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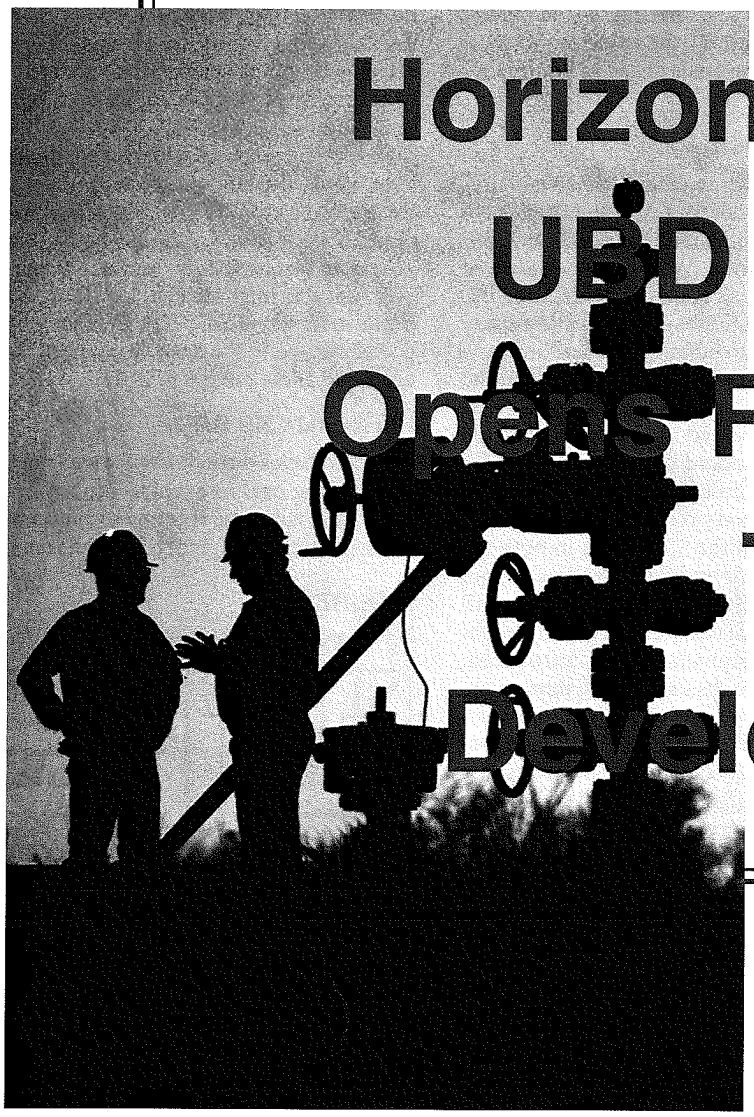
Gas Industry Strategies



Horizontal And UBD Drilling Opens Regions To CBG Development

Attachment 2

Horizontal Drilling Adds Value In CBG

By Doug Wight

DALLAS–Commercial coalbed gas activity got its jump-start only 15 years ago in the United States, yet CBG already boasts impressive production and reserve rates. In fact, coalbed gas now represents 9 percent of the nation's total daily natural gas production and 25 percent of its natural gas reserve base.

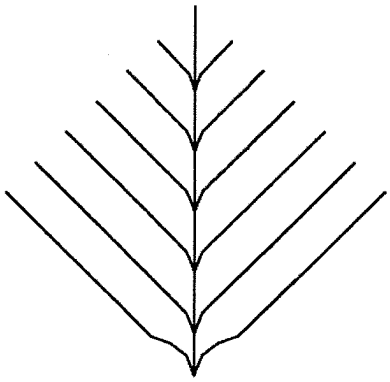
Those numbers are impressive for a resource that did not even register on the exploration and production industry's radar screen only a short time ago. In fact, coalbed gas activity has seen such phenomenal growth–especially by independent oil and gas companies–that it is easy to forget exactly how young the CBG industry is. And because the development of this unconventional resource is relatively new, the technology and methods for drilling and producing gas from coals is still largely in a state of progression, albeit a rapid progression.

