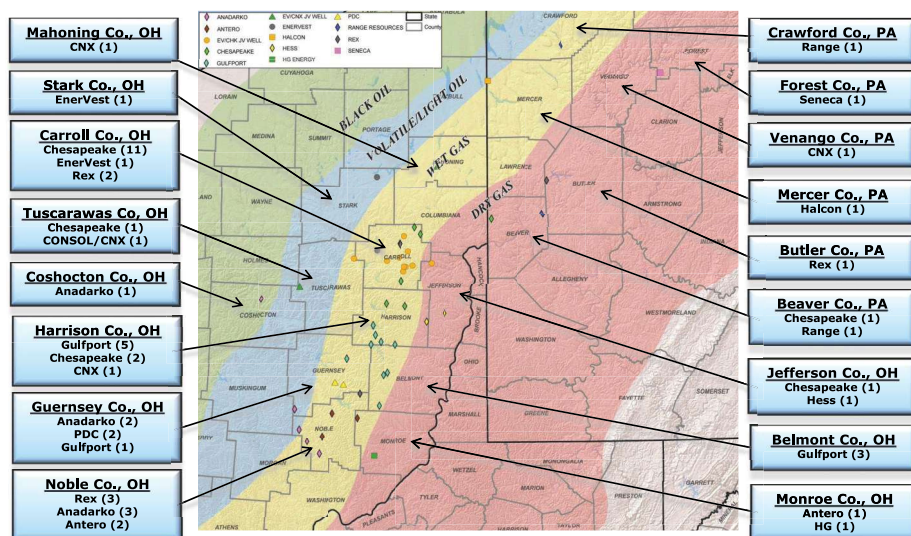
**Figure 4. Marcellus Pad Drilling**

A Hart Energy survey found operators can drill 25% more wells per year using pad drilling techniques vs. single well sites with a cost savings of 23%. Specific Marcellus well costs drop from nearly \$7 million on a single well program to \$5.3 million in a pad configuration. (Source: Hart Energy)



Richard Mason, Chief Technical Director, Upstream, E&P

## Reported Utica Test Results (54 Total Wells)



Results reported on 25 wells drilled to the Utica formation in Ohio and Pennsylvania show the concentration of wells by county, with Carroll County, Ohio, leading the way. (Source: Company reports and Imperial Capital LLC, courtesy of EV Energy Partners LP)

for Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Virginia, West Virginia, and Washington D.C. — one of the most heavily populated and heavily industrial areas of the US — averaged 10 Bcf/d of gas from April 2009 to 2011. Gas production from the area, primarily from the Marcellus, reached that 10 Bcf/d mark in April 2013.

Barclays expected gas production from the region to increase by 3.6 Bcf/d in 2013 and another 3.3 Bcf/d in 2014.

“Our projections for production growth suggest that Marcellus/Utica output may surpass Northeast demand in 2014 on an annual average basis,” the report said. “The strong seasonality of consumptions means that the region’s needs are likely to exceed production during peak demand in the upcoming winter. However, storage capacity may be sufficient to cover the seasonal deficit by the next withdrawal season.”

The Williams Cos. Inc. predicted the gas production from the combined Marcellus and Utica formations would increase by more than 109% from 2012 to 2017 from 7 Bcf/d to 14 Bcf/d.

At the same time, it predicted liquids production would grow 510% from less than 200,000 b/d of NGL to 1.1 MMb/d in 2017.

Production gains would have been even greater, but the fast-moving upstream segment outstripped transportation and storage capacity of the area. New gathering systems, pipeline systems, and processing plants are coming onstream to meet that demand.

That de-bottlenecking activity is taking place so rapidly that Barclays Capital expects the region to become a net exporter in 2015.

Those production gains and the profits that allow companies to continue drilling and

producing in the face of low natural gas prices are man-made.

The Marcellus shale contains the hydrocarbons, but the production and profits come from detailed analysis of the rock and fracture alignments, longer laterals, more stimulation stages, the use of pad drilling to reduce rig moving expenses, and dozens of additional refinements that lower costs and increase production.

Even those improvements have to face economic realities. The August 2013 Barclays Capital report said 75 rigs were working the Marcellus and Utica plays, down from 107 rigs in 2012. Pad drilling helped reduce rig count, but economics played a part as well. As operators fulfilled commitments to drill to hold land, they followed profits to the liquids-rich segment of the oil and gas industry.

Opposition to horizontal drilling and fracturing in Pennsylvania also made it more politically acceptable to move drilling campaigns to West Virginia and Ohio.

Hot or not, the Marcellus has generated a major drilling effort. It also generated a major merger and acquisition market.



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A *Pittsburgh Post Gazette* article describing PricewaterhouseCoopers' research on acquisitions for \$50 million or more said the Marcellus accounted for 18 deals worth \$19.579 billion in 2012. Eleven Marcellus transactions saw \$9.633 billion change hands the following year.

As consolidation got tighter in 2012, seven exchanges brought a value of \$5.234 billion in 2012, including two deals worth \$685 million in 4Q 2012.

The Marcellus generated three sales for \$882 million in 1Q 2013.

The most active shale deals in 2Q 2013 were the Eagle Ford with three transactions for \$1.5 billion, the Marcellus with three exchanges worth \$416 million, and the Bakken with two acquisitions valued at \$910 million.

and produce more than \$6 billion in revenues for governments. The Manhattan Institute, in a similar study, calculated each shale well drilled generates approximately \$4 million in economic opportunities.

## Upper Devonian

The Upper Devonian formations formed some 390 million years ago from deposition in huge seas stretching from the southeastern US into Canada.

In the northeast, the Rhinestreet, Middlesex, and Burkett shales, from newest to oldest, offer the best potential for production. The Burkett doesn't extend into Ohio, but the Rhinestreet and Middlesex shales do exist there.

Upper Devonian shales tend to have fewer liquids than the Marcellus and Utica.



**THE MOST ACTIVE SHALE DEALS** in 2Q 2013 were the Eagle Ford with three transactions for \$1.5 billion, the Marcellus with three exchanges worth \$416 million, and the Bakken with two acquisitions valued at \$910 million.

—Steve Haffner

"The main story in the first quarter of the year continues to be about shale. We're seeing interest in both the Marcellus and Utica, and we don't expect to see that enthusiasm dissipate anytime soon," said Steve Haffner, a Pittsburgh-based partner with PricewaterhouseCooper's energy practice. "While that interest hasn't translated to a dramatic increase in the volume and value of shale deals in the region, potential buyers are seeking the right opportunities to establish their footprint in the area – or to expand – and that includes both private equity and foreign buyers."

As it provides natural gas to end users and profits to upstream, midstream, and downstream companies, the Marcellus play contributes measurable benefits for states and individuals. Even during the lower production period of 2010, the Marcellus put \$1.1 billion in state and local treasuries and supported approximately 140,000 jobs.

A study by Timothy J. Considine estimated increased access to the Marcellus shale could create 280,000 jobs

Moving south, the Chattanooga shale in Tennessee and Alabama offers the best potential for production, but it's a gas play, and current profit potential is small, if it exists at all.

Upper Devonian shale gave the US one of its earliest hydrocarbon wells. That distinction generally applies to a well drilled in 1821 to 27 ft in the Dunkirk shale in Big Fredonia, N.Y. After testing small amounts of gas, that pioneer operator deepened the well to 70 ft and produced enough gas to provide light to Fredonia's government buildings with enough left over for street lights.

The Dunkirk-equivalent Huron black shale started producing in the Big Sandy field in Kentucky in 1914.

The shales, which lie at approximately 6,000 ft to 6,500 ft, have produced small amounts of gas since that time. Some early Huron and Rhinestreet wells produced for more than 50 years.

A 1992 report prepared for the National Petroleum Council tested 49 Upper Devonian wells in Roane and Kanahwa counties in West Virginia and





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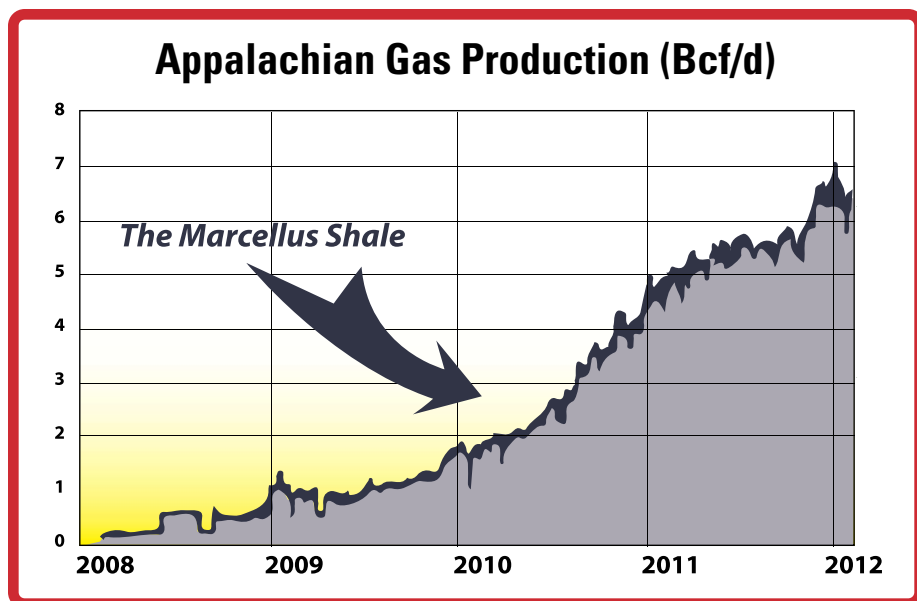
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Marcellus production catapulted from near-zero production in 2008 to 7 Bcf/d of gas by 2012. (Source: Hart Energy Mapping and Data Services)

their average estimated ultimate recoveries (EURs) at 274 MMcf of gas per well.

A 1986 report said EURs from some 10,000 shale wells in the Appalachian basin were at 3 Tcf of gas, or about 300 MMcf of gas per well.

That reputation for low-producing, long-lasting wells has changed recently as a few operators have applied Marcellus and Utica fracturing techniques in horizontal wells to improve the economics of the play.

By August, about 20 horizontal wells were drilled to the Upper Devonian in Pennsylvania and most produced dry gas.

Range Resources claims credit for opening the play after drilling its first Upper Devonian horizontal well in 2009.

With its large land position, the company estimated its Upper Devonian resources to be between 12 Tcf and 18 Tcf of gas, largely lying above its current Marcellus leases.

Stacked pay zones from that time period include the Rhinestreet, Middlesex, Genessee, and Burkett shales. The company holds an estimated 330,000 net acres in the wet gas area and 235,000 acres in the dry gas area in the state.

A test on the latest of four successful wells, this one in the super-rich gas area, tested for 10 MMcf/d of gas equivalent, consisting of 4 MMcf/d of gas,

172 b/d of condensate, and 825 b/d of NGL.

The company said its first four Upper Devonian wells performed better than its first four Marcellus wells.

Rex Energy lists 273 net potential locations in the Upper Devonian in Butler County, Pa., with EURs of 9.3 Bcf of gas containing 40% liquids for a total resource of 2.1 Tcf of gas equivalent.

That company's best well, drilled to the Burkett shale, tested at a five-day average of 7.302 MMcf of gas equivalent with 49% liquids.

CONSOL Energy is the third company to tap the Upper Devonian in Pennsylvania, and EQT Corp. is the fourth.

EQT anticipated drilling 22 Upper Devonian wells during 2013 and estimated 2.4 Tcf of gas equivalent in potential reserves from that zone. It has 170,000 net acres with Upper Devonian potential in western Pennsylvania and northern West Virginia. It estimated costs at \$5 million to \$6 million per well with returns of 6 Bcf of gas equivalent per wells with 4,800-ft laterals.

EQT's \$55-million program included testing the potential of coproducing Marcellus and Upper Devonian wells.

Antero Resources listed 44 Bcf of gas equivalent in proved reserves and 3.87 Tcf of gas equivalent in proved, probable, and possible resource on its Upper Devonian properties. It produced 4 MMcf/d of gas equivalent from the formation in the first half of 2013 and has 915 undrilled locations.

Antero's development cost currently is \$1.03/Mcf of gas equivalent with a 9% liquids content, but it expected that development cost to drop to 90 cents/Mcf of gas equivalent and a 20% liquids content of 20% by 2014.

Atlas Resource Partners, successor to the Atlas Energy company that sold most of its Appalachian holdings to Chevron for \$4.3 billion, is a major landholder in the Chattanooga shale in Tennessee. It has 100,000 net acres in the gas-prone formation. ■



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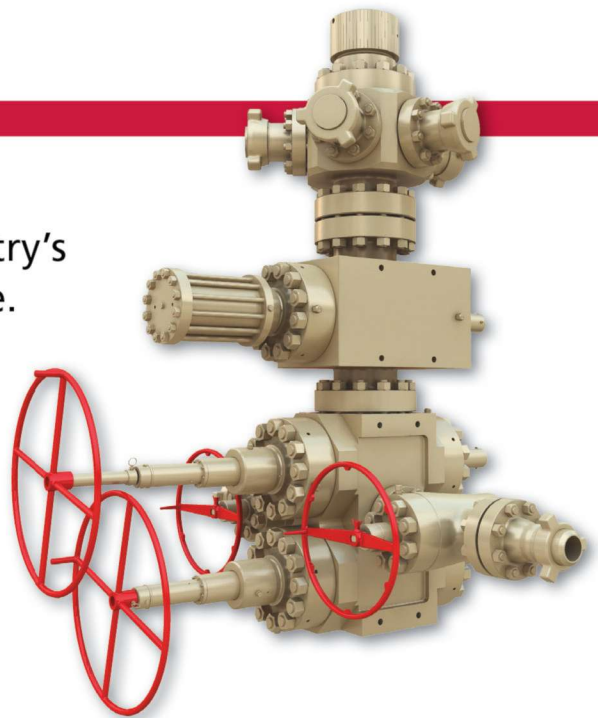
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# The Upper Devonian Rhinestreet Shale

A fresh target getting consideration in the Appalachian basin is the Rhinestreet, a thick shale that lies above the Marcellus.

**By Gary G. Lash**  
Contributing Editor

The Upper Devonian Rhinestreet shale of the West Falls formation, one of the thickest black shale units of the Appalachian basin, can be traced in the subsurface from eastern Tennessee, where it is no more than 5 ft to 10 ft thick, to outcrop in western New York where it comprises ~185 ft of heavily fractured, dark gray to black, thinly laminated pyritic shale, sparse thin siltstone beds, and carbonate concretion horizons. The Rhinestreet of outcrop is underlain by the Cashaqua shale, an organic-lean unit, with the contact being sharp and easily recognized. It passes upward through an interval of interbedded black and gray shale into the Angola shale, and the contact is generally recognized as a discontinuous concretionary carbonate layer. Total organic carbon (TOC) of the Rhinestreet shale ranges from greater than 10% at its base to 1% to 2% within its transitional contact with the Angola shale. Comparison of the S2 Rock-Eval parameter with TOC indicates that organic material of the Rhinestreet is dominantly Type II/Type III (liquid- and gas-prone) kerogen of marine origin, consistent with the plot of hydrogen index (HI) vs. Rock-Eval  $T_{max}$  (Figure 1). The same plot suggests a vitrinite reflectance of the Rhinestreet shale of 0.65% to 0.9%, placing this organic-rich unit where it was sampled in western New York within the oil-generating window. Indeed, meas-

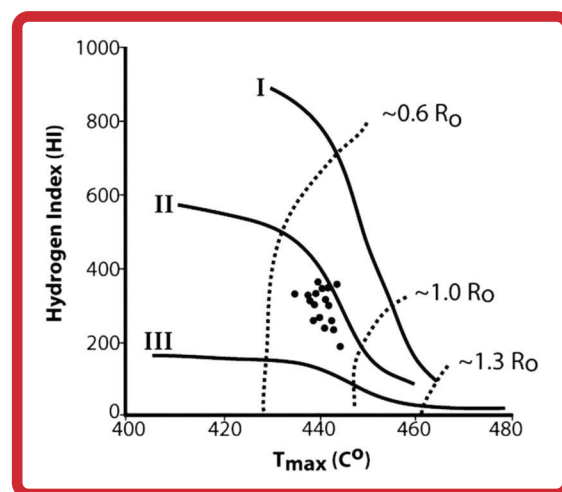


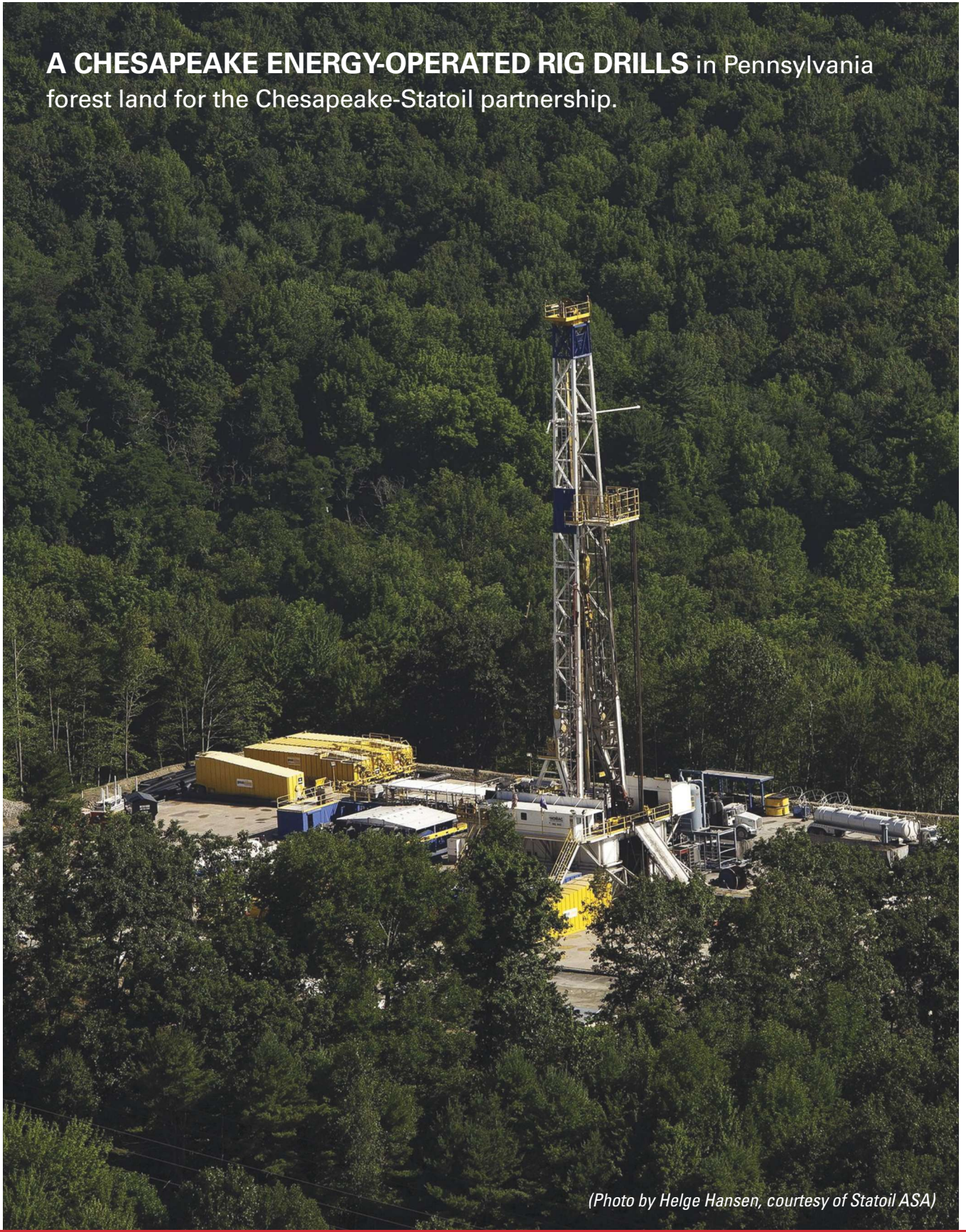
Figure 1. Van Krevelen plot of HI vs.  $T_{max}$  for the Rhinestreet shale data. (Images and data courtesy of G. Lash)

ured vitrinite reflectance values of Rhinestreet gas well cuttings and field samples range from 0.52% to 0.81%. It is likely, however, that the thermal maturity of the Rhinestreet shale increases to the south and east of the sampled portion of the basin.

X-ray diffraction (XRD) analysis of Rhinestreet and Cashaqua samples reveals mineralogic differences. Analyzed Rhinestreet samples are generally more quartzose (37% to 45% vs. 30% to 33% for the Cashaqua shale), and the quartz comprises angu-



**A CHESAPEAKE ENERGY-OPERATED RIG DRILLS** in Pennsylvania forest land for the Chesapeake-Statoil partnership.



*(Photo by Helge Hansen, courtesy of Statoil ASA)*



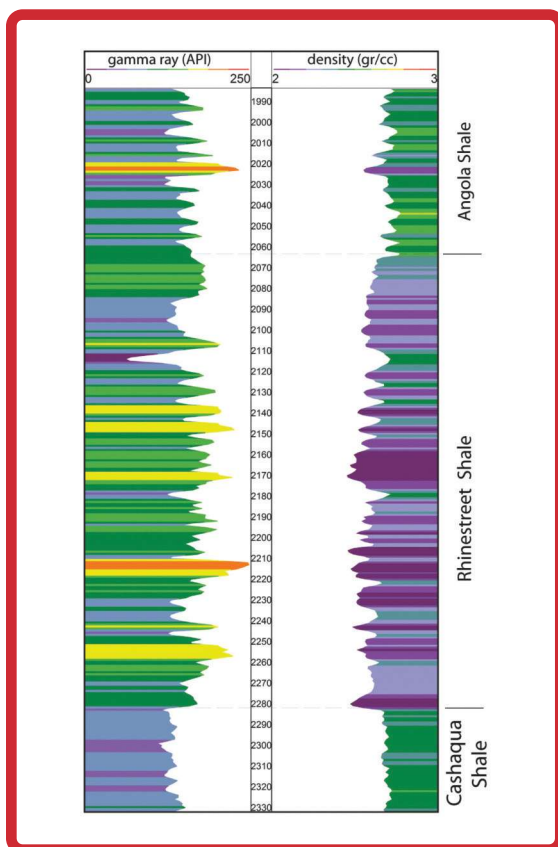


Figure 2. A gamma-ray and density log illustrates the stratigraphy of the Rhinestreet shale. The well is located in Chautauqua County, N.Y.

lar detrital grains as well as rounded nondetrital grains, perhaps precipitated from dissolved biogenic grains (radiolaria). Clay minerals comprise a greater proportion of analyzed Cashaqua samples (47% to 49% vs. 34% to 42% for the Rhinestreet). Illite is by far the dominant clay mineral in both units, followed by chlorite and kaolinite. The great abundance of illite likely reflects derivation of clastic sediment from a low-grade metamorphic source terrane rather than an indicator of thermal stress sustained by these deposits.

Reservoir characteristics of the Rhinestreet and Cashaqua shales were investigated by mercury injection capillary pressure (MICP) analysis of those samples analyzed by XRD. Samples were prepared so that pressure measurements were made perpendicular to bedding. Though capillary pressures (10% saturation levels) of both sets of samples are quite high, Rhinestreet entry pressures ( $\sim 10,007$  psia) are

more than five times those of the Cashaqua samples ( $\sim 1,800$  psia). The calculated porosity of the Rhinestreet shale sample suite is  $3.9\% (\pm 0.9\%)$ , less than half that of samples collected from the immediately underlying Cashaqua shale ( $8.5\% \pm 1.2\%$ ). MICP measurements indicate that the Rhinestreet shale ( $10^{-20} \text{ m}^2$ ) is two orders of magnitude less permeable than the Cashaqua shale ( $10^{-18} \text{ m}^2$ ). These differences likely reflect the very small average pore throat diameter of the Rhinestreet sample suite ( $\sim 8 \text{ nm}$ ) compared with that of the analyzed Cashaqua samples ( $\sim 19.2 \text{ nm}$ ). Three explanations can account for this: (1) the strongly oriented planar clay grain microfabric of the organic-rich shale precludes fluid migration perpendicular to layering; (2) bitumen generated during catagenesis of the Rhinestreet clogged pore throats; and (3) compaction related to the squeezing of abundant ductile organic matter into voids and pore throats. The above described porosity and permeability values of the Rhinestreet samples reflect a level of thermal stress less than that required for peak methane generation. It is likely that the same samples subjected to thermal stress  $> \%R_o = 1.0$  would reveal the effects of thermal maturation induced nanoporosity development within organic particles.

Field investigations of the Rhinestreet shale provide a comprehensive overview of the geometry and density of natural fractures hosted by these rocks. Locally, as many as five systematic vertical joint sets have been recognized in outcrop. The most pervasive joint sets, regionally and stratigraphically, include east-northeast-striking ( $060^\circ$  to  $075^\circ$ )  $J_1$  joints and a younger northwest-trending set ( $315^\circ$  to  $345^\circ$ ),  $J_2$  joints. Joints of both sets, but especially  $J_1$  joints, are more evenly and closely spaced (i.e., higher degree of saturation) in the organic-rich Rhinestreet shale as opposed to the underlying and overlying organic-lean Cashaqua shale and Angola shale, respectively. Moreover,  $J_2$  joints are locally more densely formed in the Angola shale than are associated  $J_1$  joints.