While the first coal mining operation in the United States occurred in 1751 in Pennsylvania on Coal Hill (now Mount Washington), it took another 200 years for the first coalbed gas well to be drilled. Coal and natural gas (and oil) are often found together, and operations to develop one resource have often been challenged by the presence of the other.

For instance, coal has historically been a hindrance to drilling and producing oil and natural gas. For oil and gas producers, coal was something to be overcome, worked around or worked through to reach the underlying hydrocarbon reserves. As natural gas began to emerge as a primary energy source in the United States, it ultimately became evident that coals were a rich source of methane, not merely an obstacle to producing traditional natural gas reserves.

FIGURE 1

Example Single Pinnate



On the other hand, the coal mining industry long viewed the methane trapped in coal deposits as a nuisance. It was hazardous to miners, and venting or flaring it from mines was time-consuming, cumbersome and environmentally undesirable. Although rural communities in the eastern United States have been fueling power projects with "gob gas" from coalbeds for many years, little effort had historically been devoted to capturing the value of the gas generated during mining. However, the increasing relative worth of natural gas in recent years has caused the mining industry to rethink the value proposition of degasifying coals ahead of mining operations.

Viable Resource

CBG began to emerge as a viable resource three decades ago. But there were no in-depth studies on the rock's gas content at that time. With firm evidence of substantial gas stores in coals, the U.S. Bureau of Mines began a scientific study in the 1970s to determine where and how much gas was stored in coalbeds in the Black Warrior Basin in Alabama. That research revealed that the gas contents of the coals could be sufficient to meet commercial production needs.

Test coalbed gas wells were drilled and completed in the 1970s-80s in both the Black Warrior and San Juan basins, but the big CBG boom did not occur until 1989, when Section 29 tax incentives for CBG development were introduced. Those tax credits ended only three years later, however, and their end marked a sudden halt to significant development of new CBG technologies and field activity.

Good things did emerge from this short, quick growth spurt. For the most part, during this relatively short time, only fracture-stimulated wells had been tested and gained a foothold in both the Black Warrior and San Juan basins. As CBG developers moved to other coal basins, it became clear that easy-to-produce Black Warrior and San Juan fields were not the norm. The industry was not yet prepared for the challenges it would face in the Rockies, Canada and other western basins.

From this initial CBG activity also came a better understanding of the coalification process and gas stores in coals. Studies of the age of coals in relation to permeability taught the industry that immature coals are more permeable and that while more mature coals hold more gas, they are tighter and harder to produce. All this information enabled CBG developers to be smarter about how and where they pursued projects, as well as the technology they used to drill and produce wells.

Most San Juan and Black Warrior wells drilled during the tax credit CBG boom targeted high-permeability coals that were easy to produce with traditional vertical drilling and fracturing techniques. Starting in the late 1990s, production moved into the Powder River Basin in Wyoming, where coals also tend to be highly permeable and easy to produce with vertical wells.

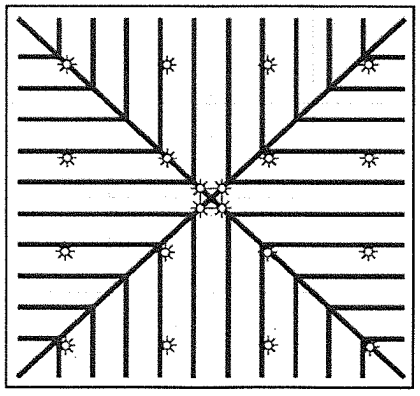
With the exception of these areas, however, vertical wells are often inefficient for coalbed gas production, requiring hundreds of wells to exploit a reservoir. Compounding that, vertically produced reservoirs take a long time to produce gas because they typically require a lengthy dewatering period to draw water from the coals and allow the gas to flow.

Horizontal CBG Drilling

Naturally, as the industry entered more challenging coal reservoirs like the Appalachian, Arkoma, Raton and Piceance basins, interest in applying horizontal

FIGURE 2

Example Quad Pinnate



■ 1 Quad pinnate pattern

■ Conventional wells

drilling gained ground. Although horizontal drilling costs can be double or more compared to a vertical drilling project, the technology has substantial benefits when implemented in CBG.