$J_1$  and  $J_2$  joints are interpreted to be natural hydraulic fractures that propagated in response to burial-induced generation of hydrocarbons. The  $J_1$ - $J_2$  chronology tracks the tectonic lithospheric stress field as it evolved through the Alleghanian



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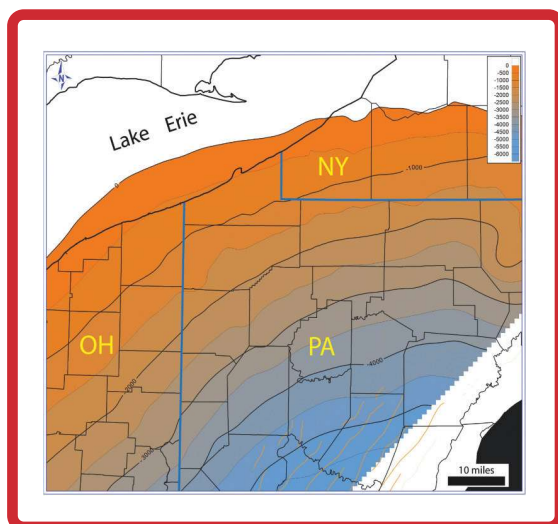


Figure 3. A structure contour map shows the base of the Rhinestreet shale in western New York, northeastern Ohio, and northwestern Pennsylvania.

orogeny. Overpressuring of organic-rich deposits, including the Rhinestreet shale, and associated natural hydraulic fracturing resulted from the transformation of kerogen to hydrocarbons close to or at maximum burial depth during the Alleghanian orogeny.  $J_1$  joints formed preferentially in Devonian

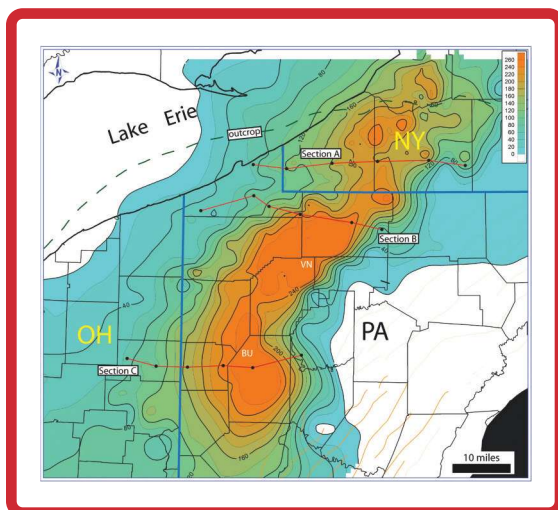


Figure 4. An isopach map of the Rhinestreet Shale in western New York, northeastern Ohio, and northwestern Pennsylvania shows the location of cross sections shown in Figure 5. The dashed green line shows the outcrop line based on the structure contour map (Figure 3). Thickness values beyond the limit of the outcrop line are projected.

black shale throughout the Appalachian basin early in the Alleghanian tectonic cycle. Some of these early joints escaped the black shale to propagate into overlying organic-lean deposits. The fact that  $J_2$  joints are locally more densely formed in gray shale suggests that by the time these fractures started to form, the black shale had been generating long enough to propagate joints well up into the overlying succession. Moreover, the formation of both  $J_1$  and  $J_2$  joints close to or at peak burial depth means that joints of both sets are carried by these rocks in the subsurface though they are likely closed. Also,  $J_1$  joints are oriented roughly parallel with  $S_{Hmax}$  of the contemporary stress field, whereas  $J_2$  joints, by virtue of their orientation at high angles to  $S_{Hmax}$ , are subjected to higher present-day joint normal stresses. Further, the greater density of  $J_1$  joints relative to that of the  $J_2$  joints in the Rhinestreet shale and their subparallelism with the  $S_{Hmax}$  of the contemporary lithospheric stress field likely impart a stress-induced permeability anisotropy that could enhance productivity of hydraulically stimulated north-northwest directed laterals.

Stratigraphic studies of the exposed Rhinestreet shale of western New York reveal the presence of four transgressive-regressive sequences, each one comprised of an organic-rich interval overlain by a relatively thin horizon of organic-lean deposits. Each black shale-gray shale sequence appears to reflect a single sea-level cycle in which carbonaceous sediment accumulated as sea level rose followed by a lowering of sea level and consequent accumulation of gray shale. Mapping of the Rhinestreet east of the Lake Erie shoreline demonstrates a reduced thickness of black shale intervals as the thickness of organic-lean shale increases. Indeed, the basal organic-rich horizons of the four Rhinestreet sequences pass eastward of the Lake Erie shoreline into discrete tongues separated by thicker successions of gray shale and siltstone. Similar lateral facies changes likely occur to the south, into western Pennsylvania.

The base of the Rhinestreet shale in the subsurface is most readily defined by a sharp decrease in density and a more gradual increase in gamma-ray response, both reflective of increasing TOC upward from the Cashaqua shale (Figure 2). The Rhinestreet-Angola contact is not as obvious in log



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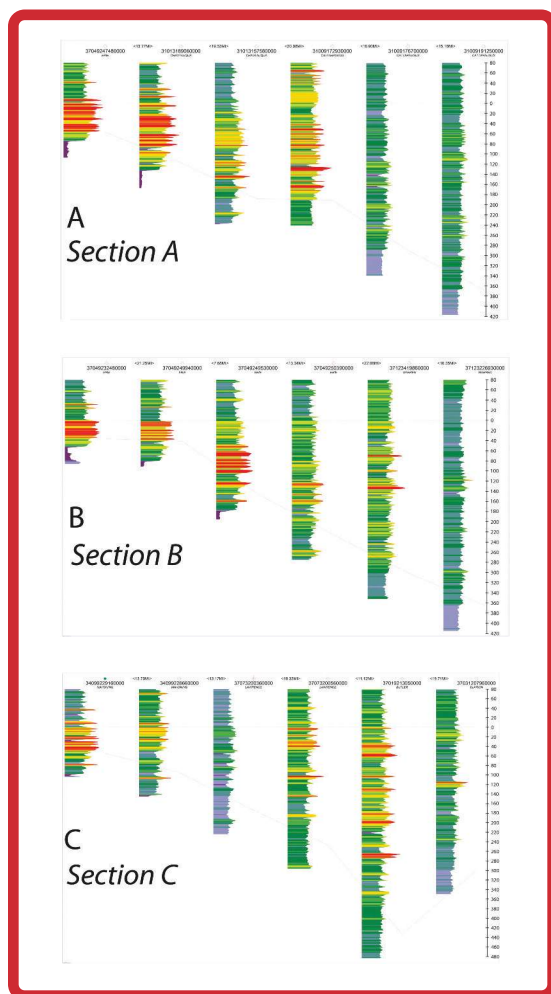


Figure 5. Gamma-ray cross sections through the region of thickness organic-rich Rhinestreet shale. Refer to Figure 4 for locations. Dashed blue lines show the base of the Rhinestreet as well as the projected top of the complete Rhinestreet (radioactive or organic-rich and organic-lean). The latter is principally included to illustrate the nature of lateral facies changes of the unit is not intended to be a robust correlation line.

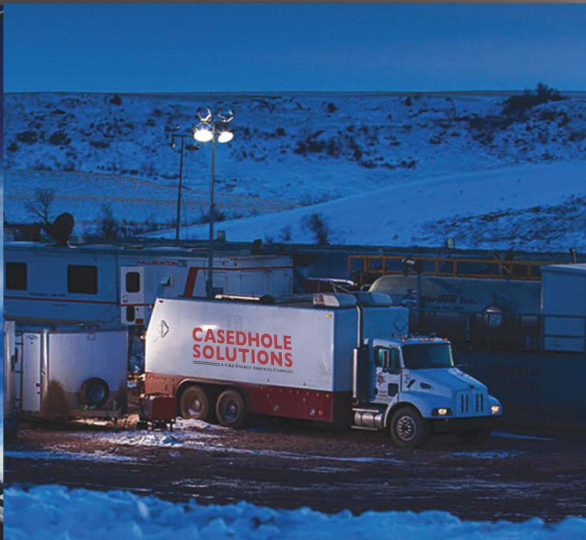
signature. The thin diagenetic carbonate horizon used to define the contact in outcrop is rarely observed in either gamma-ray or density logs because of its discontinuous nature and/or thickness relative to log tool resolution. However, the density log signature, a robust proxy for TOC in this unit, has proven to be a reliable means of delimiting the top of the Rhinestreet. The Rhinestreet of the subsurface of northwestern Pennsylvania, western New York, and northeastern Ohio describes a regional strike of

~N50°E to N70°E and a generally uniform gentle dip to the south-southeast (Figure 3). The only irregularity or disturbance of this trend occurs in north-central Pennsylvania extending into the Southern Tier of New York and probably reflects the impress of open folding documented from this region of the basin. The isopach map of the Rhinestreet shale (Figure 4) defines a gradual eastward thickening from eastern Ohio into western Pennsylvania and western New York. A more or less elongate region of thick radioactive (high gamma-ray response) Rhinestreet shale is oriented generally north-south to northern Venango County where it trends in a more northeasterly direction, thinning toward the outcrop line (zero depth contour) along the Lake Erie shoreline of western New York (Figure 4). The change in orientation of the thickness high occurs close to the trace of the Tyrone-Mt. Union cross-structural discontinuity, though the lineament is not evident from the structure contour map (Figure 3). The thickness of the radioactive Rhinestreet diminishes rapidly to the east as revealed in several gamma-ray cross sections, especially in western New York and north-westernmost Pennsylvania (Figure 5). This trend, which mirrors that documented from the field relations described above, likely reflects the eastward increase of detrital flux relative to organic input. The above-described relationship, however, is not as obvious in the southerly part of the central-western Pennsylvania region of thick Rhinestreet where cross sections suggest increasing richness toward the region's maximum thickness in Butler County, Pa., before diminishing rapidly to the east (Figure 5C).

The Upper Devonian succession of the Appalachian basin, including the Rhinestreet shale, has been tested in southwestern Pennsylvania where early results suggest that these deposits can be developed economically. Indeed, assuming such promising early results, some have postulated that the Appalachian basin could hold twice as much natural gas as projected based on considerations of the Utica and Marcellus shales alone. Further, given that the Rhinestreet shale is locally quite thick, perhaps greater than 200 ft in western Pennsylvania, and that it is several hundred feet shallower than the Marcellus shale, it is not unreasonable to expect that these deposits may yield abundant NGL. ■



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# Liquids Action Drives Appalachian Profits

Northeastern shales offer tremendous gas volume potential, but the profits lie in wet gas and liquids.

**By Don Lyle**  
Contributing Editor

Operators large and small find bottom-line gains in parts of the Marcellus and Utica fairways, while Upper Devonian shales aim for a spot on center stage.

Appalachian shales show off the three major phases of major shale plays. The Marcellus is in full development in its liquids-rich fairway; the Utica shows the enthusiastic activity of early, emerging development; and the Upper Devonian shale piques operators' interest with its potential as the few early wells promise rewarding returns.

This section offers profiles of most of the major operators in all three plays with reviews of current activity and glances at future potential.

## US Key Players

### AB Resources LLC

- *Land: More than 90,000 net acres*
- *Looking for drilling partners*

AB Resources LLC pins its livelihood on prime Marcellus shale lands in Pennsylvania and West Virginia.

Its properties are in Greene and Washington counties in Pennsylvania and Brooke, Ohio, and Marshall counties in West Virginia. Much of the acreage is contiguous in the liquids-rich area of the Marcellus fairway. The company has a history in the area with newfield discoveries in the Upper Devonian in Greene County, Pa., as early as 2007.

The privately held company looks for acquisition opportunities and drills on its own properties. It operates all of its assets, which include hundreds of horizontal Marcellus locations near interstate pipelines.

According to the company's website, "AB Resources is aggressively moving forward with an increasing number of new drilling initiatives while maintaining hundreds of unconventional Marcellus and Upper Devonian wells."

Management aims for fast-track expansion with value creation.

### American Energy Partners LP

- *Land: At least 22,535 net acres*
- *Aubrey McClendon rides again*

Although sales hadn't been confirmed at press time, multiple financial organizations in the oil and gas industry pegged Aubrey McClendon's American Energy Partners LP as the purchaser of 22,535 net acres of Utica shale land at a cost of US \$12,900 per acre.

EV Energy Partners LP sold the tract to an unnamed buyer for \$284.3 million, according to David Tameron, senior analyst at Wells Fargo. The properties are in Guernsey, Harrison, and Noble counties in Ohio in the wet gas window.

He also said American Energy Partners has been talking with Shell concerning the purchase of another 50,000 acres in the Utica in Ohio – a deal worth an estimated \$675 million.

IHS Energy lists no activity in the Utica by American Energy Partners.

As the former CEO of Chesapeake Energy, McClendon assembled some 1.2 million acres of land in the Utica shale.



## Anadarko Petroleum Corp.

- *Land: More than 560,000 net acres*
- *Appalachian operations low on priority list*

Anadarko Petroleum Corp., with its wallet in a number of unconventional plays across the US, found good reasons to focus activity on the Marcellus shale.

The company has drilled more than 70 wells to the formation at a cost of approximately US \$5/boe. Those wells return a before-tax net present value of around \$1 million. Overall, Anadarko controls 385 Marcellus wells.

The company's Marcellus development wells offer a development cost matched only by its Greater Natural Buttes field in Utah, and the Marcellus returns a better net present value. The company has curtailed drilling at Greater Natural Buttes and in the Marcellus until natural gas prices improve, according to an Aug. 13, 2013, webcast.

Its wells in Wattenberg field in Colorado, in the Permian basin, and in the Eagle Ford in Texas all cost more to develop but offer a higher net present value per well.

Anadarko estimates it holds more than 1 Bboe in net risked resource in the Marcellus in approximately 760,000 gross (260,000 net) acres of land. Those properties include operated assets in Centre, Clinton, and Lycoming counties in Pennsylvania and nonoperated land in Potter, Sullivan, and Tioga counties, also in Pennsylvania.

According to the company's website, the Marcellus holds the second largest deposit of natural gas in the world.

The company and its partners have produced approximately 350 Bcf and invested some \$6 billion in Pennsylvania and the Marcellus shale. According to the company's website, it produces more than 2 Bcf/d of gas, gross, which is enough gas to heat 10 million US homes per day.

The company also is a member of the Appalachian Shale Recommended Practices Group, formed in May 2012 by 11 large producers to develop recommended standards and practices for development of Marcellus oil and gas.

Among practices used by Anadarko are a closed-loop fluids control system with secondary containments, triple pad liners, two-person fluid transfer, and continuous contractor training. It also recycles water used in drilling and fracturing.



Anadarko lowered drilling times to about 20 days as it worked the learning curve on its Marcellus operations in Appalachia. (Photo courtesy of Anadarko Petroleum Corp.)

At one point, Anadarko had interests in 13 non-operated drilling rigs in the play and, on its operated wells, reduced drilling times to 20 days per well.

In 2010 the company signed an agreement that made Mitsui E&P USA LLC a 32.5% partner in its Marcellus properties. Mitsui agreed to spend \$1.4 billion to earn some 100,000 net acres in the play by funding all of Anadarko's development costs in the Marcellus in 2010 and 90% through 2013.

The company holds an even larger position in the Utica shale in Ohio, amounting to approximately 390,000 gross (300,000 net) acres.

Most of Anadarko's Utica properties are in Holmes, Tuscarawas, Coshocton, Muskingum, Noble, and Guernsey counties, but the company completed its initial exploration program in early 2013 after drilling and completing seven wells. It drilled two wells in 2Q 2012 and five more in 3Q 2012.

Among its better wells, the Brookfield A-3H in Noble County tested for 9,500 bbl of oil and 12 MMcf of gas in its first 20 days on stream.



### Antero Resources Corp.

- *Land: 431,000 net acres*
- *Fast track speeds production*

Antero Resources Corp. holds a substantial land position in the three most active shales in the Appalachian basin, and it's using that position to raise production rapidly.

The company holds 102,000 net acres in the Utica shale in Ohio and another 329,000 net acres in the southwestern core of the Marcellus play. Some 170,000 net acres of Upper Devonian potential pay lie under the Marcellus properties.

In an August presentation the company said it completed 188 horizontal Marcellus wells, 11 Utica horizontal wells, and two Upper Devonian horizontal wells. The three Utica wells online give the company an estimated net production of 25 MMcf/d of gas equivalent. The other eight wells were awaiting startup at that time.

The company's activities are paying off. Production rose 114% in the first half of 2013 to 421 MMcf/d of gas equivalent, including 3,300 b/d of liquids.

By early August net production increased to 580 MMcf/d of gas equivalent, including 8,400 b/d of liquids. The company had an additional 160 MMcf/d of gas equivalent, including 5,700 b/d of liquids constrained or shut in awaiting pipeline completions, compression, or processing capacity. It expected August 2013 infrastructure additions to ease those restrictions on production.

Antero's land position gives it more than 4,500 drilling locations with 6.3 Tcf of gas equivalent in proved reserves at the end of June 2013.

Proved, probable, and possible (3P) gas reserves reached 27.7 Tcf of gas equivalent, while 3P liquids reserves stood at 667 MMbbl.

The company's proved developed Appalachian reserves had a present value, discounted at 10% a year (PV-10), of US \$3 billion and total PV-10 reserves of \$5.4 billion.

The Marcellus made up the biggest part of the company's shale assets with 596 Tcf of gas equivalent in proved reserves, 18.7 Tcf of gas equivalent in 3P reserves, and 465 MMbbl in 3P liquids. Antero produced 465 MMcf/d of gas equivalent from the Marcellus in the first half of 2013 and held 2,941 undrilled locations.

The company is running 15 rigs and two fracture crews to develop the Marcellus. Those rigs are drilling horizontal wells with 7,000-ft laterals in less than 30 days with a 100% success rate.

The Utica represented the company's second largest asset with 279 Bcf of gas equivalent in proved reserves and 5.25 Tcf of gas equivalent in 3P reserves with 164 MMbbl in liquids. It produced 1 MMcf/d of gas equivalent from the formation in the first half of 2013 and had 720 undrilled locations. Antero has three rigs working the Utica shale.

The Upper Devonian is the smaller of the three plays with 44 Bcf of gas equivalent in proved reserves, 3.87 Tcf of gas equivalent in 3P reserves, and 38 MMboe in 3P liquids.

Antero produced 4 MMcf/d of gas equivalent from that formation in the first half of 2013 and had 915 undrilled locations.

The company claimed a current *pro forma* development cost of \$1.03/Mcf of gas equivalent but expected net future development costs would drop to 90 cents/Mcf of gas equivalent. Liquids make up 9% of production, the company added, and should grow to approximately 20% by 2014.

Antero posted capex of \$1.69 billion in 2012 with 53% dedicated to the Marcellus and 41% to the Utica. It drilled three Utica wells and 83 Marcellus wells.

For 2013 it originally planned to spend \$1.95 billion with 85% directed to the Marcellus and 15% to the Utica. Those funds should pay for 135 Marcellus wells and 21 Utica wells.

In September 2013, however, the company raised its expectations and its Appalachian drilling budget.

During 2Q 2013 Antero began completing Marcellus wells with fracture stage lengths that ranged from 150 ft to 250 ft instead of the 350-ft length it previously used. While history on the shorter lengths is limited, initial production rates on the first 17 short-stage wells was 25% to 35% higher than on wells in the same area with longer stage lengths at a cost of \$1.5 million to \$2 million more for 200-ft stage lengths.

With that background, company directors added \$500 million to the 2013 capital budget, raising it to \$2.45 billion, with \$1.45 billion of that money going to drilling and completion work,

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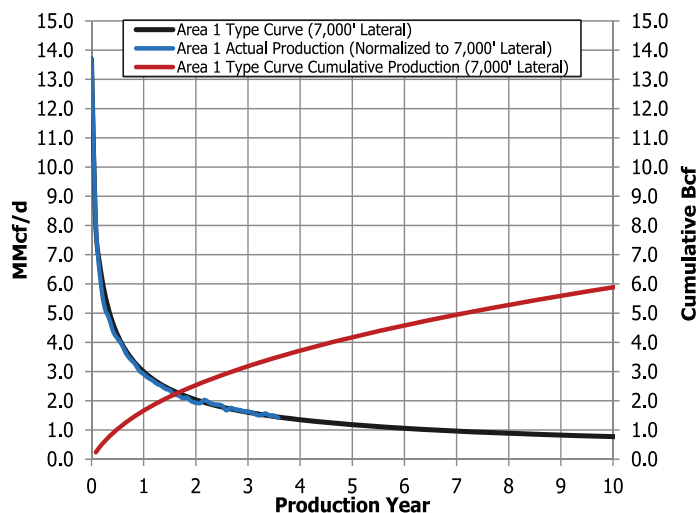
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### Antero Marcellus 1.5 Bcf/1,000' Type Curve<sup>(1)</sup>



**Note:** Type curve reflects pre-processed wellhead production.

1. Wells normalized to time-zero; production for each well normalized to 7,000' lateral length.
2. Actual wellhead IPs, not normalized.
3. Excludes 6 wells that are shut-in and waiting on infrastructure.

A type curve on a Marcellus well with a 7,000-ft lateral and 1.5 Bcf of estimated production per 1,000 ft shows initial production of 13.8 MMcf/d, dropping to 2 MMcf/d at two years and leveling off to produce a cumulative 6 Bcf of gas at the end of 10 years. (Graph courtesy of Antero Oil & Gas Corp.)

\$400 million for land acquisition, and \$600 million for infrastructure.

That money will fund 36 completions for liquids-rich Marcellus wells and allow the company to drill three additional horizontal wells in the Marcellus and four horizontal wells in the Utica formation.

For the year, Antero now plans to drill approximately 128 net Marcellus and 20 net Utica wells.

#### Atlas Resource Partners LP

- Land: Approximately 108,500 acres
- Hooking up wells in the Marcellus and Utica

Atlas Resource Partners LP, a master limited partnership, is rebuilding with the help of the Marcellus and Utica formations and a strong foundation from Atlas Energy, which was acquired by Chevron Corp. for US \$4.3 billion in 2011.

The company holds approximately 3,000 net acres of land in the Marcellus play in Lycoming County, Pa. According to an August 2013 presentation, it recently completed eight wells with 131 fracture stages in the play, and those wells were scheduled to come online in 3Q 2013. It reported average initial potentials of 20 MMcf/d of gas equivalent from well tests and the potential to drill 15 to 20 horizontal wells.

The company already operates more than 8,600 mature, low-decline-rate shallower producing wells in western Pennsylvania, eastern Ohio, and southwestern New York.

Atlas operates more than 200 vertical and 30 horizontal Marcellus wells in southwestern Pennsylvania.

The company controls another 5,500 net acres in the Utica play in addition to some 2,500 legacy Ohio wells drilled to other formations. By September 2013 it had drilled five Utica wells on a pad in Harrison County, Ohio. Atlas was fracturing and completing the wells, and those wells also were scheduled to come onstream in 3Q 2013.

The company holds another 100,000 net undeveloped acres in the Chattanooga shale in northeastern Tennessee. Although the Chattanooga isn't developed, the company has more than 450 wells in other formations and has two gas processing plants in eastern Tennessee with some 35 MMcf/d of gas processing capacity.

#### Cabot Oil & Gas Corp.

- Land: Approximately 200,000 net acres
- High returns from natural gas

Cabot Oil & Gas Corp. got its start in the Appalachian basin, and its position in the sweet spot of the Marcellus play rates the lion's share of the company's capital investment.

The company has more than 3,000 identified locations in the play, giving it more than 25 years of Marcellus drilling inventory at its current level of drilling. The formation offers Cabot returns that "rival or exceed" returns from the top liquids plays at current commodities prices, according to an August 2013 presentation.

The company also has substantial properties in the Eagle Ford in South Texas and in the Marmaton and Pennsylvania Lime in western Oklahoma and the Texas Panhandle.

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A finding cost of US 49 cents/Mcf of gas equivalent in 2012 was a big contributor to those high returns from the Marcellus.

The company ran six drilling rigs in the play in 3Q 2013 and planned to complete approximately 100 wells during the year.

Returns were the primary reason Cabot invested 63% of its \$979 million capital budget in the Appalachian basin in 2012 and raised that number to 65% of a \$1.1 billion to \$1.2 billion budget in 2013.

By Aug. 6, 2013, the company had 226 horizontal and 39 vertical wells on production, 10 wells with 245 fracture stages waiting on pipeline hookup, 14 wells with 266 fracture stages completing, and 15 wells with 347 fracture stages waiting on completion equipment.

Cabot took advantage of the learning curve to improve returns, a process that continued into 2013. In 2010, with 13% of its land held by production, the company reduced spacing between stages to 250 ft from 300 ft and had 44 producing horizontal wells.

The following year, with 29% of its land held by production, the company reduced drilling days and completion costs per stage and claimed 107 producing horizontal wells.

In 2012, 43% of the land was held by production, and the company started 200-ft spacing between stages. It also started testing the Upper Marcellus and tested downspacing that year. At the same time, the company derisked the eastern edge of its acreage. It had 185 producing horizontal wells by year-end.

The company expected to finish 2013 with 60% of its acreage held by production as it moved into development mode with improved efficiency and reduced costs. It also planned to continue Upper Marcellus and downspacing tests.

During the learning curve Cabot increased horizontal leg lengths from 2,100 ft in 2008 to 4,100 ft in 2012. Between the same years, average initial potentials rose from 7.4 MMcf/d to 17.4 MMcf/d, and average 30-day initial potentials climbed from 5.9 MMcf/d to 14.5 MMcf/d.

The curve also dictated more stages, from an average 4.6 in 2008 to 17.7 in 2012. The combination of improvements increased estimated ultimate recoveries from 5 Bcf per well in 2008 to 14.1 Bcf per well in 2012.

Cabot's drilling days dropped from 26 in 2010 to 14 in the first eight months of 2013 with a record eight days to drill one well to total depth.

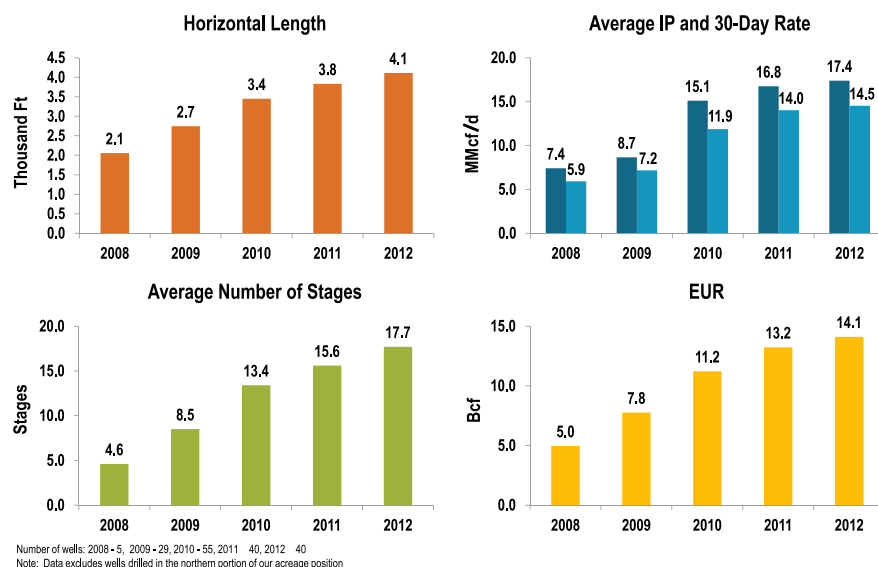
Completion costs per stage also fell from \$165,000 in 2010 to less than \$90,000 in August 2013.

The improvements show up in the company's returns. For a well costing \$6.5 million to drill and complete, Cabot expects a before-tax internal rate of return of 70% with \$3/MMBtu gas and 100% with \$3.50/MMBtu gas on the New York Mercantile Exchange.

On a \$6 million well, the return increases to 80% with \$3 gas and 115% with \$3.50 gas.

In July 2013 the company produced 1.2 Bcf/d of gas, gross, from 226 producing horizontal wells.

The company's recent achievements include completion of a two-well pad as a 5-mile step-out northeast of its Zick area, with 27

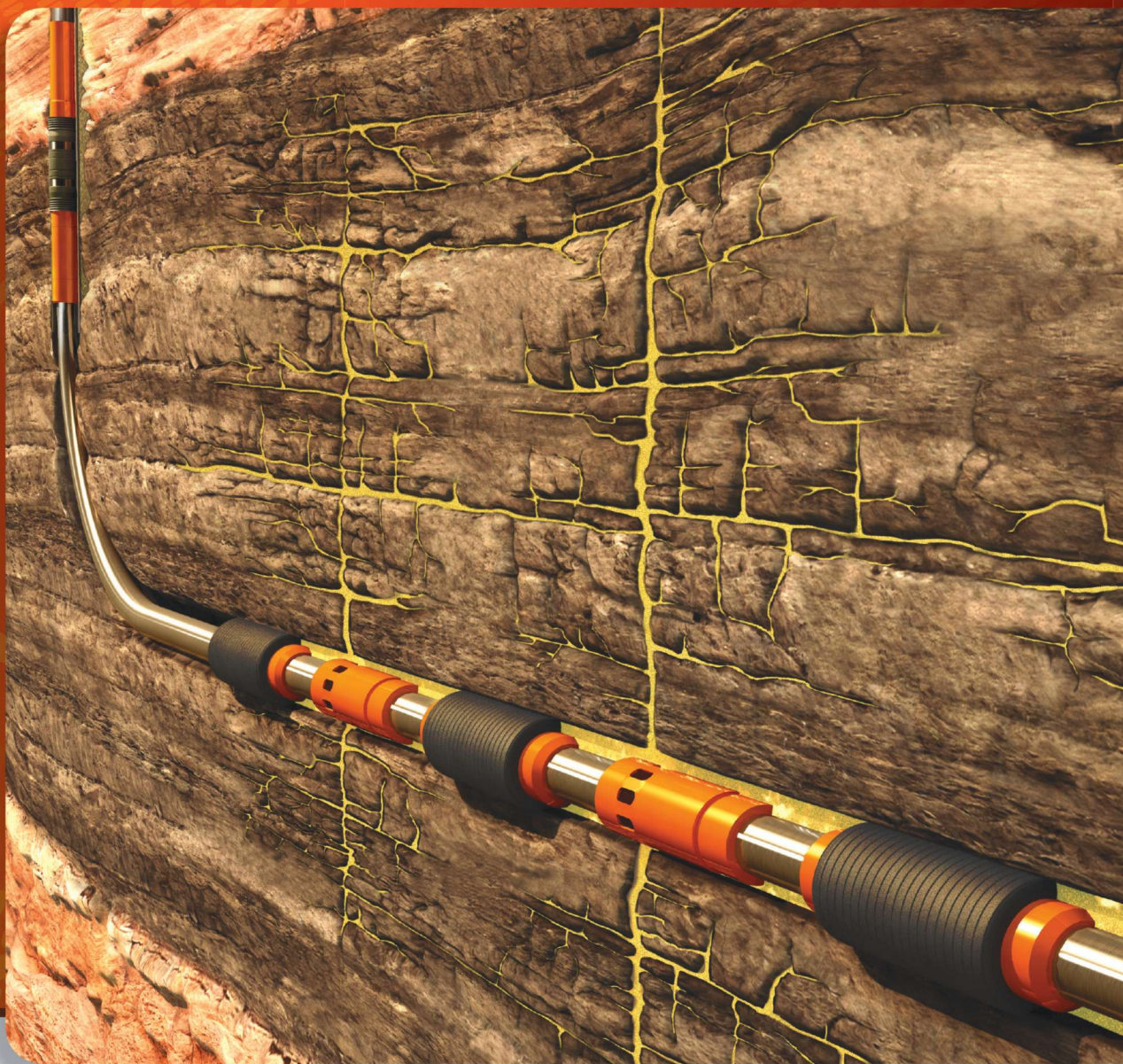


Graphs show advantages of the learning curve as Cabot Oil & Gas improved results between 2008 and 2012. (Image courtesy of Cabot Oil & Gas Corp.)



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fracture stages for an initial production rate of 34.8 MMcf/d and an average 30-day rate of 28.1 MMcf/d.

Another two-well pad with a 2-mile north step-out from the Zick area, completed with 37 fracture stages, tested for an initial 51.2 MMcf/d and a 30-day average rate of 43.6 MMcf/d.

### **Carrizo Oil & Gas Inc.**

- *Land: 83,700 net acres*
- *Concentrating on liquids plays*

Carrizo Oil & Gas Inc. downplayed its activities in the Marcellus and upgraded its Utica operations as it gave liquids production a higher priority than gas development.

The company holds some 68,200 net acres of land in the Marcellus with 13 MMboe in proved reserves. That position makes the Marcellus the company's largest holding among plays that include the Niobrara, Barnett, and Eagle Ford.

At this point, however, the company is only drilling required lease-management wells in the Marcellus, and it's curtailing production when gas prices are particularly low. It spent US \$79 million in the Marcellus in 2012 and plans to spend \$70 million in the play in 2013, according to an August 2013 presentation.

Currently, the company is only working the Marcellus in northeast Pennsylvania on 3,400 net acres of land with 3,100 drillable acres. It has 13 net proved developed wells, six net proved undeveloped wells, and another 31 probable proved undeveloped wells.

Carrizo is drilling those wells with 5,000-ft laterals and an average 16.7 fracture stages with 1,000-ft spacing between laterals on 125-acre well spacing.

The company holds 29.4 MMboe in proved and probable (2P) reserves in the Marcellus with a 2P net present value, discounted at 10% a year, of \$193 million.

From 2010 to 2012, Carrizo worked to delineate and hold its northeastern Pennsylvania Marcellus acreage and to optimize drilling techniques. It currently has 53 gross (18.6 net) wells in Susquehanna County and 28 gross (8.4 net) wells in Wyoming County.

For 2013 the company plans to drill 32 gross (10 net) wells and to fracture 32 gross (11 net) wells.

It has a current capacity of more than 60 MMcf/d.

The company has 15,500 net acres in the Utica play in Ohio. It spent \$20 million on the Utica and other plays in 2012 and plans to raise that to \$25 million in 2013.

Of the company's 15,500 net acres in the play as a 50:50 partner with Avista Capital Partners, it considers 12,400 acres drillable.

Carrizo began drilling its first well in that play in August 2013 and plans another by year-end. Designs call for 6,000-ft laterals and 21-stage fracture treatments. With no wells drilled, the company has a probable 59.8 MMboe in reserves in the Utica with a 2P net present value of \$689 million.

The acreage has the potential for as many as 85 net wells, and the company is acquiring more land as part of an optional second joint venture.

Most of the acreage is in the 1,000 boe/d fairway.

### **Chesapeake Energy Corp.**

- *Land: 5.415 million net acres*
- *Huge leaseholder and prominent driller*

Chesapeake Energy Corp. bills itself as the largest leaseholder in the Utica shale play and the largest in the Marcellus play as it maintains its position as one of the major forces in any basin where it chooses to operate.

Although the company hasn't published a current breakdown of acreage in the plays, its eastern division is made up primarily of the Marcellus and Utica shales. The 10K form in its 2012 annual report said the eastern division had 1.497 million net developed leasehold acres, 3.413 million net undeveloped leasehold acres, and 508,000 net fee mineral acres for a total of 5.415 million net acres. Like other companies, some of its Marcellus land is potentially prospective for Upper Devonian shale production.

Subsequently, the company released more than 13,000 net acres of land in Broome and Tioga counties in New York as the state continued its moratorium on fracturing to more than six years.

Chesapeake acquired Columbia Natural Resources in 2005 and with it a history of Appalachian operations dating back to the mid-1900s.

Chesapeake started active operations in the Marcellus in July 2008 in Bradford County, Pa.



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According to the company's website, Chesapeake has more than 4,500 wells in West Virginia alone and produced more than 81 Bcf of gas equivalent in that state in 2011.

The company has spent approximately US \$3.5 billion in Ohio to date on E&P and bonus and royalty payments in the Utica shale play.

For 2013 the company has allotted 12% of its drilling and completion budget to the Marcellus and 10% to the Utica out of a total of approximately \$6 billion. The Marcellus share of that budget splits into 5% for the northern portion and 7% for the south. For perspective, the company set aside 36% of its total budget for the Eagle Ford and 30% for the Greater Anadarko basin, according to an August 2013 presentation.

In a 2Q 2013 report to shareholders, Chesapeake said it produced an average 85 MMcf/d of gas equivalent from the Utica during the quarter, up 48% from 1Q 2013. The average peak daily rate for the 42 wells that started producing during the quarter was approximately 6.6 MMcf/d of gas equivalent.

The company currently works 11 rigs in the Utica but plans to drop one of the rigs by year-end 2013. On the positive side, Chesapeake reduced its spud-to-spud cycle time to 18 days during the quarter, compared to 26 days for a Utica well a year earlier.

By the end of 2Q Chesapeake had drilled 321 Utica wells, including 106 producing wells, 93 wells waiting on pipeline hookup, and 122 wells being completed.

As takeaway capacity expanded in the Marcellus play, so did Chesapeake's sales. The company connected 131 wells to sales in 2Q 2013, up from 52 wells in 1Q. Oil accounted for about 2% of the company's Marcellus production in 2Q, with another 3% in NGL and 95% in gas.

The company produced approximately 780 MMcf/d of net gas equivalent from its northern dry gas region in 2Q, representing a 58% gain from 2Q 2012 and an 11% increase from the previous quarter.

The average peak daily production rate from the 79 Marcellus wells that started producing in 1Q was approximately 9 MMcf/d of gas equivalent. The company is operating five rigs in the northern area.

The southern wet gas area gave the company a net 208 MMcf/d of gas equivalent, representing a

56% gain from the same quarter in 2012. The 52 wells that came online in 2Q tested at a peak daily rate of 6.5 MMcf/d of gas equivalent. Chesapeake is working three rigs in the area and plans to drop one of the rigs later in 2013.

### **Chevron Corp.**

- *Land: 1.337 million net acres*
- *Ramping up in Ohio*

Chevron Corp. entered the Marcellus and Utica plays in late 2010. The company is off to a strong start in the Marcellus and is beginning to pick up activity in the Utica play.

Chevron purchased more than 486,000 net acres of Marcellus shale land and another 623,000 net acres of Utica shale with its late 2010 acquisition of Atlas Energy for US \$3.2 billion in cash and \$1.1 billion in debt obligations. That purchase included 49% of the Laurel Mountain Midstream LLC joint venture (JV) in the Appalachian basin and some 271,000 acres of Antrim properties and 100,000 net acres of Utica/Collingwood properties in Michigan.

It also gave Chevron an estimated 850 Bcf of gas equivalent in proved reserves, 14 Tcf of gas equivalent in potential recoverable resource, and 80 MMcf/d of gas equivalent production.

Through the purchase Chevron also gained operating responsibility on 60% of Marcellus assets in a JV with India's Reliance Industries Ltd. Reliance agreed to pay 75% of drilling costs up to \$1.4 billion in that venture.

Chevron followed that purchase with the acquisition of 228,000 net acres of Marcellus land from Chief Oil & Gas and Tug Hill Inc. Most of the Chief/Tug Hill properties were in the southwestern Pennsylvania liquids-rich segment of the Marcellus.

In a June 2013 presentation the company said it drilled 100 Marcellus wells in 2012 and was running eight rigs in the play in 2013. Its first 65 wells online produced on average 1.8 Bcf of gas in their first 30 months online, and that was at the high end of the company's expectation for those wells.

Chevron said it was targeting a 15% reduction in costs in its Marcellus operations by concentrating on site construction, drilling, completions, and surface facilities.



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At the same time, the company said it drilled and fractured four Utica wells in 2012 and planned to drill eight more in 2013.

A September 2013 presentation by the company said it held more than 700,000 acres in the Marcellus play and had nine rigs working.

The company also said it had drilled five wells in the Utica and fractured four of those wells. It expected to spud an additional seven wells during 2013. Chevron held approximately 500,000 net acres in the Utica play.

### Chief Oil & Gas LLC

- *Land: At least 125,000 net acres*
- *Producing gas in northeastern Pennsylvania*

Chief Oil & Gas LLC, a pioneer in the Barnett shale in Texas, made an early entry into the Marcellus shale in Pennsylvania, sold a substantial portion of its properties there, and continues to produce natural gas in four northeastern Pennsylvania counties.

Chief drilled its first Marcellus well in 2007 and currently operates four drilling rigs in Bradford, Susquehanna, Wyoming, and Sullivan counties. It has drilled more than 100 wells in the area and currently holds 73 wells, according to the company's website. It's trying to add to its 125,000 net acres of leases.

The company had more land, but it teamed up with Tug Hill Inc. to sell approximately 228,000 acres of Marcellus land to Chevron Corp. in 2011. By that time Chief had drilled 131 Marcellus shale wells.

At its peak at the end of March 2011 the company had 131 wells and nine rigs working on more than 353,000 acres of land in Pennsylvania, West Virginia, and Maryland. It produced 100 MMcf/d of gas equivalent production in November 2010.

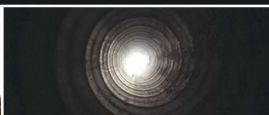
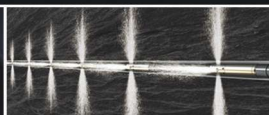
### Citrus Energy Corp.

- *Land: 26,500 gross acres*
- *First company to produce in Wyoming County, Pa.*



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The Marcellus may be big, but it still has room for smaller companies to buy land, drill wells, and make profits. It worked for Citrus Energy Corp.

The company bought land in Armstrong, Clarion, and Wyoming counties in Pennsylvania. It concentrated its efforts on Wyoming County and brought in first gas pay from the Marcellus in that county in June 2010.

In 2011, according to IHS Inc. records, Citrus had three permitted, drilling, or recently completed wells in Columbia County and 24 in Wyoming County. According to the company's website, it planned to drill 20 wells in 2011 and 2012.

Most of the company's properties are near pipelines, and, based on high-graded seismic data, more than 90% of its acreage is geologically drillable.

Citrus also locked in water permits for drilling and completing its wells and tries to recycle 100% of the water it uses in operations.

### **CONSOL Energy Inc.**

- *Land: 518,336 net acres*
- *Working with partners in the Marcellus and Utica*

CONSOL Energy Inc., a major eastern coal company, also made a mark as a pioneer operator in coalbed methane (CBM) and the Marcellus, Utica, and Upper Devonian shale plays.

Through its CNX subsidiary, now absorbed into the parent company, CONSOL was the second company to produce Marcellus hydrocarbons through a horizontal well in 2008. It was the first to use rotary tools in the Marcellus, closed-loop drilling, and fully-lined drilling sites and the first to drill a 10-horizontal-well pad in the Marcellus.

According to the company, it was the first E&P company to drill a discovery well in the Utica shale. That test in Belmont County, Ohio, tested at an absolute open flow rate of 1.5 MMcf/d of gas with no stimulation.

In 2013 CONSOL became the third company to drill to the Upper Devonian in Pennsylvania in a well that targeted the Burkett shale, the deepest Upper Devonian zone immediately above the Marcellus.

It already owned 83% of CNX, a company that started gas exploration on the company's coal properties. When CONSOL absorbed CNX at year-end

2010 it picked up 752,336 net acres of land prospective for the Marcellus. The company later signed a 50:50 joint venture (JV) agreement with Noble Energy to develop 628,000 of those acres. Although it was a 50:50 agreement, Noble worked a smaller parcel in the liquids area of the Marcellus in Pennsylvania, while CONSOL worked the larger gas-prone area.

CONSOL signed another 50:50 JV agreement on Ohio Utica acreage with Hess Corp. That deal includes 70,000 gross acres in the core Utica area and another 90,000 gross acres outside the core. The Utica core properties are in Guernsey, Jefferson, Harrison, Belmont, Noble, and Carroll counties in Ohio.

CONSOL is planning to drill 47 wells under the Pittsburgh International Airport for Marcellus pay under an agreement that calls for the company to take pains to make the rigs as inconspicuous as possible with no interruption of flight operations. Work will begin in spring 2014 with first gas expected in summer 2015.

In its 2Q 2013 report to shareholders, CONSOL said it produced 10.4 Bcf of Marcellus gas during the quarter, up from 7.2 Bcf in 2Q 2012. The gas costs less than US \$3.50/MMcf to produce, which is currently only slightly more than its CBM gas. For comparison, shallow oil and gas in the Appalachian region costs about \$5.85/MMcf to produce.

The company drilled 29 Marcellus wells in the dry gas area of central Pennsylvania in 2011, 13 more in 2012, and planned 10 wells in 2013. Operations that included Noble in liquids-rich southwestern Pennsylvania consisted of 50 wells in 2011, 70 wells in 2012, and a planned 98 wells in 2013. CONSOL drilled nine wells in West Virginia in 2011, six in 2012, and planned 11 wells in 2013 in the Marcellus. It planned a total of 119 gross wells in 2013.

In the Utica, including the properties shared with Hess, CONSOL drilled 10 wells in 2012 and planned 25 in 2013.

The companies planned to average three and a half rigs in the Utica play throughout 2013.

CONSOL, through CNX Gas, also holds properties in the Chattanooga shale. CNX drilled 13 horizontal wells to that formation in 1Q 2010 and planned to drilled 25 wells for the full year at a cost of \$28 million, or \$1.12 million per year.

The CONSOL website doesn't currently mention any activity in the Chattanooga shale.



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### Eclipse Resources Corp.

- *Land: 335,000 net acres*
- *Leveraging Utica and Marcellus assets*

Eclipse Resources Corp., formed in 2011, got a running start in the Utica shale as it drilled six wells by the end of June 2013 and planned to drill or participate in 27 more by year-end.

The company's current focus includes the Utica/Point Pleasant, Marcellus, and Genesee shales.

In a June 2013 presentation the company said it held 90,000 net acres in the core of the Utica play and another 20,000 net acres prospective for Marcellus pay, and it is acquiring more properties. Its core area is in Belmont, Guernsey, Monroe, Noble, and Harrison counties in Ohio.

In addition, it has 135,000 net acres in the oil window of the Utica, 67,000 net acres in the core of the liquids-rich Utica shale, and 23,000 net acres in the core dry gas Utica and liquids-rich Marcellus.

Some 57% of the company's Utica properties are held by production, and 85% are owned by Eclipse. Antero Resources operates another 10% of the properties.

Eclipse's Marcellus properties lie in Monroe County, Ohio, and wells there are prospective for liquids-rich hydrocarbons.

The company estimated gas in place on its properties ranging from 30 Bcf/section in western Noble County to 150 Bcf/section in eastern Monroe County, also in Ohio.

Estimated ultimate recoveries on wells range from 400 MMboe to 950 MMboe, and the company's property has a net potential of 487 wells on 160-acre spacing in the volatile oil area, 425 wells in the liquids-gas portion, and 138 wells in the dry gas area.

### Energy Corp. of America

- *Land: Less than 1 million acres*
- *One of the earliest Marcellus operators*

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Energy Corp. of America holds nearly 1 million acres of land in the Appalachian basin from New York to Tennessee with more than 4,600 wells and more than 5,000 miles of pipeline.

The company has more than 10,000 drilling locations and more than 15 Tcf of gas equivalent in resource potential.

Not all of that land or the reserves belong to its shales, but the company's current focus is on the Marcellus in Pennsylvania and West Virginia.

Energy Corp. started operations in the Appalachian basin more than 45 years ago. It has drilled as many as 100 wells a year using up to six rigs per year in recent years, focusing on the Marcellus.

The company was one of the earliest explorers in the Marcellus as it joined a well-test program in the late 1970s with the US Department of Energy. Most of its current wells have been horizontal wells in the Marcellus.

EnerVest is a top 25 oil and gas producer in the US. EV Energy Partners is an upstream master limited partnership managed by EnerVest.

In a July 2013 presentation the companies said their Appalachian holdings held 100.9 Bcf of gas equivalent in proved reserves and produced 24.9 MMcf/d of gas equivalent in 2012. They set aside a total capex budget of US \$90 million to \$110 million in 2013, and 9% of that is going into the Appalachian region.

The companies had more than 900,000 acres held by production in Ohio, and EV Energy Partners' share of that was 177,000 net working interest acres.

EV Energy Partners is in a partnership with Chesapeake Energy and Total SA to develop the Utica shale play. They have 12 rigs running with 235 wells drilled or drilling in July, another 67 producing wells, 68 wells in various stages of completion, and 75 wells waiting on pipeline connection.



**EV ENERGY PARTNERS** is in a partnership with Chesapeake Energy and Total SA to develop the Utica shale play.

The company had drilled 155 Marcellus wells by 2009.

The company works as both Energy Corp. of America and Eastern American Energy. Most of the companies' operations have been in Greene County, Pa., but it also has operations in Clearfield County, Pa., and in Logan, Upshur, and Webster counties in West Virginia.

Energy Corp. recycles nearly all of its liquids.

### **EnerVest Ltd./EV Energy Partners LP**

- *Land: More than 900,000 acres*
- *Properties placed on sales block*

EnerVest Ltd. and EV Energy Partners LP are looking for buyers for their large acreage position in the Utica play in Ohio and Pennsylvania, but the companies are working on development while waiting for sales to materialize.

The companies' current strategy calls for more fracture stages, shorter cluster spacing, and fewer clusters per stage.

They plan to drill more than 540 total wells by year-end 2014. Most of that drilling will be in the wet gas window expanding northeast out of Ohio into western Pennsylvania and south into Washington County, Ohio. They drilled six wells into the volatile oil window with marginal results.

EnerVest and EV Energy Partners have been trying to sell the properties in large packages without success but had better luck in August when they began marketing smaller packages.

They announced the sale of the first package in August 2013, a 22,535-acre parcel in Guernsey, Harrison, and Noble counties for \$284.3 million, or \$12,900 per acre. That sale is supposed to close in 3Q 2013 to an unnamed buyer.



EnerVest and EV Energy Partners may not name the buyer, but the oil and gas financial community identified the buyer as American Energy Partners, a company formed by Aubrey McClendon after he left Chesapeake Energy. Neither the buyers nor the seller have confirmed that identification.

EnerVest and its affiliate have working interest in a large acreage position in the play but overriding royalty interests ranging from 1.3% to 2.7% on nearly 880,000 gross acres.

EnerVest also has interests in midstream operations that serve the Utica play.

### **EOG Resources Inc.**

- *Land: 170,000 net acres*
- *Minimizing natural gas activities*

EOG Resources Inc., with plenty of work waiting in the Eagle Ford, Delaware basin, and Bakken/Three Forks liquids plays, has pulled back from its natural gas producing work in the Marcellus shale in Pennsylvania.

The company's 2012 annual report doesn't list the Marcellus as an active play for the company.

In July 2013 Seneca Resources, the oil and gas production arm of National Fuel Gas, said EOG did not plan to drill the minimum number of wells agreed upon in the companies' 2006 agreement that allowed EOG to earn Seneca Marcellus acreage by drilling a minimum number of wells.

That agreement doesn't cover all of EOG's properties. By July 21, 2012, EOG had earned a half working interest in 34,000 gross acres that Seneca contributed to the joint venture. EOG can't earn more acreage without drilling the minimum number of wells required, but it does retain acreage earned by meeting commitments in previous years.