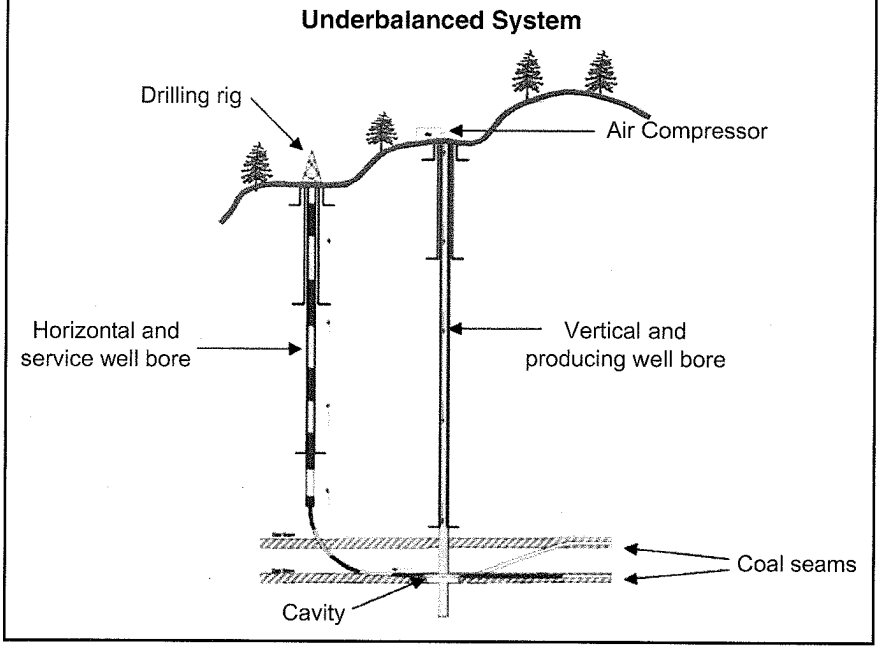
Traditional horizontal wells are best suited for highly-fractured reservoirs that can create quick initial production returns. Drilling horizontal laterals increases the likelihood of intersecting a coalbed cleat or fracture at right angles to the dominant fracture direction. With laterals in the coalbeds, the distance a gas molecule has to travel to the well is decreased and production time is minimized.

To be successful in a horizontal CBG project, it is critical to intersect the fracture plane in the right orientation to maximize the number of fractures intersected. Fracture orientation studies provide some level of assurance in drilling fractures, but it is difficult to predict perfectly.

Adding multiple laterals and underbalanced capabilities to horizontal CBG drilling and completion maximizes the value of the technology in coalbed gas development by intersecting the fracture planes in the optimal orientations and minimizing formation damage to productive coal intervals.

Figure 1 shows an example of the Z-Pinnate™ advanced multilateral underbalanced drilling and completion system optimized for CBG. Incorporating a multilateral horizontal drainage network configured in a pinnate (the structural veins in a leaf) pattern. As shown in Figure 2, multiple pinnate patterns, or drainage networks, can be nested and drilled from a single well site to drain up to 1,200 square acres of coal. This ensures significant and thorough fracture intersection while minimizing surface disruption.