A Seneca release said the company expects to drill or complete few wells on the properties during the 2013 fiscal year, and drilled-but-uncompleted wells probably will remain shut until gas prices increase.

EOG said it would make no dry gas investments in 2013 but would direct its resources to liquids activities in the Eagle Ford, Bakken/Three Forks, and Delaware basin.

All of the company's Marcellus properties are in Pennsylvania.

### **Epsilon Energy Ltd.**

- *Land: 5,750 net acres*
- *Partnered with Chesapeake Energy*

Epsilon Energy Ltd. leveraged a relatively small position in the Marcellus shale into a profit center with partner Chesapeake Energy Corp.

The company held 11,500 gross acres in the Marcellus core in Susquehanna County in Pennsylvania and teamed with the large independent in a deal that gave each company 5,750 net acres.

According to the company's website Chesapeake had invested US \$195 million in the properties, and by year-end 2012 Epsilon had 69 gross (19.3 net) wells producing a net 45 MMcf/d of gas. The company had another three gross (0.2 net) wells waiting on fracture treatments.

The companies drill from pads with six wells per pad using a pitchfork design to minimize the surface impact of operations.

According to a company presentation, two gross (0.8 net) wells were scheduled to come online in July 2013. Another seven gross (2.2 net) were due online in August, and four gross (one net) were scheduled to tap the pipeline in November.

In its 2Q 2013 report, the company said it produced 2.5 Bcf of gas from the Marcellus during the quarter and started selling Canadian assets so it could focus on the Marcellus.

### **EQT Corp.**

- *Land: Up to 3.5 million acres*
- *Marcellus takes top priority*

EQT Corp. credits the Marcellus shale in Pennsylvania and West Virginia with driving the company's growth. While its Huron horizontal wells and coalbed methane operations are holding their own, the Utica still is in the early development stages, and production from vertical wells is declining.

The company has some 3.5 million acres of land in Appalachia, but only a portion is devoted to its shale plays.

In an August 2013 presentation the company said its Marcellus properties gave it 560,000 net acres with an 87% net revenue interest and an 85%



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interest held by production. Proved reserves in the formation grew from 1.06 Tcf of gas equivalent in 2009 to 5.278 Tcf of gas equivalent in 2012, but the company has 15.6 Tcf in gas equivalent proved, probable, and possible Marcellus reserves and 21 Tcf of gas equivalent in resource potential.

That includes some 67,000 net acres purchased from Chesapeake Energy in June 2013 with three wells online and seven more planned for 2013. Some 25,000 acres of that land area are in the Marcellus core in Washington, Greene, and Allegheny counties.

The company plans 146 Marcellus wells in 2013 as part of an aggressive plan that allowed it to grow production by 70% year on year. Total company production in 2Q 2013 averaged 1 Bcf/d of gas equivalent, and 748 MMcf/d of gas equivalent came from the Marcellus.

Some 95,000 Marcellus acres are in the dry gas area of southwestern Pennsylvania, where the company has 135 wells online and 62 wells planned for

2013. It has 1,080 drilling locations in the area and develops wells with 4,800-ft laterals on 87-acre spacing. Wells cost US \$6.5 million and produce 9.8 Bcf of gas equivalent in estimated ultimate recovery. EQT used pad drilling to help control costs and reduce footprint.

In that area, 10 wells on the Tharpe pad with a 6,175-ft average lateral per well averaged 17.95 MMcf/d of gas equivalent per well during their first 30 days online.

EQT holds 90,000 net acres in its northern West Virginia wet gas Marcellus area, where it has 95 wells online, plans 74 wells for 2013, and has 1,065 drilling locations.

The company's central Pennsylvania Marcellus area, with 80,000 net acres, has another 37 wells online with 10 more planned for 2013. The company has 727 drilling locations in that area.

Overall, the Marcellus offers EQT a 96% return with a gas price of \$5/MMBtu and a 58% return at a \$4 gas price.



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Lateral Length (Ft)	3,600	4,200	4,500	4,800	5,300	6,900
Completed Stages	24.0	28.0	30.0	32.0	35.3	46.0
Fixed Costs (\$MM)	\$1.7	\$1.7	\$1.7	\$1.7	\$1.7	\$1.7
Drilling and Comp. (\$MM)	\$3.7	\$4.3	\$4.6	\$4.9	\$5.4	\$7.0
<b>Total</b>	<b>\$5.4</b>	<b>\$6.0</b>	<b>\$6.3</b>	<b>\$6.6</b>	<b>\$7.1</b>	<b>\$8.7</b>

Costs rise dramatically with lateral lengths on horizontal wells and the number of fracture stages.

*(Table courtesy of EQT Corp.)*

The company holds some 170,000 net acres in western Pennsylvania and northern West Virginia with production potential in the Upper Devonian, and the formation still has 2.4 Tcf of gas equivalent in production potential.

EQT drills horizontal wells in the Upper Devonian with 4,800-ft laterals. Horizontal wells cost between \$5 million and \$6 million, and EQT is using 2013 to delineate the formation with 22 planned wells.

EQT also has 13,600 acres of land with Utica potential in Guernsey County, Ohio. It plans eight wells with 6,000-ft average laterals on the land in 2013 at a cost of approximately \$9.4 million per well.

### EXCO Resources Inc.

- *Land: 140,000 acres held by production*
- *Reducing drilling until gas prices improve*

EXCO Resources Inc. acquires properties in some of the best liquids plays in the US, and those plays are taking precedence over the company's Marcellus shale operations.

The company began testing Marcellus properties in 2009 and formed a joint venture agreement with BG Group to develop the shale the following year.

EXCO has properties in 23 counties in Pennsylvania and 29 counties in West Virginia. Pennsylvania leases include areas favorable for the Marcellus and shallower Upper Devonian Venango, Bradford, and Elk sands. Potential in West Virginia comes from the Marcellus and Devonian zones.

In 2Q 2013 EXCO produced a net 49 MMcf/d of gas equivalent from the Marcellus in both states.

The company chose to complete its remaining drilled well inventory and turn those wells to sales in the remainder of 2013 as it reduces its drilling program because of low gas prices.

The company started drilling two Marcellus development wells in central Pennsylvania in 2Q 2013 and completed 1.5 net operated Marcellus wells in central and northeastern Pennsylvania. During the rest of the year, it planned to turn an additional 3.2 net wells to sales, two in central Pennsylvania and the other seven in the northeastern part of the state. It is running one rig in the play.

In addition to its Marcellus production, the company produced 14 MMcf/d of gas equivalent production from conventional formations.

### ExxonMobil Corp.

- *Land: 715,000 net acres*
- *Completed first Utica wells in 2013*

ExxonMobil, the world's largest public oil and gas company, took a significant position in the world's second largest gas field: the Marcellus shale in the Appalachian basin. North field offshore Qatar is the largest gas field.

According to the company's 2012 operations review, it has 625,000 net acres in the Marcellus and another 90,000 net acres in the Utica shale in Ohio and West Virginia. The company drilled its first wells in the Utica shale in 2012, with completions planned in early 2013.

ExxonMobil bought 317,000 acres in 2011 from Phillips Resources Inc. and TWP Inc. The purchase gave the company more than 700,000 acres in the Marcellus. It previously purchased 152,000 acres of



land from Linn Energy in 2008 and 145,000 acres from Pennsylvania General Energy in 2009. Its merger with XTO gave it another 280,000 acres.

The Phillips acquisition also gave ExxonMobil and its XTO Energy subsidiary a larger foothold in the Utica shale with 45,000 net acres of leases. It already had acquired 75,000 net acres.

Neither ExxonMobil nor XTO Energy has revealed development plans for its Appalachian holdings for 2013.

### Gastar Exploration Ltd.

- *Land: 63,000 net acres*
- *Currently working the Marcellus in West Virginia*

The Marcellus play provides Gastar Exploration Ltd. with nearly three-quarters of its production, and the company is working hard to increase that production.

Specifically, the company is working the liquids-rich portion of the Marcellus in Wetzel County and Marshall County in northern West Virginia in a 50:50 joint venture (JV) with Antinum Partners, a South Korean investment firm. Gastar is the operator.

Its contiguous land position allows easy equipment moves and lets the company drill long laterals, currently about 5,000 ft long. The company's position also allows it to conduct its drilling on pads that are less expensive per well than individual well sites.

The JV covers 21,100 net acres for each of the companies in West Virginia and Pennsylvania. Outside the partnership, Gastar holds 49,000 net acres, most of it in Preston, Tucker, and Pendleton counties in West Virginia. That property is prospective for dry gas, and Gastar is holding activity in those counties until gas prices improve.

The company brought 57 gross horizontal wells online in Marshall County by August 2013 and plans another 113 gross (57 net) additional horizontal wells with Antinum in 2014 and in the future.

Gastar will devote US \$60 million of its capital budget to the Marcellus in 2013.

### Gulfport Energy Corp.

- *Land: 136,000 net acres*
- *Utica pays off in eastern Ohio*

Gulfport Energy Corp., like other companies in the Utica play, has its sights set on the 100-ft-thick Point Pleasant submember of the lower Utica.

Although it owns a larger parcel, the company's efforts zero in on 128,000 net acres where it produced 3.524 Mboe/d in 2Q 2013.

In August the company held 6.59 MMboe in proved reserves and 18.18 MMboe in proved and probable reserves on 906 gross drilling locations. Potential recovery lies between 1.3 Bbbl and 5.5 Bbbl of oil and 3.8 Tcf and 15.7 Tcf of gas.

	Utica Shale <sup>(1)</sup>		Bakken	Eagle Ford <sup>(1,2)</sup>
	Low	High		
<b>Well Cost</b>	(\$MM)	\$6.0	\$7.0	\$5.5
<b>Total Vertical Depth</b>	7,500 to 9,500 ft	7,500 to 9,500 ft	10,000 ft	11,000 to 13,000 ft
<b>Lateral Length</b>	5,000 ft	5,000 ft	9,700 ft	5,000 ft
<b>Fracture Stages</b>	12 Stages	12 Stages	25 Stages	15 Stages
<b>OOIP per Section</b>	36.4 MMbo	36.4 MMbo	9.0 MMbo	9.0 MMbo
<b>Recovery Factor</b>	5.0%	10.0%	4.0%	4.0%
<b>Well Spacing</b>	160 Acres	160 Acres	1,280 Acres	80 Acres
<b>EUR per Well</b>	455 MBO	910 MBO	720 MBO	595 MBO
<b>Formation Thickness</b>	140 ft	140 ft	100 ft	100 ft
<b>Porosity</b>	8.0%	8.0%	5% to 8%	5% to 8%

The emerging Utica shale play in Ohio compares favorably with the established Bakken and Eagle Ford liquids-rich shale plays. (Table courtesy of Gulfport Energy Corp.)



## PREMIER MIDSTREAM ACCESS FROM THE MARCELLUS SHALE

**EQT Midstream Partners LP** is a growth-oriented limited partnership formed by prominent Marcellus natural gas producer EQT Corporation to own, operate, acquire and develop midstream assets. EQT Midstream Partners provides midstream services to EQT and to third parties in the Appalachian Basin through two primary assets: our transmission and storage system, which serves as a header system transmission pipeline; and our gathering system, which delivers natural gas from wells and other receipt points to transmission pipelines.

Based in Pittsburgh, Pennsylvania, EQT Midstream Partners offers a premier position in the Marcellus Shale play, serving wet and dry development areas. Our operational flexibility enables us to move natural gas through our 700 mile FERC-regulated interstate pipeline to five long-haul interstate pipelines serving northeast and east coast markets, as well as four local distribution companies. This system is supported by 14 associated natural gas storage reservoirs with approximately 400 MMcf per day of peak withdrawal capability and 32 Bcf of working gas storage capacity. With approximately 2,000 miles of FERC-regulated low pressure gathering lines, our pipeline is also connected to multiple high pressure third-party Marcellus gathering systems to offer producers system optionality for moving their product.

EQT Midstream Partners...your premier infrastructure resource for moving natural gas from the Marcellus to the market.





Gulfport is running seven rigs in the Utica/Point Pleasant and plans to complete 55 to 60 gross wells during 2013 with capex between US \$494 million and \$504 million, more than any other area in its producing inventory.

The company produced 320,718 boe from the Utica in 2Q 2013.

One good recent well, the Boy Scout 2-33H, went into production at an average seven-day sales rate of 747 b/d of condensate, 2.1 MMcf/d gas, and 298 b/d of NGL, or 1,308 boe/d, assuming full ethane recovery and a natural gas shrink of 25%.

The Boy Scout 4-33H well came online at a seven-day sales rate of 519 b/d of condensate, 2 MMcf/d of gas, and 264 b/d of NGL, or 1,043 boe/d.

Gulfport spud 16 gross (11.78 net) wells in 2Q 2013. At the end of the quarter, it had four gross wells awaiting completion, three gross wells drilling in the horizontal leg, and nine additional gross wells drilling in the vertical wellbore.

The company finished the quarter with 13 gross producing Utica/Point Pleasant wells. It added two more gross wells to sales in 3Q 2013 and plans to flow four to six gross wells to sales in 3Q 2013 and 25 to 30 gross wells to sales in 4Q 2013.

Gulfport's properties are in Belmont, Carroll, Columbiana, Guernsey, Harrison, Jefferson, Monroe, and Tuscarawa counties in Ohio.

### **Halcón Resources Corp.**

- *Land: Approximately 142,000 net acres*
- *Pioneering the northern Utica in Ohio*

Halcón Resources Corp. boasts a pioneering history, and its activity as a newcomer in the Utica shale enhances that reputation.

The management of Halcón, which formerly oversaw PetroHawk, pioneered the Haynesville gas shale play in Louisiana and the Eagle Ford play in South Texas. Now, it's starting work in the northern segment of the Utica/Point Pleasant combination in Ohio.

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In a September 2013 presentation the company said it has drilled its first nine wells in the play with only two on production. Production averaged 90 boe/d in 2Q 2013. It has another six wells waiting on pipeline hookup and one well resting. Halcón said it is evaluating the results of those early wells drilled across 70 miles in five counties.

The company has some optimistic news from at least one well. Its Kibler 1H tested at a higher rate than any liquids-rich well in the northern portion of the play in Ohio, the company said. That Trumbull County well tested at 2,233 boe/d with a 75% liquids content. The nearest liquids-rich well is 40 miles to the south in northern Carroll County, Ohio. The company expected pipeline pickup for the well in September 2013.

Halcón's Allam 1H well in Venango County, Pa., tested at 1,652 boe/d.

The company had one rig working in the first half of the year and planned three to five wells in the second half of 2013. Company-wide, Halcón planned to spend US \$510 million on its wells, and the Utica/Point Pleasant will get 7% of that budget. The company allotted 10% of its \$1.375 million capex for the full year to the Utica.

Halcón operates 99% of its 142,000 net acres in Ohio and western Pennsylvania with an average 96% working interest in its acreage, a 91% working interest in its wells, and an average 75% net revenue interest in its wells.

The company has drilled pilot holes with complete log suites on five of its nine wells. In addition, the company has gathered 1,844 ft of conventional core samples and is undertaking a 285-sq-mile 3-D seismic survey.

### **Hess Corp.**

- *Land: 80,000 net acres*
- *Accelerating activity in the Utica*

Hess Corp., the company that drilled the first Bakken well in North Dakota, took on the Utica play in Ohio in a joint venture (JV) with CONSOL Resources.

Each of the partners holds 35,000 net acres in the Utica core and another 45,000 net acres outside the core.

The companies plan 27 gross wells during 2013 with 11 operated by CONSOL and 16 by Hess. Hess operated three rigs during 2012 and drilled 10 wells.

By 2012 Hess had spent US \$1.2 billion on the Utica, \$770 million to purchase Marquette Exploration, and \$500 million on the JV with CONSOL.

CONSOL and Hess planned to run an average 3.5 rigs during 2013, with three by Hess; grow to 4.5 rigs in 2014, with four by Hess; and jump to five rigs in 2015 on the JV properties.

In a press release Hess said it planned to reduce its budget for the Bakken formation from \$3.1 billion in 2012 to \$2.2 billion in 2013. At the same time, the company said it would increase spending in the Utica from \$300 million in 2012 to \$400 million in 2013.

The Hess-operated portion of the JV lies in Belmont, Harrison, Guernsey, and Jefferson counties in the liquids-rich section of the Utica, while CONSOL will work the oil window in Portage, Tuscarawas, Mahoning, and Noble counties.

### **Lario Oil & Gas Co.**

- *Land: 25,000 net acres*
- *Beginning work on Utica acreage*

Lario Oil & Gas Co. and an industry partner drilled a "science" well on Lario's property in the northern rich-condensate area of the Utica/Point Pleasant in 2Q 2013. Lario plans to follow up with a horizontal drilling program.

The Wichita, Kan., company began soliciting Utica leases in eastern Ohio in 2011 and had put together commitments for almost 20,000 acres by February 2012. The company planned to increase its position to 50,000 acres by year-end 2012.

The strategy worked for the company in its Bakken and Niobrara acquisition program. In the Niobrara, Lario bought approximately 46,000 net acres of leases and later sold the property for US \$200 million to ConocoPhillips.

### **Magnum Hunter Resources Corp.**

- *Land: Up to 465,451 net acres*
- *Working shales through subsidiaries*

Magnum Hunter Resources Corp. works Appalachian shales through its Triad Hunter and MH Production subsidiaries.



Triad Hunter oversees the company's efforts in its 81,001 net acres in the Marcellus formation and its 79,530 net acres in the Utica. MH Production handles Devonian shales and other formations, including some 304,920 net acres in the Huron and Weir zones in Appalachia, according to an August 2013 presentation by the parent company.

The company holds 62,490 developed and 18,511 undeveloped acres in the Marcellus and 59,469 developed and 20,062 undeveloped acres in the Utica play.

The company's proved reserves total 30.6 MMboe in the Marcellus, and probable and possible reserves for the play total 11.7 MMboe. The company holds 142.9 MMboe in proved, probable, and possible (3P) contingent resources and 185.2 MMboe in unrisked contingent resources in the Marcellus.

It describes its Marcellus assets as low-risk development potential.

Magnum Hunter does not have any 3P reserves in the Utica, but it has 496.2 MMboe in contingent resources on its Utica land. It categorizes its Utica assets as having significant exploration potential in the wet and dry gas window in Ohio and West Virginia.

MH Production's Devonian shale and other formations contain 7.2 MMboe in proved reserves, 45.4 MMboe in contingent resource, and 52.6 MMboe in 3P unrisked contingent resource.

The company has more proved reserves in the Marcellus than all of its other working formations combined, including the Eagle Ford and Bakken/Three Forks. In addition, the company has more contingent resources in the Utica than in all of its other plays combined.

According to the August presentation, Magnum Hunter has drilled and hooked up 27 Marcellus wells, including 10 in Tyler County, W. Va.; 16 in Wetzel County, W.Va.; and one in Monroe County, Ohio. Two more wells were awaiting completion and 11 gross (seven net) wells were drilling.

Some of the company's wells are operated by Stone Energy.

Magnum Hunter's best Marcellus well, the WVDNR, tested at an initial potential (IP) of 10.5 MMcf/d of gas equivalent and a 30-day average IP of

7.078 MMcf/d of gas equivalent from 16 fracture stages.

After spending US \$6.5 million on an average well that yields 7.8 Bcf of gas equivalent, including liquids, the company expects an 80% internal rate of return and a net present value, discounted at 10% a year, of more than \$9 million, assuming a gas price of \$3.70/MMBtu.

The company agreed to acquire 32,000 net acres of Utica properties in Monroe, Noble, and Washington counties in Ohio from MAW Energy LLC. That property, purchased for \$4,400 an acre, will go into the Triad inventory.

Magnum Hunter started drilling its first Utica well in April 2013 on its Farley pad, which has a capacity for four wells with 10 laterals. It started fracturing the well in August. The company also plans 18 laterals on its Stadler pad. It spud its first well on that pad in July using a state-of-the-art robotic rig.

### **National Fuel Gas Co. / Seneca Resources Corp.**

- *Land: 775,000 net acres*
- *Combining solid development with delineation*

National Fuel Gas Co. and its Seneca Resources Corp. oil and gas E&P arm have worked Appalachian hydrocarbon formations for more than 100 years. The companies have added the Marcellus and Utica formations to their inventory of successes.

Seneca operates more than 3,000 shallow wells and more than 150 deep wells in New York and Pennsylvania. Throughout Appalachia, the company spent US \$631 million in oil and gas operations in 2012, with plans to lower that number to between \$445 million and \$475 million in 2013 and to raise it back to between \$460 million and \$520 million in 2014.

The company produced 62.9 Bcf of gas equivalent from its Appalachian operations in 2012 and forecast an increase of between 98 Bcf and 104 Bcf of gas equivalent in 2013 and another increase of between 114 Bcf and 124 Bcf of gas equivalent in 2014.

Currently, the company operates both Marcellus and Utica wells in Pennsylvania in two distinct areas: the eastern development area and the western development area.

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Ancillary Drilling Costs (Trucking, etc.)	Ancillary Drilling Costs (Trucking, etc.)
\$150,000 per well	\$25,000 per well
Fracture Mobilization	Fracture Mobilization
\$7,000 per well	\$1,200 per well
Water Hauling vs. Infrastructure	Water Hauling vs. Infrastructure
\$200,000 per well	\$50,000 per well
<b>Cost Savings of Pad Drilling: ~\$1.2 Million per Well</b>	

Pad drilling in the Marcellus formation saves Seneca Resources approximately \$1.2 million per well on six well pads compared with single-well locations. *(Table courtesy of Seneca Resources Inc.)*

55,000-net-acre eastern development area, which is mostly leased land with 16% to 18% royalties in Tioga and Lycoming counties. The first expiration on those leases comes up in 2018.

The company produced a gross 300 MMcf/d of gas equivalent from 98 producing wells in three production areas in that region. Its most prolific well tested for an initial potential of 15.4 MMcf/d of gas and an average estimated ultimate recovery of 11 Bcf from a 5,008-ft lateral.

The company's western development area contains some 720,000 net areas where it owns mostly mineral rights with minimal royalties. It's evaluating the rich-gas potential and initiating dry gas development in that area.

The company's best well in that area, drilled in fiscal 3Q 2013 with a 5,500-ft lateral section and 37 fracture stages, was the Clermont 9H. That well tested at a peak rate of 8.8 MMcf/d of gas and a seven-day rate of 10 MMcf/d of gas in Elk County. The company is moving forward with full development in the Clermont area.

Seneca also is testing the Utica shale in western Pennsylvania. Its first Mount Jewett well in southern McKean County tested for 1.6 MMcf/d of gas from three fracture stages. Typical wells in that area produce from 17 fracture stages.

Also in the Utica, the company tested the Tionesta horizontal well in northern Clarion County, Pa., in fall 2012 at a peak 24-hour rate of 3.9 MMcf/d of

gas. It also tested the Henderson vertical Utica well in Venango County, Pa.

In a December 2012 presentation the company said it had 300,000 net acres of land in the shallower Genesee shale, but that holding probably overlies its Marcellus acreage.

### **Noble Energy Inc.**

- *Land: 314,00 net acres*
- *Working JV with CONSOL Energy*

Noble Energy develops two onshore core areas: the Denver-Julesburg basin in Colorado and Wyoming and the Marcellus shale in Pennsylvania.

The company likes the Marcellus, according to its website, because "the Marcellus shale is recognized among the lower cost domestic shale plays, and it is ideally located near major demand markets in the northeastern US."

That's the reason Noble teamed with CONSOL Energy for a 50:50 joint venture (JV) to develop 628,000 acres of potential Marcellus shale land contributed by CONSOL.

With a background in coal and natural gas, CONSOL operates rigs in the dry gas segment of the Marcellus, while Noble, with its liquids experience, concentrates on the wet gas area of the play.

Noble plans to drill 120 Marcellus wells in 2013 as it works to its potential 600 MMcf/d of gas equivalent in 2015.

In a December 2012 presentation to analysts, Noble said it more than doubled production from the Marcellus during 2012 to 140 MMcf/d of gas equivalent, while its resources rose 41% to 10 Tcf of gas equivalent. The company expected to finish 2013 producing 200 MMcf/d of gas equivalent with a full-year average of 165 MMcf/d of gas equivalent, up 80% from 2012. Its 2Q 2013 report to shareholders said it finished the quarter producing 150 MMcf/d of gas equivalent from the Marcellus.

At that time, the company expected to drill 50 dry gas and 75 wet gas wells in 2013 and 275 wells in 2015.

Currently, the company is concentrating its efforts in Washington, Greene, and Westmoreland counties in Pennsylvania, specifically on the Majorsville area of Pennsylvania with five well pads. To the southeast the company has 200 potential well locations in its Normantown project area.

It holds 130,000 net acres in the wet gas area of Majorsville.

As it drills, the company uses the learning curve to lower costs. It trimmed top-hole drilling costs by US \$170,000 per well and completion costs by 10%, or \$300,000, on wells with 5,000-ft laterals. It also found well-efficiency increases with lateral length.

The company increased activity in the wet gas area in 2013, doubling planned wells to six, with three of those wells at Majorsville and three delineation wells in another area.

In a later presentation in May 2013 Noble said it would drill 126 Marcellus wells.

At the end of June 2013 Noble operated three horizontal rigs in the wet gas area and planned to add two more rigs in the second half. It reached total depth on 14 wells in the Majorsville and Normantown areas in 2Q 2013.

Noble also drilled its longest lateral – more than 10,400 ft – during the quarter and put its 11-well WEB-4 pad online with an initial gross production rate of more than 50 MMcf/d of gas and 3,000 b/d of liquids.