FIGURE 3

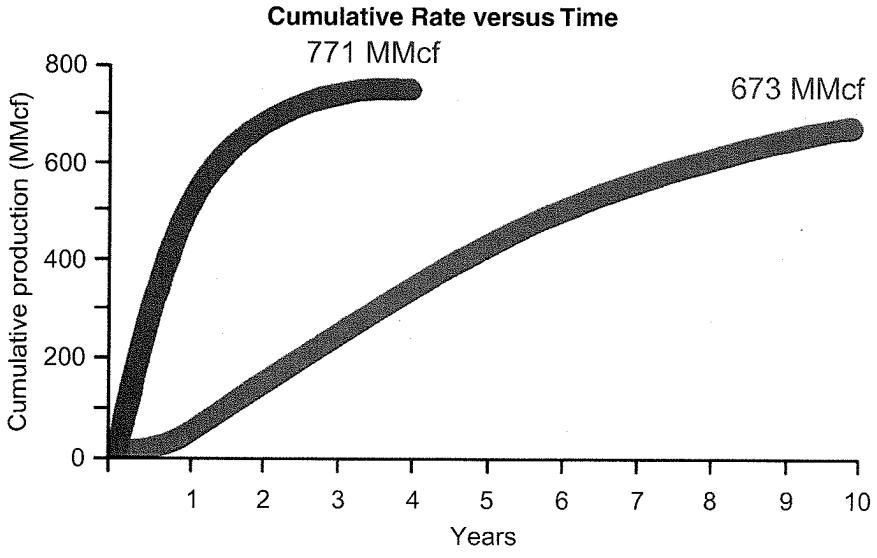


By comparison, traditional vertical drilling and fracturing recovery methods require one well for every 80 acres of coal. Reservoir benefits aside, the ability to drain gas from 1,200 acres of coal from one well site is a critical advantage, since many CBG plays are located in areas where environmental sensitivities are high. The gross coal area drained by a single well location could become even larger in the future, with work now underway to expand the effective drainage network from 1,200 to 2,000 acres from one well site.

The dual-well multilateral horizontal system provides efficient downhole water separation, allowing water to be easily pumped off. This creates ultralow bottom-hole pressures, which in turn, enables high ultimate gas recoveries and low residual gas content at the time of mining. The dual-well system also allows for economical underbalanced drilling, as shown in Figure 3.

The combination of the leaf-shaped pinnate drainage network and dual-well underbalanced horizontal drilling enables the recovery of 80-90 percent of the CBG in only 24-48 months, as illustrated in Figure 4. Of course, accelerated recovery rates provide significant economic benefits, and economies of scale are achieved when a single 1,200-acre drainage network replaces 16 conventional vertical wells. Other benefits include minimal surface disruption, uniform drainage, increased safety in mining operations, and very low overall methane emission rates.

FIGURE 4



Underbalanced System

The key differentiating aspect of this technology is the underbalanced system.

By intersecting the main well bore, an underbalanced environment is established. This minimizes, or even eliminates altogether in some circumstances, one of the principal obstacles to effective CBG production: formation damage from mud weights. In conventional overbalanced drilling (i.e., the hydrostatic pressure of the mud column is greater than the internal pressure of the reservoir), even lighter-weight drilling muds can plug coal pores and fractures, thereby plugging off permeability and gas flow.

The first application of the new CBG drilling technology was at U.S. Steel Mining's Pinnacle Mine in southern West Virginia. USM had been using underground drilling techniques to predrain gas in advance of mining operations. Underground access constraints made it impossible to produce a sustainable gas supply, and the process required drain holes every 75 feet. Although methane was being adequately drained, costs were high because of the high-density underground drilling operations.

Horizontal drilling operations initiated from the surface appeared to offer significant benefits compared to underground drilling. Surface drilling operations can take place well in advance of mining. Similar to underground drilling operations, surface-initiated horizontal wells also offer higher ultimate recoveries than vertically drilled and fractured wells. Yet, problems relating to dewatering and cost still remained.

Using the dual-well multilateral horizontal system, more than 20 billion cubic feet of methane gas has been recovered to date from the USM Pinnacle Mine alone. In fact, CDX Gas ranks as West Virginia's largest CBG producer, with production of more than 14,000 Mcf of gas a day.

Against a backdrop of general supply tightness in the North American gas marketplace and higher commodity prices, domestic oil and gas operators are increasingly turning to unconventional resources like CBG to secure new gas supplies. Total North American coalbed gas reserves are projected to increase to 7.5 trillion cubic feet within the next few years, up from 4.5 Tcf in 1998, making coalbed gas the fastest-growing source of natural gas.