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### PDC Energy Inc.

- *Land: 171,250 net acres*
- *Utica oil outranks Marcellus gas*

PDC Energy Inc. backed away from the Marcellus gas-prone play in 2012 in favor of the liquids-rich Utica play in Ohio and its Wattenberg field operations in Colorado.

Gas prices just didn't look like the best investment for the company. It did resume a one-rig drilling operation in the Marcellus in January 2013. And it has one rig running in the Utica shale play, according to an August 2013 presentation.

The company holds 125,250 net acres in the Marcellus, 97% held by production, and it produced 22.708 MMcf/d of gas equivalent in August for a 25% internal rate of return. It had 47 producing wells at that time, 32 of them horizontally drilled. It planned 15 wells during 2013 at a cost of US \$57 million.

PDC operates its Marcellus properties in northern West Virginia under the PDC Mountaineer joint venture (JV) with Lime Rock Partners. It has approximately 600 potential well locations, and its focus area in Taylor, Harrison, and Barbour counties contains 350 of those locations. It has 179 Bcf of gas equivalent in proved reserves, according to its 2012 annual report.

The JV also operates 46,000 net acres, 57% of which are held by production, in the Utica shale in Ohio. PDC was drilling its ninth well in August 2013, and the seventh for the year. PDC plans 11 wells during 2013 at a cost of \$96 million.

The company planned for average production of 1,074 boe/d during 2013. Its acreage contains room for 200 horizontal wells, and its wells give the company an internal rate of return between 30% and 80% with 50% to 80% liquids.

PDC drills on pads in the Utica using 5,000-ft to 6,000-ft laterals, spaced 1,000 ft apart between horizontal wellbores. It conducts 20 to 30 fracture stages in each well and used microseismic to fine-tune the fracture treatments.

The company acquired 45,000 net acres of its Utica land in the wet gas window in 2012 for approximately \$2,000 per acre, and its first two horizontal wells in the formation came in at 1,800 boe/d and 2,200 boe/d during the best hour of testing in a 24-hour period.

During February 2013, PDC sold its noncore Colorado assets to raise money to focus its activity in the Utica and in the Wattenberg field.

### Pennsylvania General Energy Co. LLC

- *Land: Up to 439,000 net acres*
- *Focus on Pennsylvania and New York*

A veteran of more than 30 years in the Appalachian basin, Pennsylvania General Energy Co. LLC took part early in the Marcellus shale play, drilling its first well early in 2005 in Elk County, Pa.

The company's acreage in Pennsylvania and New York contains Marcellus potential as well as potential for other formations, and the company had three rigs working on horizontal wells by year-end 2011. Overall, it operates more than 1,100 oil and gas wells in Appalachia.

Pennsylvania General also strives to keep a technology edge. In August 2012 the company awarded

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Alcoa a contract to supply lightweight aluminum alloy drillpipe that would allow it to extend the reach of carrier-mounted drilling rigs used to drill for gas in the Marcellus.

### **Penn Virginia Corp.**

- *Land: 45,000 net acres*
- *Marcellus work halted by low gas prices*

After selling reserves and production in West Virginia, Virginia, and Kentucky in July 2012 for US \$100 million, Penn Virginia Corp. concentrated its eastern operations on the Marcellus shale in Pennsylvania. Low gas prices halted that activity, though.

According to a September 2013 presentation, Penn Virginia plans to resume work in its properties in the dry gas area in eastern Potter and western Tioga counties in 2013 or 2014 “subject to the price of gas.”

The company had an inventory of 150 Marcellus drilling locations with 520,000 boe in reserves at year-end 2012, all of which are gas, and 23% proved developed.

Penn Virginia drilled its first well in the Marcellus in 2008 and its first horizontal well in the play in early 2011. In a 2011 presentation the company said it planned to drill 13 net horizontal Marcellus wells during that year and expected a 10% internal rate of return at a Henry Hub gas price of \$3.48/MMBtu.

### **Range Resources Inc.**

- *Land: Approximately 1 million net acres in the Marcellus*
- *Stacked pay compounds opportunities*

Range Resources Inc., a major landholder and producer in the Appalachian basin, pioneered and discovered the Marcellus shale in 2004 and drilled the industry’s first horizontal Utica and Upper Devonian shale wells in 2009.

In all, the company has 1.98 million net acres in Pennsylvania alone. The stacked pay zones give the company an opportunity for multiple developments at 1,000-ft intervals with 500-ft spacing prospective on most of its acreage. This large inventory provides Range with the opportunity to achieve 20% to 25% line-of-sight growth for years.



A fish-eye lens captures an Appalachian shale drilling site and the wooded country surrounding the site. (Photo courtesy of Range Resources Inc.)



The company's 1 million net acres in the Marcellus in Pennsylvania include 315,000 acres in the northwest part of the state with 89% held by production, 145,000 acres in the northeast with 69% held by production, and 540,000 acres in the southwest with 51% held by production.

Stacked pay means some overlapping of acreage. For example, Range's Upper Devonian assets include the Rhinestreet, Middlesex, Genesee, and Burkett shales, from shallowest to deepest. The company holds 330,000 acres in the wet part of that play and 235,000 acres in the dry section.

In the Utica/Point Pleasant/Trenton Lime, the company holds 180,000 acres in the wet segment and 400,000 acres in the dry zone.

According to the company's latest presentation, it holds 38 Tcf to 49 Tcf of gas equivalent potential in the Marcellus, another 12 Tcf to 18 Tcf of gas equivalent in the Upper Devonian, and an unreleased additional potential in the Utica shale.

Range has the potential for 6,750 wells on 80-acre spacing in southwestern Pennsylvania and currently has approximately 460 producing wells. Those wells typically produce 530 MMcf/d of gas equivalent.

In its 110,000 acres of super-rich production in southwestern Pennsylvania the company turned 51 wells to sales by year-end 2012 with average laterals of 3,975 ft and 15 fracture stages. Range plans to go to 4,500-ft laterals for the future, a move that will raise estimated ultimate recoveries (EUR) to 1.82 MMboe from the current 1.32 MMboe. These 1.82 MMboe include 112,000 bbl of condensate, 926,000 bbl of NGL, and 4.7 Bcf of gas.

At the current New York Mercantile Exchange (NYMEX) strip prices, Range will get a 105% return on its investment in this area.

In the wet gas area Range put 200 Marcellus wells on production in the past four years, including 62 wells in 2012 with an average 3,200-ft lateral and 13 fracture stages. It plans to move to 4,200-ft laterals to raise EUR to 12.3 Bcf of gas equivalent. Wells in this area return 106% at NYMEX strip prices.

The company's Pennsylvania Marcellus dry gas area offers an industry average 5 Bcf to 20 Bcf of gas per well. Although the company isn't very active in that area now, it is planning wells with 5,000-ft lat-

erals with 12.2 Bcf of gas EUR. That area offers a 97% return at current strip prices for gas.

Range has tested 500-ft spacing in two projects in the super-rich and wet areas of Washington County, Pa. After producing for three years, the company found that the tighter spaced wells produced at 80% of the returns of the 1,000-ft spaced wells. If all of the super-rich and wet areas were developed at the tighter spacing, they would add 12 Tcf to 15 Tcf of gas equivalent resource potential for the company.

The company's Utica/Point Pleasant interests lie in 500,000 acres in the company's southwest Pennsylvania dry gas area and in 180,000 net acres in the northwestern Pennsylvania wet gas area.

Range called its first four Upper Devonian shale wells successes. On a 24-hour test, the company's latest super-rich well tested for 10 MMcf/d of gas equivalent consisting of 4 MMcf/d of gas, 172 b/d of condensate, and 826 b/d of NGL.

So far, the company said, all industry participants have drilled 20 successful wells to those zones. Range's first four wells performed better than its first four Marcellus wells.

### **Rex Energy Corp.**

- *Land: 98,600 net acres*
- *Campaigning for Utica profits*

Rex Energy Corp. waged an aggressive campaign on its 900 drilling locations in the Appalachian basin to reach a big piece of its 5 Tcf of gas equivalent ultimate recovery potential.

Specifically, the company is developing the wet gas window in the Pennsylvania Marcellus and the Ohio Utica.

Rex holds 21,000 net acres in two Utica patches in its Warrior Project in Ohio and another 50,200 net acres in Butler County in western Pennsylvania that are prospective for Marcellus, Upper Devonian, and Utica pay, according to a September 2013 presentation.

The company's Pennsylvania property also includes 11,300 net acres in Warren and Mercer counties in the northwest and 16,100 net acres in the Westmoreland/Clearfield/Centre area.

Some 71% of the 2013 Rex budget of US \$275 million is directed at the Utica in Ohio and Butler County, Pa.





A rig drills to the Marcellus shale near Wellsboro and the Pennsylvania Grand Canyon. *(Photo courtesy of Shell Oil Co.)*

In the Utica the company has 16,500 acres in its Warrior North properties in Carroll County. It planned six wells in 2013, and four had been drilled by September.

Rex has another 4,300 net acres in Warrior South in Guernsey, Noble, and Belmont counties with 38 potential drilling locations.

In addition to Utica potential in Butler County, Pa., the company has drilled to the Upper Devonian Burkett shale where its best well, the Drushel 6HD, gave it a five-day average production rate of 7.302 MMcf/d of gas equivalent with 49% liquids. Rex has 273 net potential drilling locations for that formation with wells that offer



9.7 Bcf of gas equivalent recoveries with 40% liquids and a potential 2.1 Tcf of gas equivalent resource potential.

The company has drilled four Upper Devonian Burkett wells in Butler County.

Also in Butler County, Rex has 220 net potential drilling locations in the Marcellus shale where wells offer recoveries of 9.7 Bcf of gas equivalent with full ethane recovery. Those wells offer 40% liquids including ethane, and the formation has an unproved net resource potential of 1.6 Tcf of gas equivalent. The company's best Butler Marcellus well, the Meyer 2H gave up an average 6.929 MMcf/d of gas equivalent pay with 49% liquids over a five-day period and an average 6.603 MMcf/d of gas equivalent hydrocarbons over a 30-day period.

Coming into 2013, Rex drilled 19 wells, put 23 wells in service, and had another 15 wells awaiting completion.

The company had 11 nonoperated wells scheduled in 2013 on its Clearfield, Centre, and Westmoreland County properties.

### Royal Dutch Shell Plc

- *Land: More than 900,000 gross acres in Marcellus*
- *Major commitment in people and resources*

The Shell Energy North America LP arm of Royal Dutch Shell Plc made a major commitment when it bought East Resources for US \$4.7 billion in 2010, but the commitment didn't stop there.

Since that time, Shell increased its land position from 750,000 gross acres to 900,000 gross acres. The company also opened a regional office in Sewickly, Pa., with more than 300 employees in Pennsylvania and 50 employees headquartered in Tioga County, Pa., its main area of operations.

Shell started working the Marcellus play, but it also began exploration in the deeper Utica in Lawrence and Butler counties in western Pennsylvania.

The company plans to continue development in Tioga County and exploratory work in Butler and Lawrence counties.

The company also has Utica properties in Ohio, and, although Shell hasn't confirmed the leaks from analysts, the financial rumor mill said Aubrey McClendon's American Energy Partners put up a high bid for 50,000 acres of Shell land in Ohio with Utica potential. McClendon is the former CEO of Chesapeake Energy.

The East Resources acquisition also gave Shell properties in New York, West Virginia, and Utica production from 70,000 acres in Butler and Lawrence counties near the Ohio border. Shell added another 30,000 acres in the area with Utica potential in mid-2011 and started drilling to delineate that potential.

In addition, the company drilled the first Marcellus well in Lawrence County.

To provide a market for its production, Shell plans to build a \$2 billion ethane cracking plant with at least part of the capacity devoted to its Utica production.

The East Resources buyout also gave Shell the Northern Pipeline Co. with approximately 400 miles of gathering system in Butler, Clarion, Forest, McKean, Venango, and Warren counties.



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The major producer also set up a 50:50 joint venture with Ultra Petroleum covering Marcellus activity in Potter, Bradford, Forest, McKean, Butler, Lawrence, and Jefferson counties in Pennsylvania.

### Southwestern Energy Co.

- *Land: 337,300 net acres in Pennsylvania*
- *Acquisition boosts Marcellus growth plan*

Some companies cut back on their Marcellus activities pending higher gas prices, but not Southwestern Energy Co. It acquired 162,000 net acres in the play from Chesapeake Energy for US \$93 million in the first half of 2013 to add to the more than 175,000 acres it already held in the play.

In the first half of 2013, the company – which pioneered the Fayetteville shale play in Arkansas – had 816 Bcf of gas equivalent in reserves and 53.6 Bcf of gas equivalent in production in 2012 from its northeastern Pennsylvania properties. It produced 33.9 Bcf of gas in 2Q 2013.

By the end of 2Q 2013 the company's Marcellus properties produced 503 MMcf/d of gas from 129 operated horizontal wells.

Southwestern Energy planned eight wells in Lycoming County, 37 wells in Bradford County, and 55 wells in Susquehanna County during 2013. It also has properties in Wayne, Lackawanna, Wyoming, Luzerne, and Sullivan counties.

During 2Q 2013 the company's average 30-day production from 28 wells brought onstream was 5.525 MMcf/d of gas. The company planned to add 100 wells to its inventory during 2013. On June 30 it had 99 Marcellus wells in progress.

### Stone Energy Corp.

- *Land: 90,000 net acres*
- *Working Marcellus and testing Upper Devonian and Utica*

Stone Energy Corp. makes its way in the oil and gas world drilling deep- and shallow-water offshore wells and onshore properties, and the Marcellus represents 44% of its 129 MMboe in proved reserves.

The company has allocated 31% of its total US \$710 million capex for 2013 to the Marcellus – more than any other onshore area.

Stone drills its Appalachian wells in the gas-rich Marcellus area and plans 30 wells each in 2013 and 2014, according to a September 2013 presentation. It also plans to test the Upper Devonian in its Mary field during 2013 and the Utica formation in 2014 and 2015.

The company's current activity is in the 39,000 net acres in the Mary and Heather areas in northern West Virginia where it plans to run a one-rig drilling program through 2017.

Stone plans to assemble between 380 Bcf and 410 Bcf of gas equivalent in reserves in 2013 and raise that figure to between 505 Bcf and 620 Bcf of gas equivalent in 2017. At the same time, it will increase production from as much as 75 MMcf/d of gas equivalent in 2013 to twice that amount in 2017.

The company calculates its proved, probable, and possible Appalachian reserves at 1.4 Tcf of gas equivalent.

### Talisman Energy Inc.

- *Land: 208,000 net acres*
- *Making gas work in a liquids world*



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Talisman Energy Inc. calls the Marcellus a “predicable self-funding growth area” for the company, and it plans to continue working the rich-gas play as long as prices hold up.

The company adjusts its Marcellus activity according to its ability to turn a profit. President and CEO Hal Kvisle said on the company’s website, “In North America we have improved operational execution across the portfolio with strong results in Western Canada, the Marcellus, and the Eagle Ford plays. Our Marcellus team has sustained production with very little capital investment over the past year, and we are now ready to resume drilling and development activity in response to stronger forward market gas prices.”

In a September 2013 presentation Talisman said it planned to drill to protect its acreage position in the short term, using wells to optimize production. That technique works. The company said its break-even cost was less than US \$3/Mcf of gas, and its break-even price has been less than \$2.50/Mcf on 70 wells.

The minimal operations in the Marcellus led to lower production from natural declines. The company produced 426 MMcf/d from the play in 2Q 2013, down from 442 MMcf/d of gas in 1Q 2013 and 525 Mcf/d of gas in 2Q 2012. It planned to finish 2013 by producing between 440 MMcf/d and 459 MMcf/d of gas equivalent and bringing home a 25% internal rate of return on that production.

Talisman will spend \$225 million in the Marcellus in 2013, including \$50 million on completions and tie-ins in 2013 and additional funds to drill 20 wells. The company will evaluate the results of that program in 4Q 2013. It plans to run one rig in the play.

The company’s proved and probable reserves in the Marcellus totaled 2.4 Tcf of gas equivalent, and it has some 1,600 gross well locations remaining on its property. During 2012 its average estimated ultimate recovery was 4.8 Bcf of gas equivalent per well.

## Total SA

- Land: 154,750 net acres
- Partnered with Chesapeake Energy

Total SA signed a partnership deal with Chesapeake Energy and EnerVest Ltd. in 2012 that allowed it to contribute US \$2.32 billion in cash and drilling and completion carries to earn a one-fourth of 619,000 acres in the Utica play in Ohio.

That land is concentrated in the wet gas window of the formation and area in which Chesapeake has focused its drilling and completion efforts. Results from wells in the area led

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Chesapeake to forecast estimated ultimate recoveries between 5 Bcf and 10 Bcf of gas equivalent per well.

Total previously bought into Chesapeake's Barnett shale holdings in 2010 and has entered shale plays in Europe, Africa, and Australia as well as North America.

Chesapeake operates the joint venture, but Total agreed to contribute \$610 million in cash and \$1.42 billion in drilling and completion carries to the project through 2014. Those carries will cover 60% of the costs of the wells.

### Ultra Petroleum Corp.

- *Land: 260,000 net acres*
- *Pennsylvania Marcellus pays off*

Ultra Petroleum Corp. works traditional Marcellus zones but sees potential in Upper Devonian shale in Pennsylvania.

The company has plenty of experience in tight formations, from the Jonah field in southwestern Wyoming to the Marcellus in Pennsylvania.

The company holds 170,000 net acres in Potter and Tioga counties with 70% held by production. It had 202 producing wells at year-end 2012 and another 90,000 net acres. In Clinton and Lycoming counties, the company operates another 120 producing horizontal wells, and 85% of its land is held by production.

In both areas the company controls 1,700 net future locations with 7.4 Tcf of gas equivalent in potential resource that will require US \$11.3 billion in future capital to develop, if the finding and development cost is \$1.52/Mcf of gas equivalent.

Ultra's sweet spot is the Wellsboro area of Tioga County where wells come in with an average initial potential of 7.2 MMcf/d of gas equivalent. A 7 Bcf of gas equivalent well, drilled to 8,400 vertical ft with a horizontal leg at a cost of \$6.2 million gives up a 47% internal rate of return with payout in 25 months. Returns range from 12% of a 5 Bcf of gas equivalent well drilled to 5,600 ft at a cost of \$7.2

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million to 82% for a 9 Bcf of gas equivalent well drilled to 8,399 ft at a cost of \$6.2 million.

The company also has upside potential in the Genesee (Upper Devonian) shale where it has a net risked resource potential of 3.3 Tcf of gas equivalent. That play area has been delineated by 14 horizontal wells in the Ultra leasehold. Ultra has Genesee participation wells in Clinton and Tioga counties, and additional industry wells have been drilled in Potter and Lycoming counties.

The company plans to invest \$105 million of its total \$415 million in capex in Pennsylvania in 2013 to drill 14 net (28 gross) wells. It will put 40 gross (20 net) Pennsylvanian wells online.

### WPX Energy Inc.

- *Land: 114,067 net acres*
- *Williams spinoff milks Marcellus*

WPX Energy Inc., a spinoff that received The Williams Companies Inc.'s oil and gas assets in 2011,

has an active program in the dry gas area of the Marcellus where it will keep one rig working during 2013.

The company's management has been operating in the Marcellus since 2009 and held 100 wells there at the year-end 2012. It invested US \$356 million in the popular formation in 2012 on properties in Susquehanna and Westmoreland counties. It planned to spend more than \$125 million in the two counties in 2013.

As it drills, WPX increases efficiency. Its drilling times have dropped from a high of 45 days to a record 10.8 days, while completions costs fell 46% during 2011 and 2012. It completed more than 50 gross wells in 2012.

In its 1Q 2013 report to shareholders WPX said it had 322 Bcf of gas equivalent in proved reserves in the Marcellus and proved, probable, and possible reserves of 2.023 Tcf of gas equivalent. It produced 63 MMcf/d of gas in 2012, and up to 30 MMcf/d of gas was constrained by infrastructure bottlenecks in 1Q 2013. It maintains 561 gross drilling locations, and it is evaluating additional resource potential. ■



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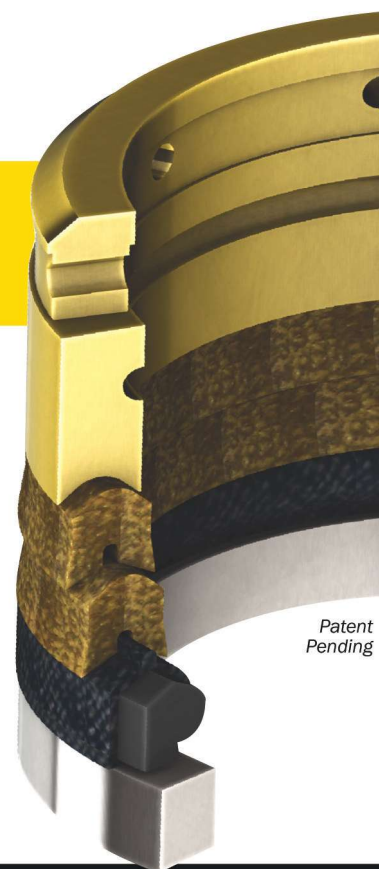
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# Drawing on New Drilling and Completion Technologies

Large pad sites in the Appalachian basin are now a standard as operators and service companies boost wellsite efficiencies.

**By Glenn R. Meyers**  
Contributing Editor

Outsiders might think of the Appalachian basin as simply one of the world's largest coal deposits. For the last 154 years, however, there has been plenty more in this basin in the way of recoverable hydrocarbons since oil was first discovered in Pennsylvania's Drake well. The success of this discovery well marked the onset of longstanding success for the oil and gas industry, earmarked by periodic production upticks and downturns.

This present uptick, spurred by the advent of horizontal drilling, features technology toolkits designed to increase efficiencies and productivity from 15% to 20%. These include the construction of multiple-well pads. One Ohio pad has an 18-well capacity that will target the Marcellus and Utica formations.

Make no mistake about how this prevalence of new technologies breaks out. In fact, there happens to be no Appalachian basin standard that has yet emerged concerning the deployment of best new technologies.

The various plays of the Appalachian basin comprise too vast a stretch of land. Specifically, this elongate, asymmetrical foreland basin accounts for some 230,000 sq miles in area, measuring more than 1,000 miles in length and up to 350 miles in width as it spreads under parts of New York, Pennsylvania, Ohio, Maryland, Virginia, West Virginia, Kentucky, Tennessee, Georgia, and Alabama, filled with more than 500,000 cubic miles of Paleozoic rock.

According to Wallace de Witt Jr., reporting for the US Geological Survey, large tectonic fan-delta com-

plexes containing coarse-grained siliciclastic reservoir rocks are concentrated mainly on the eastern side of the basin, with carbonate rocks more abundant on the western side. Oil and associated gas are found mainly in this part of the basin, with dry gas more common in the central and eastern parts where temperatures are too high for the existence of oil.

Plays for this technology report include the Upper Devonian, the Chattanooga, the Marcellus shale, and the Utica beneath the Marcellus. Estimates have the basin containing 3.379 Bbbl of oil, with the Utica shale showing a mean of 940 MMbbl of unconventional oil resources and a mean of 208 MMbbl of unconventional NGL.

Completions in a number of Appalachian basin plays have changed markedly over the past five years, except in the Marcellus shale where plug and perf (PNP) remains a viable standard, said Lonnie Jeffers from Packers Plus Energy Services Technical Sales, which has drilled more than 1,500 wells in the basin.

A former fracture engineer for five years, Jeffers once saw almost all completions started in this basin as strictly PNP operations. This completion methodology was not bulletproof, though. "We just weren't getting it done," he said. "On a 10-stage well, we would spend a week to two weeks on a well. We went from PNP to openhole completions and compared the results to see if they were better or worse. We got better results."

Completions have gotten more difficult over the last half-decade, and lateral lengths have grown significantly longer, with stage counts increasing and well



A rig drills for Marcellus gas for Chesapeake Energy Corp. and Statoil ASA at a drillsite in Bradford County, Pa. (Photo by Helge Hansen, courtesy of Statoil ASA)

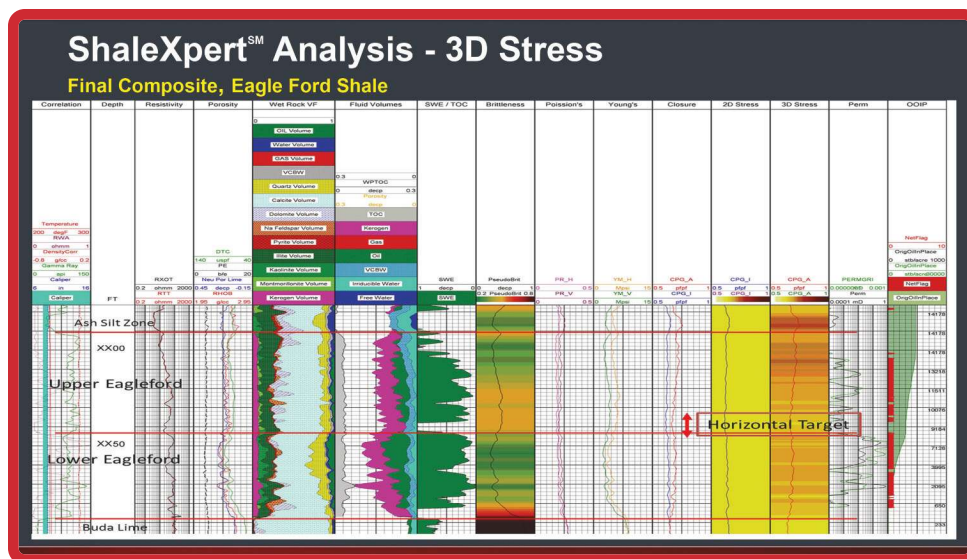
cycles significantly decreasing, said Mark Morris, Baker Hughes operations manager, northeast US, summarizing significant changes he has seen take place.