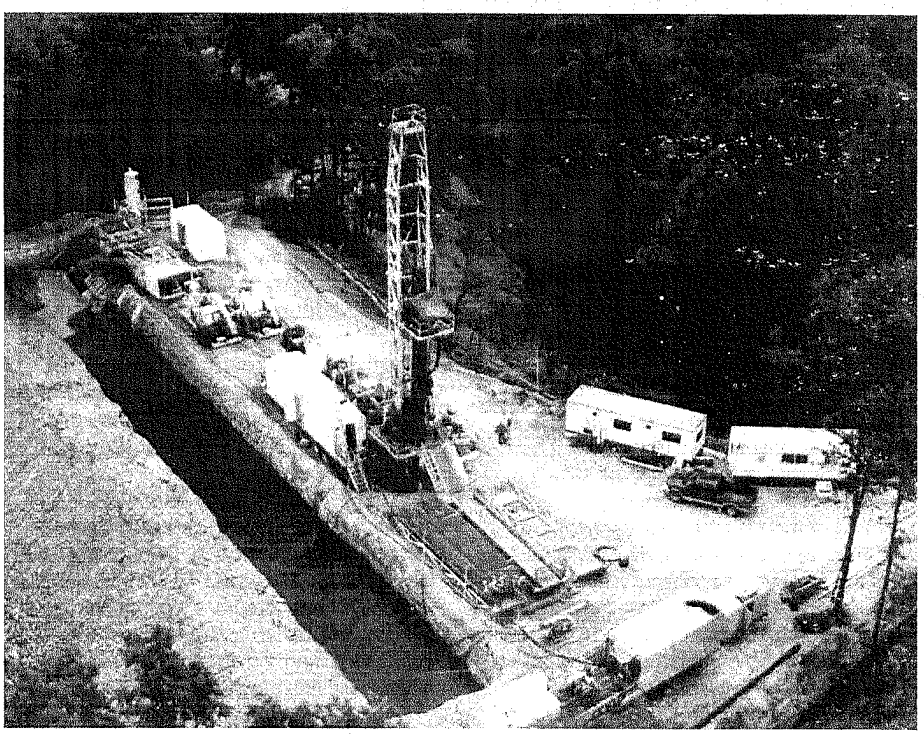
The technology for producing the nation's valuable CBG resource has come a long way in a short time, but greater things are yet to come as pilot projects spread to new coal-rich areas and development projects in basins all across North America gain momentum. As coalbed gas field activity proliferates, the technology for drilling, completing and producing CBG wells will continue to evolve. Looking forward, it will be interesting to see what other new technologies emerge for tapping CBG and other gas-rich unconventional reservoirs. ❐

DOUG WIGHT *is vice president of corporate development at CDX Gas LLC, which holds 25 patents for its Z-Pinnate™ horizontal drilling and completion system for coalbed gas drilling and production. CDX is applying the technology primarily through joint venture agreements with U.S. Steel, Talisman Energy Inc., Penn Virginia Corp., Magnum Hunter, and Dart Energy Corp. LLC.*

Unconventional vision frees gas reserves

Innovative techniques backed by solid technology are changing coalbed methane drilling and production from an art to a science.

BY DICK GHISELIN, Production & Drilling Editor



CDX small footprint — one well drains up to 1,200 acres.

North America is sitting on trillions of cubic feet of technically recoverable coalbed methane (CBM) reserves. This information is not new. But sitting on something is not the same as holding it in your hand, and for many years production of CBM could not be economically justified. The gas was adsorbed within coal cleats, which resemble small blocks, and held in place by tons of interstitial water. For years, coalbed methane was viewed as merely an impediment to coal production. Miners needed to degas their mines before they could safely work in them — a lesson many learned the hard way. The first coalbed wells were drilled prior to mining to lessen the risk of explosion. Later, entrepreneurs started thinking of ways they could capture and monetize the gas, and the race was on.

Traditionally, the technique for getting at the CBM was to drill a well into a coal seam and spend the next several months dewatering it. This reduced the hydrostatic head on the coal so the gas could desorb and make its way through the matrix to the cleat system and finally into the well. In many cases it was a gamble. Wells were drilled and thousands of dollars invested in dewatering only to find out that the gas volume was insufficient to support an economic producer. Now, thanks to a patented technique being applied by independent CDX Gas of Dallas, Texas, coalbed methane can be successfully drilled and produced — scientifically.