### Today's technologies

Operators and service companies are applying a panoply of advanced tools and technologies in the Appalachian basin. Companies showcasing technologies and tools include Magnum Hunter Resources, which operates an 18-well pad (Stalder pad) that will serve as the base for a robotic rig (Schramm T500XD); an openhole 20-stage fracturing system from Packers Plus Energy Services (StackFRAC HD), plus a Stack-

FRAC case study; two software applications from Halliburton (ShaleXpert and TightGasXpert), plus wireline and perforating tools (monoconductor tension device [MCTD]); advanced drilling fluids from Newpark (synthetic-based CyberPhase and diesel or mineral oil-based OptiPhase); lateral drilling advances from Schlumberger subsidiary PathFinder (PowerDrive Archer high-build rotary steerable system [RSS]), including a Marcellus shale case study; and the introduction of advanced drillbits from Baker Hughes (Talon 3-D Vector-Accurate polycrystalline diamond compact [PDC] bits), its invert emulsion system (NEXT-DRILL), and its AutoTrak Curve RSS.





The final integrated ShaleXpert analysis displays all parameters required to populate a complete reservoir model. (Image courtesy of Halliburton)

### Correct reservoir analysis drives the play

Understanding what shale reservoirs in the Appalachian basin will yield in gas or oil is a fundamental for production success. Halliburton's ShaleXpert software application allows an integrated analysis that is based on a calibrated workflow for organic shales.

With this software, reservoir models can be built that define the resource volumetrically and provide accurate kerogen volume. This allows engineers to know what fracturing procedures are needed and where perforations should take place. This solution brings "all the requisite pieces of an exploration shale play analysis into a single place," according to Halliburton's website.

Features of this software include:

- Total organic carbon (TOC) estimation and organic maturity;
- Fluid and minerals evaluation;
- Advanced saturation modeling;
- Mechanical properties and brittleness;
- 3-D stress and orientation;
- Permeability; and
- Pay analysis.

Total porosity in organic shales is resolved by combining log-measured relative amounts of geochemically derived minerals with the previously solved TOC. Analysis involves calibrating minerals

found by core X-ray diffraction (alternately X-ray fluorescence).

ShaleXpert analysis has been designed to determine fracture initiation pressure, fracture closure pressure, and closure stress gradient.

Concerning permeability, ShaleXpert analysis uses a linear regression technique to match the core-measured Gas Research Institute's matrix shale permeability.

Final composited ShaleXpert analysis brings together different workflow modules in a display that aids in primary sweet spot identification, identifies in-place reserve estimates, and delivers everything required for an

optimized fracture stimulation design. It also can generate individual quality-control plots and logs from any of its workflow components.

### New software for tight gas formations

Halliburton recently launched a software package targeting tight gas formations called TightGasXpert.

Tight gas is trapped in a highly mixed mineralogy sandstone or limestone formation, which can be impermeable and nonporous. While conventional natural gas deposits, once drilled, contain gas that can usually be extracted quite readily and easily, more effort has to be put into extracting gas from a tight formation. These formations, like shale gas reservoirs, require hydraulic stimulation. However, they typically exhibit permeabilities that are three to four orders of magnitude better than their source rock counterparts.

Dan Buller, a Halliburton global adviser for unconventional, said, "Our TightGasXpert solution is a follow-up from ShaleXpert, consisting of an integrated workflow that uses nuclear magnetic resonance [NMR] moveable fluid analysis, calibrated NMR texture permeability, and a new anisotropic stress analysis to identify pay zones and fracture stages within nonsource rock tight gas formations. It enables operators to optimize completion decisions and stimulation design to maximize gas recovery."

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### Multiwell pad magic in Ohio

When Magnum Hunter announced it had spud its first well on the Stalder pad site in Monroe County, Ohio, significant interest was generated as this was no common pad. This particular unit had been designed and permitted to drill up to 18 wells (10 Marcellus and eight Utica wells). In addition, drilling would be undertaken using a new Schramm T500XD robotic drilling rig, which was delivered in early May.

Magnum Hunter reported the first well drilled on this pad would test the Marcellus formation, and the second one would test the Utica formation. The development plan is to drill both Utica and Marcellus wells first, then fracture stimulate them, tentatively testing the wells sometime in 4Q 2013.

About this undertaking, Gary C. Evans, chairman of the board and CEO, said the eastern portion of Monroe County was an area of interest due to Magnum Hunter's significant acreage position and its ability to exploit so many wells on just one drilling pad. The project, he said, "should create significant savings on costs as well as time."

Unlike traditional drilling rigs that are anchored on rails, with movement limited to left and right positions or front and back positions, the T500XD has a walking subbase. This foundation mechanism can lift the rig 6 in. above the ground, allowing the rig to rotate its position. In addition, the rig walks at a 30 ft/hr pace. As for rig capacity, it can drill to a total depth (TD) of 19,000 ft and features a Load Safe XD automated pipehandling system that racks drillpipe horizontally for loading and offloading. The net result from this device also is expected to improve operator safety.

The T500XD features 35,000 ft-lb of top-head torque, a third-party directional steering interface, and 80,000 lb of hydraulic pull-down capacity.

Evans added that Magnum Hunter worked with Schramm some six months on design and development of the drilling rig, targeting it for the Appalachian basin and some of its difficult terrain conditions.

"Pad drilling also is the wave of the future in the shale plays in order to properly exploit leasehold positions," Evans said.

### Drilling more efficiently

"One of the exciting things I think we will see going forward is automation of the rigs," said Jeff Meisenhelder, Schlumberger vice president of unconventional resources, at the Hart Energy roundtable, *"Better, Faster, Cheaper Wells."* He pointed to a closed-loop feedback system allowing for the control that both pump and rotation can generate "[for] another 15% to 20% improvement."

Kevin Wutherich, Schlumberger stimulation domain expert for the northeast US, added a realistic appraisal on the deployment of multiple-pad wells. He said, "There is no doubt that to effectively drain these ultra-tight shales, tightly spaced horizontal wells are needed. In this context it is obvious that drilling multiple wells from a single pad results in improved logistics and lower surface costs while minimizing the environmental impact, which has always been a concern in the Appalachian basin. Proper well planning is required on every well to ensure that risks are minimized and wells are placed as intended."

### Launching faster RSS drilling systems

One thing that is certain is drilling technology bears little resemblance to the tools that existed just five years ago.

As Robin Robinson, Baker Hughes vice president of drilling services, said during that same roundtable, "Whatever benchmarks we set for performance, we think they can't be beat. However, five years later, we're doing it faster and better than ever before. I think the industry will be seeing similar advancements in drilling, too. We're going to see more well-spacing issues that require more complex well pads, which means you're probably going to need to bring in rotary steerable systems [RSS]."

"The future is optimizing where you fracture and the production you get as a result. One of the things that we're going to see in the future is tools that are run in the drilling process that give us greater insight into the completion process."

Some of the most significant changes over the past five years – occurring not just in the Appalachian basin but elsewhere – include technologies such as

- Custom-built rigs for a given area, specifically designed for pad drilling;

- Advancements in rotary steerable directional drilling technology; and
- Increased drillbit technology for both conventional and RSS.

RSS technologies include tools like Baker Hughes' AutoTrak Curve RSS. "It's a system that provides better drilling economics, exact wellbore placement, and faster drilling in unconventional plays," Baker Hughes' Morris said.

The efficiency of the AutoTrak Curve RSS is enhanced when paired with a Baker Hughes Christensen Talon PDC bit. Talon high-efficiency PDC bits provide optimal performance in first-bit-under-the-surface, intermediate, vertical, near-vertical drilling, and hard-to-drill and abrasive applications. Talon 3-D vector-accurate bits also perform well in unconventional gas applications, including shale plays, and are ideal for conventional directional drilling. The bit's one-piece steel body with a short bit-to-bend dimension allows greater buildup aggressiveness and longer life.

According to Baker Hughes, the system has drilled more than 1,136 miles in the past 32 months, with operators using it for drilling vertical, curve, and lateral sections in one run with the same bottomhole assembly (BHA).

The AutoTrak Curve also has had successful runs in the Utica reducing and eliminating the need to reorient the drillstring or adjust the toolface, even in high stick/slip environments, according to the company.

For steering precision in reservoirs, a real-time azimuthal gamma-ray service delivers near-bit measurements. Expandable pads on a slow-rotating sleeve maintain trajectories, allowing fluid circulation to carry cuttings out of the hole. Directional control at surface allows for changes in targeting.

### RSS system for one-run drilling

An operator in the Utica formation of the Appalachian basin needed to drill a horizontal well with a 10°/100-ft dogleg severity curve section. The operator drilled this section with the Baker Hughes AutoTrak Curve RSS, using an 8¾-in. Baker Hughes drillbit.

A target change at 70° of inclination in the curve section of the wellbore was required. With its advanced steering technology, the system delivered a 17.56°/100-ft buildup rate at 52 ft/hr ROP. The high build rate pro-



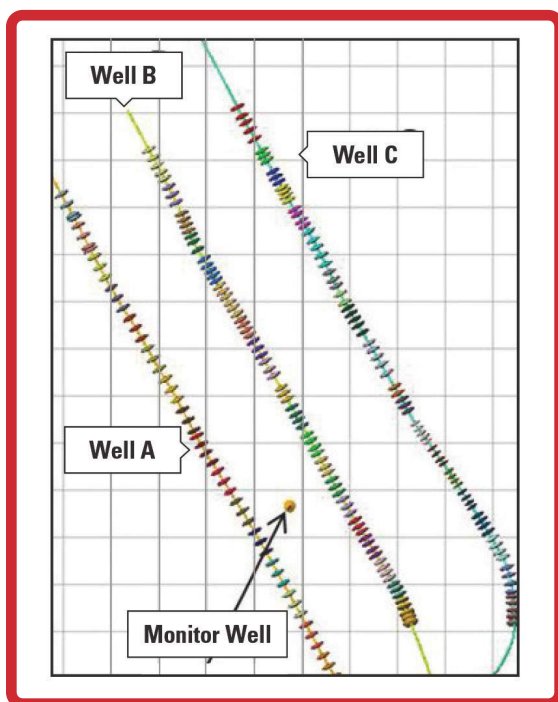
The Baker Hughes AutoTrak Curve RSS can be used to efficiently drill vertical, curve, and lateral hole sections in a single run while achieving a precise 3-D well profile. *(Image courtesy of Baker Hughes)*

vided by the system allowed the operator to land the well in the planned reservoir zone of interest and maximize reservoir exposure without any nonproductive time, unlike a conventional drilling system that would require drilling operations to stop to trip the drillpipe and change the motor bend angle settings.

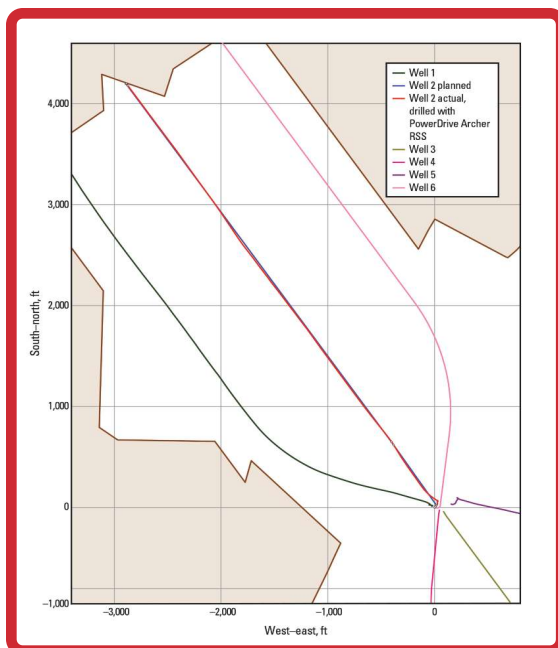
This lateral was drilled at a high ROP, and the wellbore was kept in the target reservoir interval using the close-proximity gamma sensor along with near-bit inclination.

The 1,048-ft curve section was accurately landed in only two rig days, including trip time while running in hole. The 5,400-ft lateral section of the wellbore was drilled to TD in 3.2 total rig days, which included rig time tripping to the surface after the well had been drilled to TD. The average ROP for the combined





A map view of the target wells shows perforation clusters (colored by stage) along the lateral. Well A has geometric perforation clusters, while wells B and C have engineered completion designs. (Images courtesy of Schlumberger)



The Pathfinder directional drilling team landed the curve and lateral sections with no deviation from the plan, taking full advantage of the lease.

curve and lateral section was 95.4 ft/hr. In addition, the system averaged 1,247 ft of drilled footage per rig day while it was in the hole, eliminating a total of 5.2 rig days from the 10-day drilling plan.

### Drilling efficiency

Schlumberger's Wutherich believes the implementation of pad-based drilling has allowed the industry to deliver a step change in drilling efficiency. "Additionally, the increasing length of the horizontal laterals has driven a need for more robust and sophisticated drilling BHAs that can deliver the curves and laterals in one run in the right place without wasting valuable rig time," Wutherich said.

PathFinder, a Schlumberger company, has focused its efforts on developing effective drilling systems that reduce the overall time to drill shoe to shoe and increase well productivity by staying in zone in these long laterals.

As wells are being drilled longer in smaller target intervals, the complex evaluation work has been determined well in advance, Wutherich said.

### Drilling the curve, lateral in one run

An operator in the Marcellus shale wanted to improve ROP in a horizontal well while decreasing the number of trips required. The operator's goal was to complete the curve and lateral in one run. Previously this had not been possible with traditional motor BHAs due to the length of the laterals. Additionally, there had been a need to trip after the curve for the dedicated RSS run.

Pathfinder proposed using the PowerDrive Archer high-build RSS featuring an electromagnetic telemetry system to drill the curve and lateral in one run – the first deployment of such paired technologies.

The PowerDrive Archer RSS drilled the curve and lateral with an average ROP of 128 ft/hr. The curve was landed in one run approximately 1 ft to the right and 1 ft above the plan. The lateral was placed 100% in zone with the use of real-time gamma-ray measurements. The well exceeded the expectations with no deviation from the plan, and the operator plans to use the PowerDrive Archer RSS with electromagnetic telemetry in other Marcellus shale wells.



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The Baker Hughes NEXT-DRILL emulsion fluid system provides greater drilling efficiency in Appalachian wells by better managing downhole fluid pressure. *(Image courtesy of Baker Hughes)*

### Innovations in drilling fluids

To support new drilling modes, Newpark Drilling Fluids has introduced proprietary products and fluid systems incorporating new components designed to advance drilling demanding wells under harsh conditions.

Newpark marketing director John Beltz recently announced that the shale boom and its horizontal drilling technology had brought a burst of onshore drilling fluids business to Newpark.

According to company literature, the designs Newpark uses target not only new approaches for cost-effective drilling-fluid chemistry but also methods that are based on “respect for the environment.”

One Newpark product line, DeepDrill water-based drilling fluids, has been released as an alternative to invert emulsion systems. In addition, Newpark’s FlexDrill system is customizable to address a wide range of drilling environments.

CyberPhase (synthetic-based) and OptiPhase (diesel or mineral oil-based) salt-free internal phase are invert systems. The company also has developed other proprietary products to provide solutions for issues such as shale stabilization, inhibition, and penetration rates.

### Invert emulsion fluid system

In the Appalachian basin, Baker Hughes offers its NEXT-DRILL invert emulsion drilling fluid system to help operators improve their drilling efficiency. The system reduces viscosity in the drillstring that causes wasted pump pressure while maximizing viscosity in the annulus for more efficient cuttings transport. The ability to better manage circulating pressure can lead to improved ROP, said Brian Teutsch, product line manager for emulsion fluids. “These performance improvements will boost well economics and get production online sooner,” he said.

The NEXT-DRILL system features a rapid-set/easy-break gel structure that prevents cuttings in

the vertical section from settling into the curve during connections and trips. It also has elevated ultra-low shear rate viscosity to prevent cuttings in the lateral from agglomerating on the bottom of the wellbore.

The resulting clean wellbore minimizes the torque and drag associated with cuttings beds in the lateral section. The gels break easily, allowing pumps to initiate circulation with minimum pressure spikes.

### Completion advances in wireline and perforating

The Mono-Conductor Tension Device (MCTD) from Halliburton has been manufactured to operate with perforating guns or other explosive services. This tool provides downhole tension measurements at the cablehead to improve operational control.

According to Halliburton, when running perforating guns in highly deviated or horizontal wells, reliance on traditional surface wireline tension measurements may not provide accurate indications as to real downhole conditions. This can be especially the case for horizontal wells with long lateral sections.

Available in 2¾-in. outside diameter, the MCTD was specifically designed for use with perforations in challenging wells. Halliburton recommends this tool be used with its Pump-Down Visualization software.

Additionally, the company's Cable Safe Release tool provides visibility and control should a tool string get stuck downhole, which reduces guesswork and minimizes nonproductive time. The MCTD also is combinable with standard "shooting" casing collar locator tools.

### Shifting from cemented completions to openhole techniques

Not only are changes prevalent for drilling technologies and fluids technologies, completion methodologies show anything but the status quo. It is apparent more openhole completions are now evident in the Appalachian basin, said Jeffers from Packers Plus.

He added that for under-pressured shale plays he is seeing much in the way of nitrogen fracturing. "Just 100% nitrogen – no chemicals, no sand. We're pumping 1 MMcf per stage at 100,000 cf per minute," Jeffers said.

### Multistage fracturing system a success

The Packers Plus StackFRAC HD multistage fracturing system has increased reservoir access in Kentucky.

Estimates of natural gas are high in the Devonian shale, but this has been tempered by low recovery rates averaging 10%.

An operator working in the Devonian shale wanted to prove out a multistage completion technology as he prepared for drilling and completing longer laterals in the area. Extending the reach of openhole laterals was necessary to meet the operator's objectives of optimizing production and lowering costs.

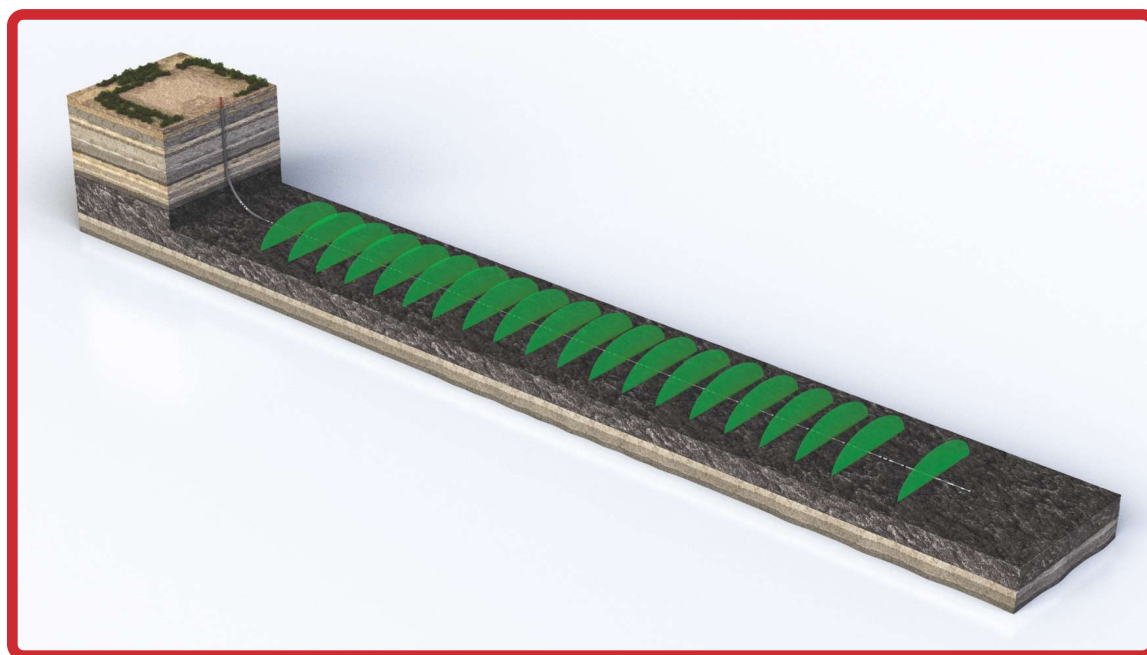
It became necessary to find a multistage completions system capable of handling additional stages to cover the length of the extended-reach laterals.

The operator used a Packers Plus StackFRAC HD multistage fracturing system, as it allowed for more stages in a single system. As a result, it is now running the system exclusively vs. the standard system. The well design was for a TD of 6,325 ft and a lateral length of 3,435 ft, and the average length between the stages was approximately 200 ft.

All 18 stages were fractured and completed in one day. These were gas fractures using 500 Mcf of nitrogen per stage. Since this well, 22-stage systems are being run using 1 MMcf of nitrogen per stage.

### Ongoing completions discovery

According to Baker Hughes, traditional completion methods consisting of cemented long strings and composite plugs also are being deployed in the



The Packers Plus StackFRAC HD multistage fracturing system has proved successful in Kentucky.  
(Image courtesy of Packers Plus)



Appalachian basin. This is primarily driven by pad size and water management challenges.

Over the past several years, operators and service companies have worked to optimize the PNP completion method with a combination of composite fracture plugs, coiled tubing (CT) and wireline perforating systems, and CT conveyed milling services. During this completion process, the liner is run to TD in the horizontal well and cemented in place. To gain access to the formation to begin fracturing, the first stage has typically been perforated using tubing-conveyed perforating guns and then fractured. To complete the next stage, a composite fracture plug and perforating gun assembly is run to the desired depth; the plug is set to isolate the zone; the guns are fired to connect the well to the formation; the guns are retrieved; a ball is dropped; and the stage is fractured. This process is repeated 20 or more times until the entire lateral is fractured. Then a CT milling assembly, including a downhole motor and specialized mills, is run in the well to remove the composite plugs and fracture balls, removing flow obstructions and enabling full production.

To maximize efficiency during this operation, Baker Hughes has continually improved its QuikDrill line of composite fracture plugs to ensure reliable setting and to minimize metal components, making them easier to mill out. QuikDrill plugs have been used to fracture more than 100,000 stages in US unconventional basins. The new SurePerf perforating system enhances efficiency of PNP operations by incorporating redundant guns and firing heads to provide backup in case of misfires, saving wireline trips. The company also has developed Advanced Milling Technology mills with patented Glyphaloy cutters that have improved the efficiency of removing composite plugs after fracturing, with a single mill drilling out as many as 52 plugs in a single run.

Some traditional PNP completions are being undertaken using new technologies to further increase efficiency. The company's Alpha Sleeve pressure-actuated valves and SHADOW series fracture plugs are increasing efficiency and reducing costs in this basin. The pressure-actuated valves provide interventionless access to the formation for the first stage of the fracture job without

requiring a dedicated tubing-conveyed perforating trip, saving time and cost. The SHADOW series fracture plugs provide advantages over composite plugs by eliminating the need for milling after hydraulic fracturing has been completed. The series plugs have a large flow path and use IN-Tallic disintegrating fracture balls to hold pressure during pumping operations. When exposed to produced fluids, the IN-Tallic balls disintegrate, enabling the well to produce without obstruction. The series plugs improve wellsite efficiency and enable accelerated production because the plugs and balls do not need to be milled. The plugs also are ideal for remote locations where CT units aren't easily available. In addition, SHADOW plugs can be set in horizontal sections deeper than the reach of CT, enabling operators to drill and complete longer lateral wellbores and maximize access to their pay zones.

### **CCPP or openhole?**

In the Marcellus shale, Packers Plus has reported using openhole systems to maximize assets where challenges like low porosity and permeability have demanded cost-intensive completion solutions.

"When compared to openhole completions, some will contend that cemented casing plug-and-perf (CCPP) methodology is more cost-intensive due to the additional time and equipment. This results in an inefficient and time-consuming process. Production using this method also can be limited, as cementing a wellbore can reduce or eliminate communication with natural fractures and fissures that might contribute to overall production.

Packers Plus has developed openhole, multistage systems so operators can take advantage of natural fractures and obtain maximum contact with the formation. These openhole completions allow for production from the entire length of the wellbore, as opposed to CCPP, which restricts production to perforations only, according to Packers Plus product information.

### **Openhole systems maximize assets in the Marcellus shale**

A comparison study was done in the Marcellus to measure production of 17 wells completed with Packers Plus StackFRAC HD systems compared to



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surrounding offset wells in the field completed using the CCPP method (SPE paper 155095). The two study areas were in Washington County, Pa., and Susquehanna County, Pa., and cumulative production was compared at six, 12, and 24 months.

In both study areas the wells completed with Stack-FRAC HD systems outperformed the CCPP completed wells producing from 43% to 84% higher in Washington County and up to 37% in Susquehanna County compared to the offset CCPP average. In addition to higher production, the Stack-FRAC HD systems also provided improved efficiency and cost savings compared to the CCPP method. The system's completed wells were stimulated in less than a day compared to approximately two to three days required for the CCPP wells. This efficiency also reduced equipment and personnel costs.

Schlumberger's Wutherich brings a different perspective to the table. "By far, the vast majority of shale wells being targeted in Appalachia are being completed with horizontal wells that are cased and cemented," he said, adding hydraulic fracturing on such well completions uses the PNP-ft technique in which several stages of three to seven clusters of perforations spaced 40 ft to 100 ft apart are fractured simultaneously. "Most often operators are using slick-water type fracturing treatments or a hybrid-style treatment with slick water followed by a more viscous linear or crosslinked gel depending on the specific reservoir properties," Wutherich said.