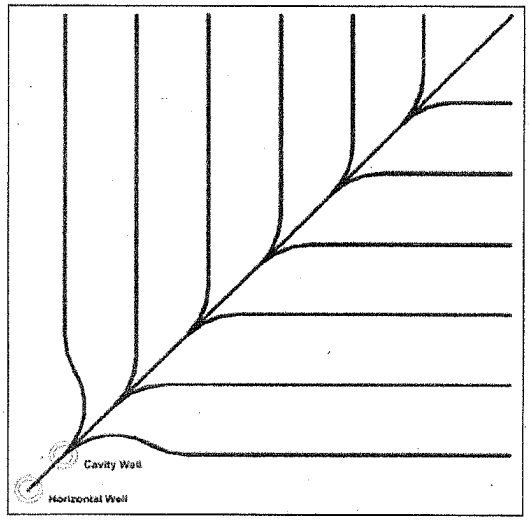
How much is there?

According to estimates by the Potential Gas Committee and others, the US has more than 703 tcf of coalbed methane, with 147.4 tcf being technically recoverable. Currently, almost 1.5 tcf are being produced per year — about 10% of total annual US natural gas production. Canada is like a sleeping giant with reserve estimates ranging from an ultra conservative 146 tcf to more than 3,000 tcf.

Most of Canada's CBM (352 tcf) is found in the Alberta plains, with the foothills of British Columbia and Alberta combining to add another 179 tcf. A small amount can be found in the Maritime Provinces. All areas are potential targets for CDX' technique.

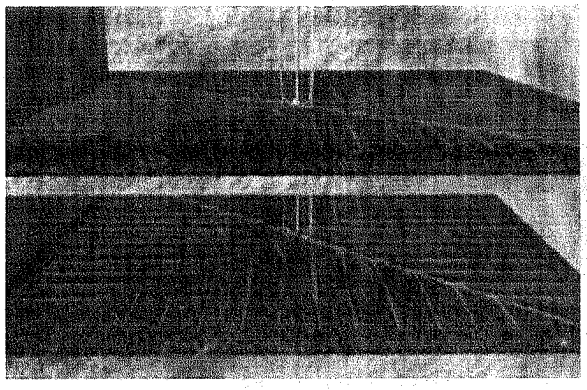
The most prevalent drilling method for CBM has been conventional vertical wells. Unfortunately, production from these wells is inefficient and hundreds are required to exploit a reservoir. Deviated wells that place long horizontal drain holes within the coal seam produce more efficiently, especially after hydraulic fracturing, but are often cost prohibitive. And after-the-fact techniques called GOB drilling seek to recover attic gas from abandoned mines by drilling into caverns formed when mine pillars are pulled as the last coal recovery effort before the mine is closed.

In each case, marginal economics put a damper on activities. Most reservoirs give up their coal gas slowly, and only after extensive and expensive dewatering. Surface locations are large and costly, and conventional well spacings fail to drain the reservoir adequately.



Horizontal Pinnate drainage pattern with producing (cavity) well and horizontal (draining) well.

Attachment 3



Multiple seam completion technique.

A new wrinkle

CDX Gas set the objective to develop game-changing technology to economically produce unconventional reservoirs. The key was higher rate gas recovery, uniform drainage and early production contemporaneous with dewatering activities. Impact to the environment had to be minimized, so a technique had to be developed that maximized production from a limited number of surface locations. To accomplish these objectives CDX formed a wholly-owned subsidiary company, CDX-DART Drilling & Technology, LLC (CDDT). They created a unique "Pinnate" drilling and drainage technique that involves drilling two wells. First, a vertical well is drilled to the target coal seam. If seams are stacked, it is possible to extend the vertical well downward to pierce additional seams.