Wutherich added that due to the relaxed nature of the Appalachian basin, the magnitudes of the principal horizontal stresses are very close to one another. This can lead to the creation of a complex fracture network when hydraulic stresses are applied, as opposed to more bi-wing type hydraulic fractures that may be found in more tectonically active basins. "It is believed that this complexity is further enhanced by using very close cluster spacing, which is why a cased-hole completion is used."

One emerging trend, referred to as the super-frac technique, uses reduced cluster spacing. Fracture stage lengths are decreased, while the spacing between perforation clusters also is decreased.

"By effectively increasing the number of fracturing stages performed on the well, operators can ensure that the entire lateral is better stimulated," Wutherich

said. "But this results in significantly higher costs and time required to complete the well."

### **Water recycle/reuse strategies affect marginal well economics**

Regardless of the play, water remains a key part of leading-edge completion formulas. But the involvement of a plain-old-water solution becomes more complex, especially as production increases.

In the Marcellus an increasing number of mobile treatment technologies are being applied in a cost-efficient manner. As the well count is increasing so is the available water for reuse.

"The days of just diluting are beginning to dwindle," said Shawn Shipman, Baker Hughes area manager of water management. "As these reuse water volumes rise, issues with water quality, as well as fracturing fluid compatibility, become much more sensitive. We're prepared to address those concerns with our H2pro water management service."

Shipman added that the challenge remains for developing robust mobile treatment technologies while also modifying fracturing fluid chemistries that generate positive completions. He cited a number of SPE pertinent case studies titled, "Maximizing Flowback Reuse and Reducing Freshwater Demand: Case Studies from the Challenging Marcellus Shale."

### **Evolution of plays in the Appalachian basin**

Today's Appalachian is a far cry to when reserves were easily exploited from those early shallow oil wells to the deep Trenton lime and more recently coalbed methane, Wutherich said.

"From a technical standpoint, the early days of the Marcellus were characterized by an influx of operators seeking to get these wells on as fast as possible. Now as the play develops, more and more operators are taking their time to fully evaluate the play. More logs are being acquired, and best practices are being used. Wells are being drilled longer and in smaller and smaller target intervals, which are determined well in advance. Good cementing practices, such as properly designed mud cleaning systems, proper centralization, and pipe rotation while cementing are being used. Microseismic monitoring is being used to learn how our induced fractures develop, and these data are being used to model and improve on the entire process," Wutherich said. ■



A woman wearing a hard hat, safety glasses, and a high-visibility vest stands with her hands on her hips in front of a large industrial machine, likely a generator or pump, with various pipes and tanks in the background.

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# Northeast Production Creating Infrastructure Demand

New projects and infrastructure will be a major part of the landscape of the Marcellus and Utica shales in the next 10 years.

**By Frank Nieto**  
Editor, Hart Energy

One easy way to describe the development of the Northeast shale plays is “new.” Although Pennsylvania was the birthplace of this country’s first oil rush in 1859 in Titusville, the Northeast has long been seen as a marketplace for oil and gas and not as a producer.

This resulted in much of the midstream infrastructure in place being pipelines bringing volumes to market from places like the Gulf Coast and the Rockies. This has suited the area well for years, but that has now changed with the advent of the shale revolution.

Beginning in 2008, producers began to develop the Marcellus shale and later the Utica shale. The early days of this production saw the estimated reserve

*(Image courtesy of Blue Racer Midstream)*



figures grow on a regular basis. These estimates and initial productions (IPs) have grown at such an extreme rate that demand for new midstream infrastructure also has increased at a similar rate.

Originally, many in the midstream industry assumed that it was necessary to provide producers with outlets to the Gulf Coast to handle the additional ethane being produced from the Marcellus. But the midstream is nothing if not resourceful and found additional markets for this production in Sarnia, Ontario, Canada, as production has exceeded initial forecasts. Increasingly, though, the market has embraced the notion of building new infrastructure such as processing plants, fractionators, ethane crackers, and more, besides just pipelines.

It is now believed that Northeast production outpaced local demand for the first time last spring.

means that the region's needs are likely to exceed production during peak demand in the upcoming winter. However, storage capacity may be sufficient to cover the seasonal deficit by the next withdrawal season."

As of 2012, there were 107 rigs in the Marcellus, but this amount has decreased to just 78 working rigs at this time, according to Baker Hughes. A sizable portion of these rigs are directed at holding acreage and will likely be moved to other plays once these leases are maintained. "This is particularly true for those with joint venture [JV] commitments in the region, who have a wide range of drilling targets outside of the Marcellus," the report said.

The play's production growth is attributed to improved production levels out of wells due to the implementation of better land targets, reduced cluster spacing completions, longer laterals, and more



**PRIOR TO THE DEVELOPMENT** of the shale plays, if you were looking for a processing plant you would call up facility vendors, buy a used plant, fix it up, and put it where you wanted. All of a sudden 2008 shows up, and there are no used plants to be found anywhere.

—Jack Lafield, *Blue Racer Midstream*

This will require the development of additional outlets to other markets to prevent potential gluts from being formed in the local market.

According to a recent Barclays Capital's edition of *Gas and Power Kaleidoscope*, consumption for states north of Virginia and east of Ohio (including Connecticut, Delaware, Washington D.C., Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Virginia, and West Virginia), averaged 10 Bcf/d of natural gas consumption from April 2009 to 2011. The production output crossed this 10 Bcf/d threshold last April.

Further, natural gas production out of the region is expected to increase by 3.6 Bcf/d this year and an additional 3.3 Bcf/d in 2014, according to the report.

"Our projections for production growth suggest that Marcellus/Utica output may surpass Northeast demand in 2014 on an annual average basis," the report said. "The strong seasonality of consumptions

efficient fracturing designs that have led to both better efficiency and reduced drilling times.

Thus far, infrastructure bottlenecks have kept pace with production growth out of the Northeast, but these will begin to be alleviated in the next year and a half, according to Barclays Capital. In 2012, pipeline capacity grew by 3.2 Bcf/d, and it is expected to grow by 2.7 Bcf/d this year with another 1.4 Bcf/d scheduled to come online in 2014. The bulk of this new infrastructure will increase capacity for dry gas out of the region.

Wet gas transportation capacity will be increased as new natural gas processing capacity is added along with new ethane takeaway capacity. Combined, this new infrastructure will enable an additional 3.5 Bcf/d of wet gas to be transported out of the Marcellus/Utica by year-end 2014.

According to the Energy Information Administration, the Northeast's working natural gas storage

## Ethane takeaway and processing infrastructure of the Marcellus and Utica shale plays

Operators	Project	Capacity (Mb/d)	Service date
Aither Chemicals LLC	Plans to build an ethane cracker in the Kanwha Vallet region of West Virginia.	-	2015
Appalachian Resins	Plans to build an ethane cracker, close to the Ohio River for water/river transportation and CSX railroad lines.	-	Year-end 2015
Buckeye Partners LP	Union Pipeline project: new ethane 12-in. pipeline to Sarnia, Ontario, Canada.	90 to 170	TBD
El Paso Midstream Group Inc. and Spectra Energy Corp.	Marcellus Ethane Pipeline System (MEPS) project: an 850-mile line reversal and a new 200-mile pipeline, compression facilities, vaporization, and liquefaction facilities.	60	After 2014
Enterprise Products Partners LP	Appalachia to Texas Pipeline (ATEX Express): a 1,230-mile ethane pipeline to the Gulf Coast. Proposal to build an ethane cracker, transporting ethane into the Gulf Coast with an initial capacity of 125,000 b/d and expandable to 190,000 b/d. Start-up timeline was extended 90 days into 2Q 2014.	190	1Q 2014
	ATEX pipeline loop, pumps, and receipt facilities are on open season. Project proposes to move propane to Mont Belvieu, Texas.	TBD	1Q 2015
Kinder Morgan Energy Partners LLC (subsidiary Cochin LLC)	Marcellus lateral pipeline project: a 240-mile, 16-in. pipeline and 150-mile existing 12-in. pipeline to Sarnia or Windsor, Ontario, Canada, where there are in-place crackers. This project has been dropped.	25 to 150-plus	Cancelled
MarkWest Energy Partners LP, The Energy & Minerals Group, Sunoco Logistics Partners LP	Mariner West: Sunoco pipeline - a 420-mile, 8-in to 10-in. LPG line will be converted for ethane service from Pennsylvania to petrochemical plants in Sarnia, Ontario, Canada and also includes a 45-mile new ethane pipeline to the existing Sunoco pipeline system.	50	Oct. 2013
	Mariner East: Phase I includes a 45-mile pipeline from MarkWest Liberty's Houston, Pa., processing complex to an interconnection with an existing Sunoco Logistics pipeline at Delmont, Pa., and additional processing facilities. Sunoco will convert an 8-in. refined products pipeline to ethane service.	70	Propane shipments start in the first half of 2014, ethane in mid-2015
	Mariner East: Ongoing development of Phase II was discussed in 4Q 2012. No capacity or timeline was disclosed.	-	Proposal
MarkWest Energy Partners LP	MarkWest Liberty Midstream & Resources LLC's plan to construct a Marcellus ethane pipeline to transport ethane from Majorsville, W.Va., to Houston.	-	Presumed complete in 2Q 2013
Royal Dutch Shell Plc	Shell announced plans to build a Marcellus ethane cracker in Monaca, Pa. It will be holding an open season during 4Q 2013.	-	Proposal
	Shell announced plans to build a Utica ethane cracker in Beaver County, Pa.	20	Proposal
Westlake Chemicals Corp.	In 4Q 2012 Westlake announced the conversion of a Calvert City, Ky., ethylene cracking plant to use Marcellus ethane as feedstock along with an expansion from an annual ethylene production rate of 450 million pounds to 630 million pounds. Conversion and expansion are said to be in service in the second half of 2014, vs. an earlier target of 2Q 2014.	-	Pushed into the second half of 2014
Williams Partners LP	The company planned a Utica de-ethanizer at Fort Beeler, W.Va.	30	Mid-2013

Source: Hart Energy Research and Consulting, North American Shale Quarterly 3Q 2013





The Natrium plant includes a storage capacity of up to 127,000 bbl of NGL.  
(Image courtesy of Blue Racer Midstream)

capacity is 843 Bcf with a maximum daily deliverability of 19.5 Bcf/d. While storage demand is expected to increase to the point that it will be able to cover any seasonal deficit by 2015, this coming winter could see a potential glut if there isn't strong heating demand from a cold season. Increased storage also will help the region become a net exporter, which Barlays Capital anticipates to begin in 2015.

The sheer size of the amount of natural gas production out of the region has caused midstream companies to reverse or backhaul systems, such as the Texas Eastern Transmission Pipeline, Columbia Gulf Transmission Pipeline, and the Rockies Express Pipeline, that were previously used to import volumes into the Northeast. Bentek reported that natural gas flows from Canada into the North-

east fell 30% in 2012 and 44% on a year-over-year basis while natural gas flows from the South and Midcontinent into the Northeast fell 24% in 2012 and are down 27% year over year.

This new market dynamic has resulted in some basis points trading at negative differentials, and these could deepen further, according to the report. "Northeast gas will have to flow out of the region. We expect Northeast prices to be increasingly discounted, not only relative to Henry Hub but also to the Midcontinent and western markets," the report said.

This price decrease has been aggravated by the lack of ethane capacity out of the region, but the near-term differential may fade in the coming months as new processing plants and ethane



pipelines are brought online. On a long-term basis, Barclays Capital anticipates the discounts to deepen and become more widespread as demand will fail to keep pace with an even further increase in production growth over the next three to five years.

### Pricing culture changing focus of drilling

One of the reasons for the change in the forecast for the Marcellus and Utica shales has been the change in focus on which parts of the plays are being drilled. “These shale plays are more prolific than first thought,” Jack Lafield, Caiman Energy’s founder, chairman, and CEO, said. “In the current pricing environment, the industry will continue to see a decline in the lean gas areas and continued growth in activity in liquids-rich areas.”

While both natural gas and NGL prices have taken a downturn the last two years, NGL has much greater value and provides stronger returns to producers.

This focus has increased the need for processing and fractionation capacity since NGL must be extracted from the stream before going to the market. More and more midstream operators are choosing to build new processing and fractionation plants closer to the end markets in the Northeast, rather than piping volumes to the Gulf Coast and then bringing them back to the Northeast.

Since the Utica has more liquids-rich regions than the Marcellus, producers are turning their attention to this region, and midstream operators are doing the same. While producers make more money from liquids – which will result in increased use of midstream infrastructure focused on liquids – the downside is that these facilities cost at least three times as much to build as dry gas infrastructure.

“Effective and large-scale midstream players have to be visionary, forward thinkers. You also have to be a diligent student of the reservoir. It also requires an enormous amount of capital and a commitment to taking risk alongside the producers, because you have to build these facilities ahead of the drilling,” Lafield said.

The lead time for processing plants has been growing longer in recent years as it now typically takes midstream companies two years to build a processing plant and place it into service. Prior to the increased development of rich-shale development, it was pretty simple to put a new processing plant in place.

“Prior to the development of the shale plays, if you were looking for a processing plant you would call up facility vendors, buy a used plant, fix it up, and put it where you wanted. All of a sudden 2008 shows up, and there are no used plants to be found anywhere,” Lafield said.

One way that companies such as Caiman Energy battle the need for long lead times is to order a plant before deciding where it will be placed. This brings risk, but it does ensure the company will have the facility and its materials ready to go on a specific date, if not at a specific location.

It has been safe for the company to assume that the location will be in the Northeast either way. In fact, the region has been such a large focus for the company that it formed a JV in December 2012



with Dominion Resources to provide midstream services in the Utica shale.

The JV combined Caiman's midstream expertise and private equity funding with Dominion's presence in the region along with its experienced operations team. Upon the formation of this entity, Dominion contributed 500 miles of its Dominion East Ohio gathering pipeline and the 200 MMcf/d Natrium processing plant in Marshall County, W. Va., along with related pipeline assets.

### Imposing a Gulf Coast model in the Northeast

The past several years have seen the governments of Ohio, Pennsylvania, and West Virginia attempt to lure a petrochemical company to build world-scale crackers in their states. The company that has

Each state offered financial incentives to companies that selected them for construction of the petrochemical plant, including Pennsylvania's Keystone Opportunity Zone program. This program provides owners or businesses in certain locations with reduced or tax-free status for a certain period of time and is expected to generate millions of dollars in incentives for Shell.

Though midstream operators can largely take some of the lessons and best practices used in other plays, this shouldn't always be the case, according to James Cutler, CEO of Appalachian Resins.

Cutler has been involved in nearly every aspect of the midstream industry on both a financial and operational viewpoint since the 1960s, including posts at Allied Chemical and Getty Oil. His vast experience in the industry has given him a unique perspective on the industry and some recent devel-



**WE STILL SEEM TO HAVE THIS MENTALITY** that all units have to be world-scale. Having crunched the numbers for many years, I think the numbers bear out that this concept in many aspects is a myth.

—James Cutler, *Appalachian Resins*

attracted the most attention is Shell, which has indicated that it would build a world-scale ethylene plant capable of cracking approximately 2 billion pounds of ethane per year. Such a plant would require about 60,000 b/d of ethane feedstock and be a further economic boon to these states.

In March 2012 Shell Chemical LP signed an agreement for an option to purchase Horsehead Corp.'s zinc plant in Monaca, Pa., for an undisclosed fee. Shell will evaluate the site as a potential location for an ethane cracker that would handle volumes from the Marcellus and Utica shales. The option, if exercised, would require Horsehead to vacate its Monaca site by April 30, 2014.

Should Shell choose to proceed with construction at the site, located in Potter Township in Beaver County, it would take roughly four years to build the facility, which is expected to cost approximately US \$2.5 billion. It would be the company's fifth ethane cracker in the US.

opments. One development in particular is the push for a world-scale ethylene plant in the Northeast.

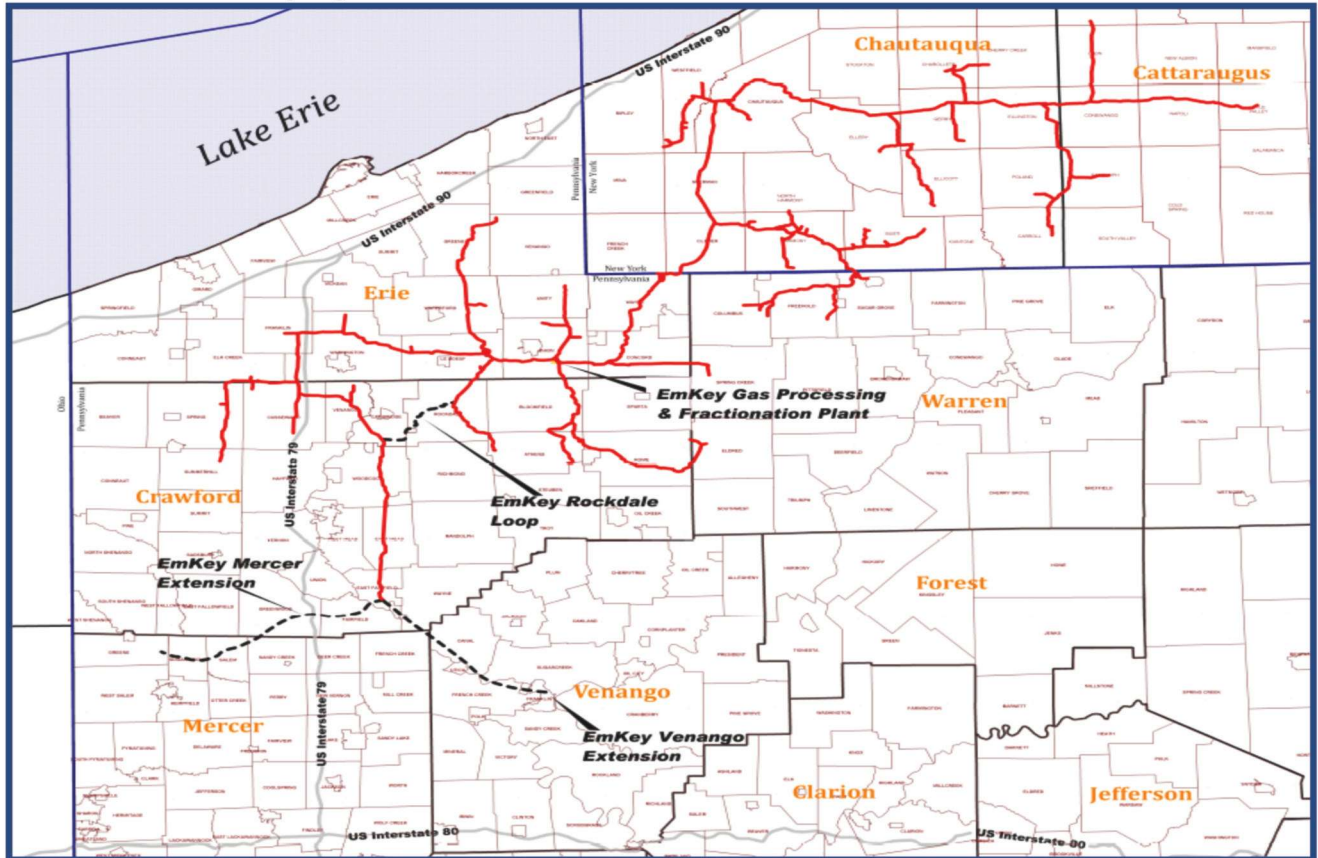
"During the sixties, while we were expanding the chemical business, the thought process was to either build the plants near the end-use markets or close to where the feedstocks were going to be. Because the petrochemical industry was frequently integrated with refineries, the popular thought was you build petrochemical plants near refineries and where the feedstocks were," he said.

As this thought prevailed, it led to the development of vast salt dome caverns unique in the world to Mont Belvieu, Texas, which is connected to every market in North America with facilities as large as possible to handle all of the volumes coming and going from the hub.

"There were plants elsewhere — Clinton, Iowa, for example — but these were aberrations to the original concept of building big plants near refineries. We still seem to have this mentality that all units have to



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**THE HOT OIL HEATER** at the Natrium plant is used in both the fractionation and gas processing facilities as a heat medium.

*(Image courtesy of Blue Racer Midstream)*

be world-scale. Having crunched the numbers for many years, I think the numbers bear out that this concept in many aspects is a myth,” Cutler said.

He said that there isn’t much of an economy of scale with ethylene plants, particularly those using ethane as a feedstock. What often is overlooked is that when you start up a plant, it usually doesn’t operate at full capacity since most plants run between 80% and 90% of capacity.

“That last increment of capacity you’re not getting, and it shouldn’t even be considered. Even if you filled up the plant, then you have to start stepping out to get additional volumes, and your netback is not the same. You also need to review what rolling stock it takes to move your material out as you’ll start to lose your economies of scale through transportation requirements,” he said.

Cutler suggests that what is happening with the push for an ethylene plant in the Northeast is that the industry is superimposing a Gulf Coast model on the Appalachian basin.

“I don’t think we’re looking at true economic development. It’s like running around with a screwdriver and looking for loose screws. We’re trying to superimpose an old model in a brand new environment. The world has changed,” he said.

While world-scale plants make sense along the Gulf Coast, which has a spaghetti bowl of pipelines throughout, such a system is not in place in the Northeast, Cutler said. “We have a large concentration of petrochemical facilities in the Gulf Coast, and all of the plants are big. This is what most people in the midstream industry see every day. There is a wonderful interconnectivity that we see nowhere else in the world. We think that this is the way to do things everywhere. We look at the tremendous opportunity in Appalachia, and rather than asking, ‘What is the best way to do things right now in that region,’ we work with a system that we know.”

According to Cutler, a 500-million-pound plant can be economical and viable in the region. This size is still quite large, but it also is flexible and doesn’t require as much additional infrastructure.

“If you look at what you have to do with the development of storage and the peripheral projects associated with a world-scale plant, you are talking

about billions of dollars of investment. But with a 500-million-pound plant, you have the capability to integrate regional plants. While you don’t have the so-called economies of scale, you can have the plants feed off one another,” he said.

Another benefit of this smaller approach is that it provides more market stability since the market isn’t hammered when a facility goes down or an event like a natural disaster occurs.

If the Northeast were dependent on a single world-scale cracker, it would make it difficult to store ethane in the region when the plant was down for maintenance or due to an unforeseen event. However, this isn’t the case with a smaller plant, which can store volumes in above-ground tanks.

“If a facility were down longer term, 14,000 b/d from a smaller plant have a much easier way of finding a home through pipelines than do 60,000 b/d from a world-scale plant,” he said.

### **Smaller scale plants must come to market first**

Despite the positives that such an approach would have, Cutler said that if a world-scale cracker were to be built in the region, it would become very difficult for a smaller plant to get built.

“It would make it more difficult to find the financing for smaller plants. Venture capitalists look at a 20% rate of return with a 10-year payout. If Shell or someone else builds a world-scale plant, then the economics change. When you buy feedstocks, you don’t get a discount for volumes. It’s either the same price or you start bidding the price up. If you have a world-scale ethylene plant, with the Enterprise pipeline moving ethane to Mont Belvieu and the Sunoco Logistics pipeline moving ethane to Sarnia, there still would be ample ethane, but you start to get to the ragged edge of supply.

“That triggers two concerns for potential financiers of smaller plants: how do you know you’ll get the necessary production volumes from natural gas because you can’t get the gas liquids out without the production; and we’re seeing a lot of gas liquids now, but what happens if production begins to focus on dryer plays? In that case, higher production doesn’t mean higher liquids production,” Cutler said.





The Natrium processing plant was developed by Dominion before being included in the \$1.5 billion JV with Caiman Energy to create Blue Racer Midstream. (Image courtesy of Blue Racer Midstream)

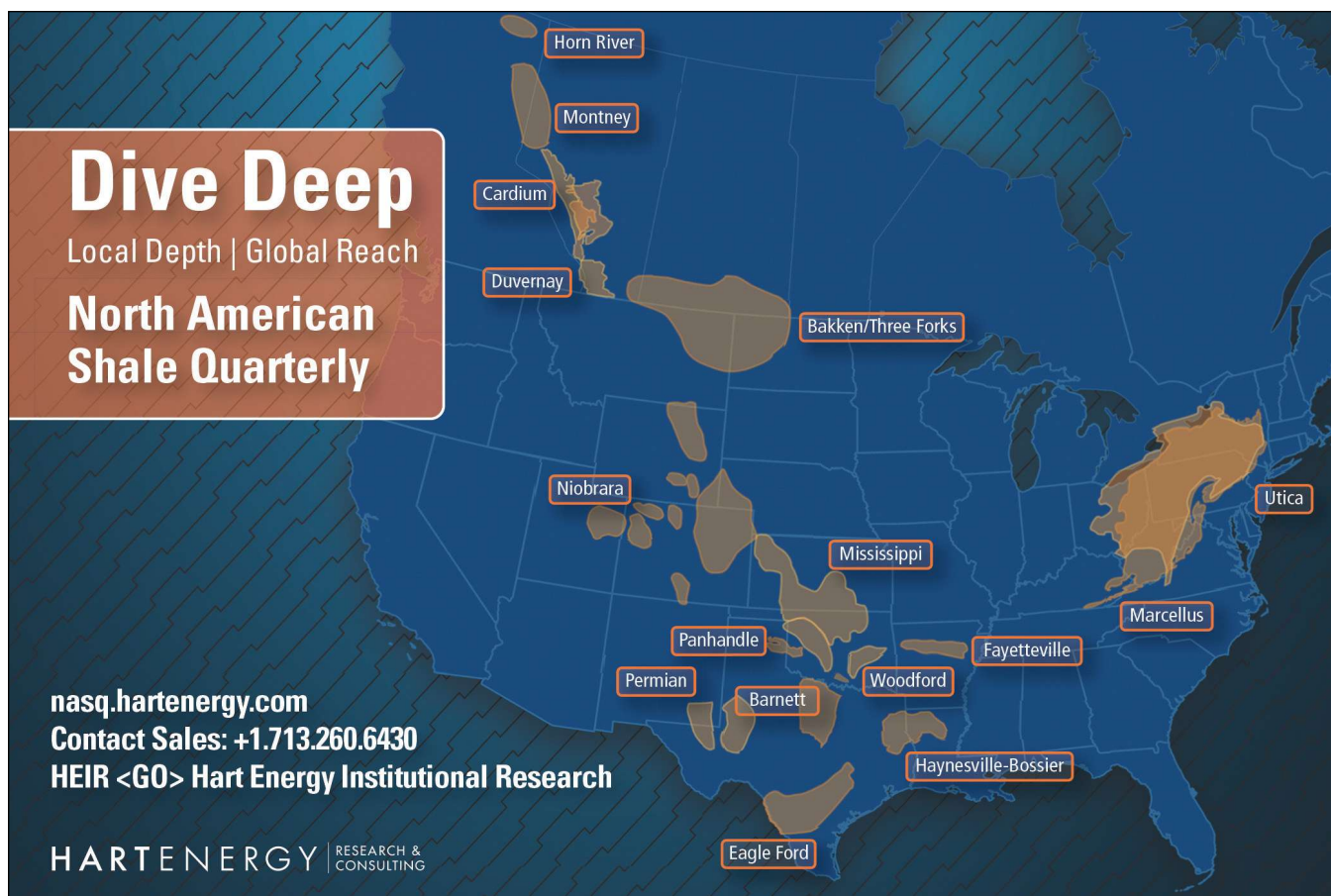
He added that the fact that Shell and other companies are even discussing building a large plant in the Northeast makes it more difficult for companies seeking to build smaller plants to gain traction on their plans.

According to Cutler, after an ethane cracker, the midstream infrastructure that is most needed in the Appalachian basin is an upgraded rail system. The current rail system hasn't been updated in years. Also, there should be more competition so that rail rates would be lower. "That's something that should be done no matter the size of the ethane plant," he said.

"Not only do I believe that regional-sized ethylene plants will be profitable, but more regional ethylene plants would contribute to Homeland Security. This not only covers potential terrorist activities but, more importantly, natural disasters like hurricanes and floods," he said.

This realization is what caused Culter to form Appalachian Resins, which is in the planning and development stage for a proposed ethylene and polyethylene plant in the Northeast that will match his theory.

"We're taking a different approach than the Shells and Dows who are looking at world-scale plants. A lot of these plans don't include the secondary operations, they just sell to other companies



to polymerize it and make it into resins. We're looking at a smaller scale and not just the ethylene plant. We'd look to buy ethane out of the Marcellus shale and turn it into ethylene as well as several different polyethylene resins, which we would sell into the East Coast marketplace," Bob Mifflin, president of Appalachian Resins, said.

The estimated cost of the facility was put at \$400 million. In the event of plant downtime, reinjecting ethane into the gas stream would be manageable relative to a 60,000 b/d intake for a world-scale plant, Cutler said.

Ethane-based facilities tended to be less capital intensive than those based on naphtha, given the need for more back-end units with the latter, Cutler said. Also, in comparing ethane-based facilities of varying sizes, he emphasized that the ethylene yield of the facilities was constant at 80%, regardless of facility size, and indicated that regional plants would have the same variable costs as world-scale plants.

In addition, an ethylene facility in the Marcellus would enjoy an advantage in being near the major polymer consumption areas of the US. By not having to transport ethane to the Gulf Coast and then ship end products back to north-eastern markets, "the potential freight savings would more than take care of the nominal savings of a world-scale plant."

Cutler said an ethane-based ethylene plant could be set up in a master limited partnership structure by having a long-term tolling arrangement under a "take or pay" type of contract. This could generate a steady, measurable amount of cash flow somewhat similar to the characteristics of a pipeline. The ethane "just moves through the ethylene plant," he said. Such an arrangement assumes good credit standings

on the part of the polyethylene purchasers supporting the tolling agreement.

There still are uncertainties about multiple projects in the Marcellus and Utica shales, but one thing that is certain is that new projects and infrastructure will be a big part of the landscape for at least the next decade. ■



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# The Appalachian Basin Continues to Attract Operators

Despite lower natural gas prices, activity within the Appalachian basin continues at a steady rate.

**By Jessica Garrison**

Upstream Research Analyst, Hart Energy

North American shale gas plays are continuing to change the energy landscape as operators find economic value by focusing on the liquids-rich areas within the plays. The production boom is driven by horizontal drilling, hydraulic fracturing, and increasing pad development across all North American unconventional plays. Shale gas production in the northeastern US has been boosted by the super-giant Marcellus, which is part of the Appalachian basin. The Marcellus and its underlying neighbor, the Utica shale, have an estimated combined reserve potential of 122 Tcfe, according to the US Geological Survey. Larger international companies as well as smaller domestic operators are focusing on the cost-competitive development of liquids-rich plays, driven primarily by the lowered natural gas pricing environment over the past several years. Despite the lowered natural gas price environment, activity within the Appalachian basin continues at a steady rate as low-cost production from the Marcellus continues to back out natural gas supplies from other regions in the US. Utica production also is ramping up in the condensate/NGL window along the western border with Pennsylvania and Ohio. The Chattanooga shale already has drawn operator interest in the southern part of the Appalachian basin.

## The Marcellus shale

The Marcellus and Utica shales are stratigraphic neighbors separated by significant geologic time. The similar lithologies make each of these formations an attractive source of hydrocarbon production given their related depositional environments and trapping mechanisms. The long-standing Marcellus shale continues to ramp up production at a steadily increasing rate with a forecasted year-end 2012 rate of 7.8 Bcf/d, as estimated by the *North American Shale Quarterly* (NASQ). The NASQ's 3Q 2013 forecast estimated Marcellus production will average an additional 1.0 Bcf/d, further solidifying it as the No. 1 natural gas-producing unconventional play in North America. Operators have increased the cadence of development in the liquids-rich portions of the play to benefit from NGL pricing.

The largest operator by acreage in the play is Chesapeake Energy Corp., which holds approximately 1,524,000 net acres across Pennsylvania, West Virginia, Ohio, and New York, all in the high-valued areas. Chesapeake is followed closely by Range Resources and the international giant Royal Dutch Shell with 890,000 net acres and 850,000 net acres, respectively. Smaller domestic operators have shown increasing presence in the play as Southwestern Energy continues to report increased production rates along with a recent acreage acquisition of

**LOW-COST PRODUCTION** from the Marcellus continues to back out natural gas supplies from other regions in the US. Utica production also is ramping up in the condensate/NGL window along the western border.

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## Top Marcellus Operators by Acreage

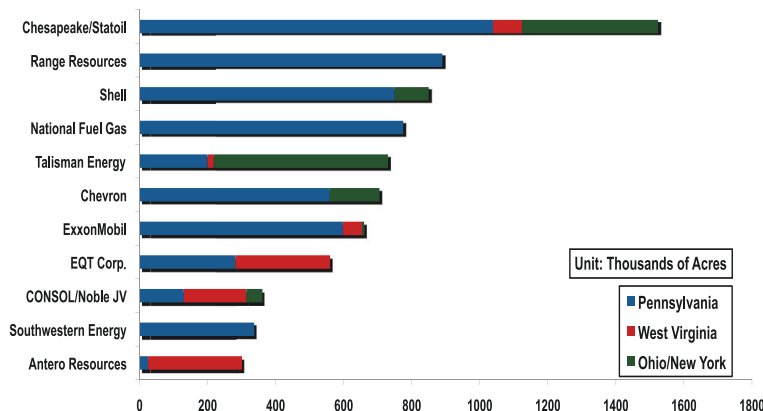


Figure 1. The largest operator by acreage in the Marcellus is Chesapeake Energy Corp., which holds approximately 1,524,000 net acres across Pennsylvania, West Virginia, Ohio, and New York, all in the high-valued areas. (Images and data courtesy of Hart Energy Research and Consulting)

approximately 162,000 net acres from Chesapeake during 2Q 2013. Southwestern recently entered into an agreement with DTE Pipeline Co. to provide additional capacity to the Millennium and Tennessee gas pipelines, which are a part of the Bluestone Gathering System in Pennsylvania. Likewise, Antero Resources is running an aggressive drilling program with 15 drilling rigs along its acreage position in West Virginia. While most operators are adding acreage, Carrizo Oil & Gas Inc. divested 2,850 undeveloped net acres within the noncore area of the play. The top acreage holders are listed in Figure 1.

The hydrocarbon production forecasts for the Marcellus consist of primarily gas at 72%, with high levels of NGL (28%), and less condensate (0.4%), as seen in Figure 2. High liquid and gas yields coupled with the shallower depths relative to its underlying neighbor allow the Marcellus to retain its economic value. The shallow depths of the Marcellus, ranging from an approximate 4,000 ft in the west to 8,500 ft in the east, allow average capital well costs to remain relatively low, at roughly US \$6.13 million, when compared with other shale plays such as the Haynesville that are deeper and have higher well costs.

Low-cost wells and a play-wide average 30-day initial production rate of 6.34 MMcf/d make the Marcellus one of the fastest-growing plays in North America, especially in the liquids-rich southwestern corner of the play in Pennsylvania and West Virginia. The break-even gas and oil prices for select wells are estimated by NASQ. The pre-tax break-even prices in Pennsylvania are higher at approximately \$3.35 Mcf, as shown by a Chesapeake well (Figure 3). West Virginia shows lower break-even prices of \$2.01 Mcf, as shown by a Range Resources well. Figure 3 shows the economic analysis of the Marcellus shale play.

The Marcellus is expected to provide a steady and increasing source of natural gas in the medium term as current operators likely will continue developing their acreage. While the forecast production for the Marcellus does not exhibit an increase after 2020,

unlike what is forecast in the Utica, further development and exploration may increase these estimates in a more robust natural gas pricing environment.

## The Utica shale

In the current low natural gas pricing environment, large and small operators alike have found themselves moving toward the attractive liquids-rich fairway of the Ohio Utica shale. Stretching across approximately 170,000 sq miles of Ohio, Pennsylvania, New York, and West Virginia, the Utica is generally found at deeper depths than the Marcellus, with thicknesses ranging from 150 ft to 350 ft. The thickness and fracability of this formation make it highly attractive for operators to develop the condensate/NGL window of eastern Ohio and the NGL-rich gaseous area of western Pennsylvania. The Utica consists of well-defined zones of hydrocarbon type that trend northeast-southwest with over-mature dry gas to the east transitioning to the oil window in the west. The characterization of the play enables operators to easily target the high-valued zones – which is why it is compared to the Eagle Ford shale – and tap existing infrastructure across the Appalachian basin helping to minimize opex for development costs.

The Utica's exploration activity is centered within the condensate/ NGL window of Ohio and Pennsylvania, with Chesapeake Energy leading operations by acreage. Chesapeake holds approximately 1,268,000 net acres, followed by EV Energy Partners and Chevron with 713,434 net acres and 600,000 net acres, respectively. EV Energy Partners recently divested approximately 22,535 net acres in Ohio to an undisclosed buyer, bringing the company to its current total of 713,434 net acres. Further positions include Anadarko with 300,000 net acres in Ohio, National Fuel & Gas with 562,500 in Pennsylvania, and the joint venture between CONSOL Energy and Hess Corp., which holds 200,000 net acres in Ohio.

Smaller operators, such as Antero Resources and Gulfport Energy, are quickly gaining know-how in the play. Gulfport, for example, recently acquired an additional 8,000 acres giving it a total of 136,000 net acres after stringing together several excellent well results from drilling operations in 2013. REX Energy Corp. announced

## Marcellus Production Forecast

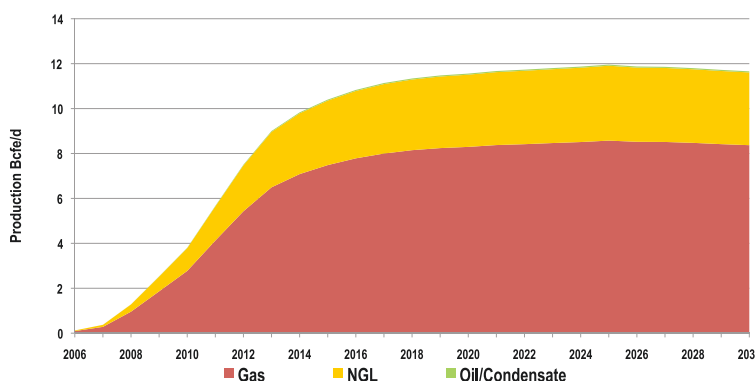


Figure 2. The hydrocarbon production forecasts for the Marcellus consist of primarily gas at 72%, with high levels of NGL (28%) and less condensate (0.4%).

an acquisition of 600 acres in Ohio bringing the company's total acreage to 21,000 net acres. The top operators by acreage are shown in Figure 4.

The hydrocarbon forecast for the Utica is similar to that of the Marcellus, although there is slightly

## Economics for Select Marcellus Wells

Case Name	Well and Acreage Parameters			Product Splits			Type Well NPV		Break-even Oil Equivalent Price		Break-even Gas Price	
	IP at 30 days (MMcfe/d)	30 Year EUR (Bcfe)	CAPEX (\$mm)	G (%)	NGL (%)	Oil (%)	Pre-Tax (\$mm)	After-Tax (\$mm)	Pre-Tax (\$/boe)	After-Tax (\$/boe)	Pre-Tax (\$/Mcf)	After-Tax (\$/Mcf)
Chesapeake (Wet Gas, Marshall Co., WV)	8.4	4.32	6	0.773	0.221	0.006	1.95	0.54	22.63	24.99	2.91	3.45
Chesapeake (Dry Gas, Bradford Co., PA)	5.27	4.42	6	0.93	0.067	0	1.29	0.27	21.57	23.64	3.35	3.74
CONSOL Energy (Greene Co., PA)	5.1	5.06	6.6	0.696	0.299	0.005	1.76	0.38	24.26	26.88	2.91	3.57
Cabot Oil & Gas (Susquehanna Co., PA)	9.39	5.66	6	0.946	0.054	0	2.42	0.68	20.23	22.45	3.13	3.55
Range Resources (Marshall Co., WV)	6.3	3.8	5.1	0.633	0.363	0.362	2.56	0.95	22.19	24.51	2.01	2.64

Figure 3. The economic analysis of the Marcellus shale play.



### Top Utica Operators by Acreage

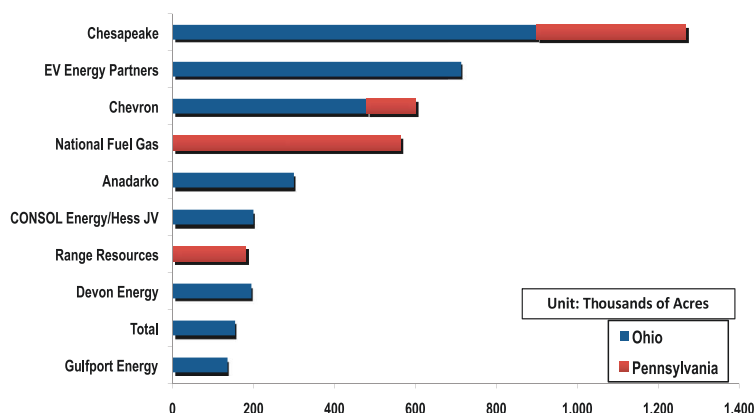


Figure 4. The Utica's exploration activity is centered within the condensate/NGL window of Ohio and Pennsylvania, with Chesapeake Energy leading operations by acreage. Chesapeake holds approximately 1,268,000 net acres, followed by EV Energy Partners and Chevron with 713,434 net acres and 600,000 net acres, respectively.

more condensate volume coming out of the condensate/NGL fairway in Ohio. Utica production consists primarily of gas at 57%, NGL (32%), and condensate (11%), as seen in Figure 5. The liquids-rich expectations have proved to be more diverse

### Production Forecast for the Utica Shale

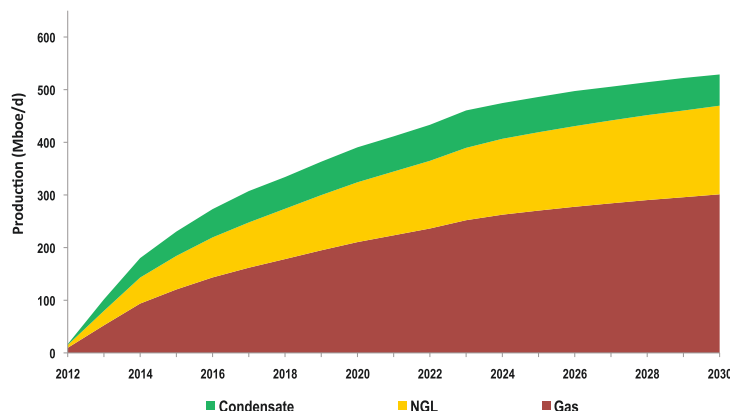


Figure 5. The hydrocarbon forecast for the Utica is similar to that of the Marcellus, although there is slightly more condensate volume coming out of the condensate/NGL fairway in Ohio. Utica production consists primarily of gas at 57%, NGL at 32%, and condensate at 11%.

than previously expected as the play continues in the delineation phase and moves into the optimization phase of development. Year-end 2012 production is estimated at 16.63 Mboe/d, but Hart Energy's 2013 production forecast is 101.72 Mboe/d, primarily driven by an increase in offtake capability and operator drilling cadence after mid-year. NASQ estimates a steady increase in long-term production.

Utica wells have a higher capital cost than the overlying Marcellus at an average of \$8.7 million mostly because of the increased depth of the formation and also because the play is in an early development stage. While capital costs are higher in the Utica, strong condensate and NGL yields have driven investment in the play. As operators begin to develop their acreage more intensively, drilling and completion costs are expected to decrease. The Antero Resources well located in Monroe County,

Ohio, demonstrates the highest pre-tax net present value (NPV) in comparison to the other wells shown in Figure 6. Despite having a low condensate yield, the NPV is \$9.18 million because of the well's exceptionally high production rate. In comparison, Chesapeake's well located in Carroll County, Ohio, shows the lowest economic metrics as low production coupled with low liquids yields make the well only marginally economic. The remaining wells demonstrate liquids yields and production profiles that fall within these two extremes. Negative break-even gas prices are associated with wells in areas of the Utica that contain large amounts of NGL, which contribute to the majority of the wells' revenue – so much so that the wells are economic even if the gas has no value. Average well economics from the top operators are shown in Figure 6. The location of these wells with their associated gas-oil ratios (GORs) is shown in Figure 7.

Full production capacity is expected to be slightly inhibited until large-scale infrastructure begins to come online by year-end

## Economics for Select Utica Wells

Case Name	Well and Acreage Parameters			Product Splits			Type Well NPV		Break-even Oil Equivalent Price		Break-even Gas Price		Break-even Oil Price	
	IP at 30 days (MMcfe/d)	30 Year EUR (Bcfe)	CAPEX (\$mm)	G (%)	NGL (%)	Oil (%)	Pre-Tax (\$mm)	After-Tax (\$mm)	Pre-Tax (\$/boe)	After-Tax (\$/boe)	Pre-Tax (\$/Mcf)	After-Tax (\$/Mcf)	Pre-Tax (\$/Bbl)	After-Tax (\$/Bbl)
Chesapeake Energy (Carroll County, OH)	4.21	3.53	8	0.63	0.19	0.19	1.03	0.55	33.62	36.64	3.09	3.91	65.96	78.6
Chesapeake Energy (Harrison County, OH)	4.46	3.74	8	0.46	0.08	0.46	5.39	2.37	34.62	37.98	-2.18	-0.95	42.47	49.42
EV Energy Partners (Guernsey County, OH)	4.64	3.89	8	0.37	0.2	0.43	5.98	2.69	33.45	36.71	-4.18	-2.7	41.82	48.23
Gulfport Energy (Harrison County, OH)	5.23	4.38	8	0.37	0.1	0.54	9.07	4.32	31.72	34.98	-7.13	-5.65	33.56	38.98
Antero Resources (Monroe County, OH)	12.12	10.16	11.5	0.64	0.36	0.01	9.18	4.14	18.93	20.82	1.22	1.72	11.25	23.48

Figure 6. The Antero Resources well located in Monroe County, Ohio, demonstrates the highest pre-tax NPV. The NPV is \$9.18 million because of the well's exceptionally high production rate. In comparison, Chesapeake's well located in Carroll County, Ohio, shows the lowest economic metrics as low production coupled with low liquids yields make the well only marginally economic.

2013 and into 2014. At this time the Utica is expected to substantially increase production to an estimated average of 180.12 Mboe/d (1.08 Bcf/d) by 2014 as operators complete and connect wells to pipelines and infrastructure begins operating at full capacity. It is expected that current operators will expand their acreage base and continue to develop multiple positions in the play as other operators begin to enter the promising Utica shale, resulting in a steady increase in production through 2030, peaking at 528.86 Mboe/d (3.2 Bcf/d). Continued infrastructure buildout and the reporting of positive well results could ultimately increase these estimates.

The unconventional plays in the Appalachian basin should continue to attract operators after demonstrating a plentiful source of liquids-rich hydrocarbons. Additional offtake capacity and LNG buildouts also will help to alleviate any production limitations due to infrastructure in the highest demand region in the US. ■

### Location of Utica Wells Showing Associated GOR Values



Figure 7. The location of Utica wells with their associated GORs are shown.



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For more details on the Appalachian shales, consult the selected sources below.

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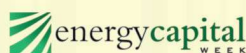
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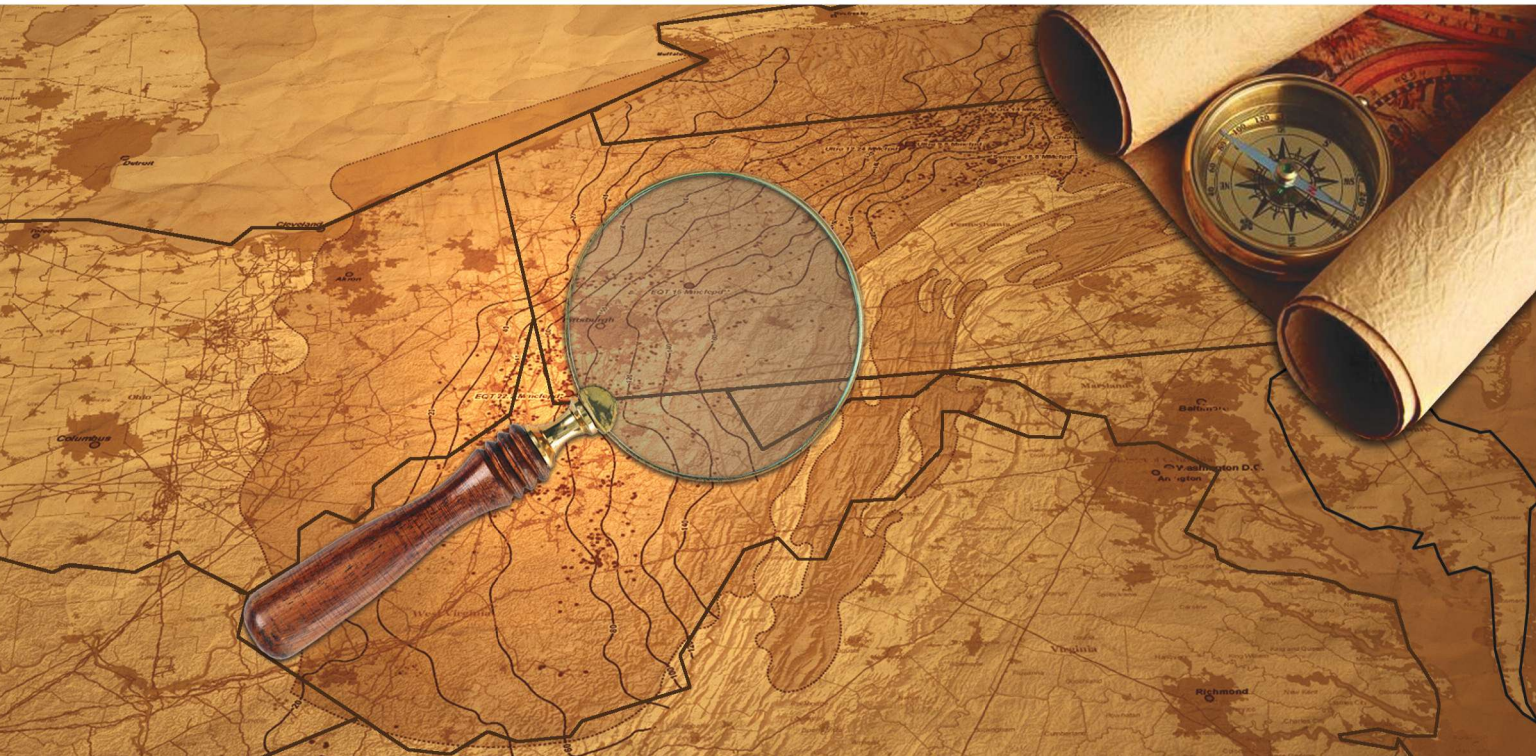
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