A cavity is reamed in the vertical well at each seam to create an accumulation chamber or sump for water collection. Next, a directional well is drilled nearby and steered to intersect the cavity horizontally, then continuing to pierce the coal seam laterally. Branch laterals, totaling as much as 25,000 ft are drilled off the main lateral until a roughly square drainage pattern is made. Subsequently, as many as three additional pinnates can be drilled from a single surface location in a "quad-pinnate" pattern. This provides 360° of drainage, optimizes both dewatering and production, and replaces 16 standard 80-acre locations.

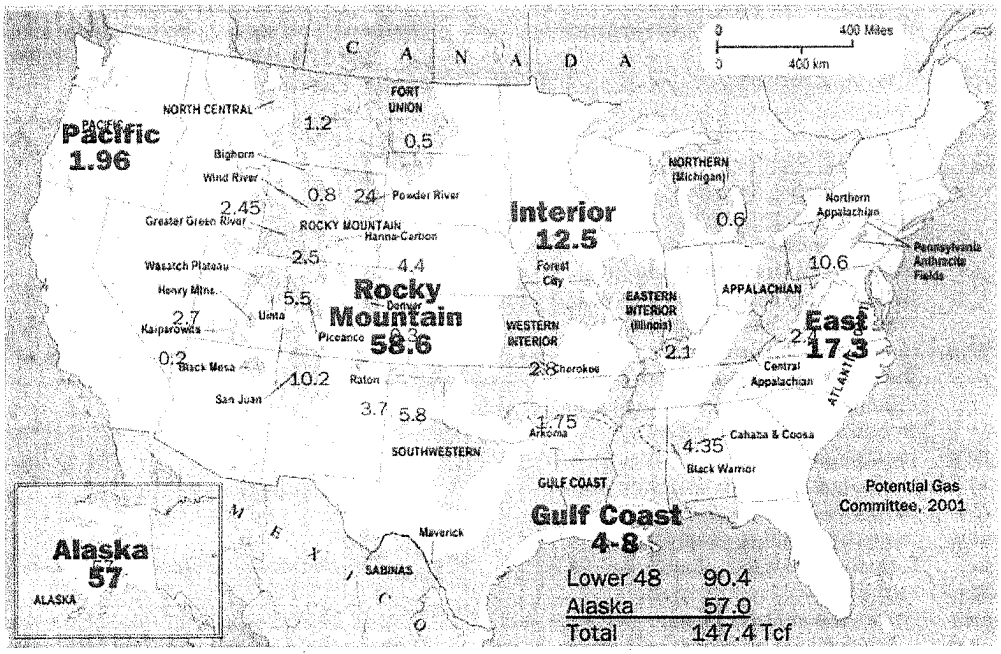
Most importantly, a horizontal pinnate well can produce gas immediately, while dewatering is taking place. Comparing a 500 MMcf horizontal pinnate well with a 500 MMcf fracture stimulated well, the pinnate well produces at a high initial rate and depletes in slightly more than 6 years, whereas the conventional well starts very slowly and takes 15 years to give up the same volume of gas.

Some advantages of pinnate drilling include recovery of up to 85% of gas in place within 36 months at flow rates ranging from 1.2 MMcf/d to 2.5 MMcf/d from low permeability reservoirs. A one-mile radius drainage pattern from each well can cover up to 1200 acres from a single location. And productivity tests to support business models are quickly acquired without waiting for a lengthy dewatering process. Most importantly, the horizontal pinnate technique creates minimum environmental impact, operating from small widely spaced locations and requiring few roads, surface facilities or gathering systems. And pinnates can extend under adverse land obstacles that would ordinarily preclude vertical well drilling.

Turning to the right

CDDT has created a fleet of purpose-built rigs to drill CBM wells around the country. Many leases are in mountainous country where road access and large drilling sites are limited, so the company set out to build modular, highly mobile rigs suited to the environment. Even though capable of draining up to 1,200 acres from a single site, CDDT wants to leave as small a footprint as possible. Their CBM rigs pull only singles or doubles, and get by with minimum-size drilling pads, often sited on the shoulders of switchback roads. Still, they have chalked up six world drilling records. They lead in single run footage with 4.75-in insert bits and PDC bits at 9,019 ft and 18,384 ft (2,750 m and 5,607 m) respectively. With the same bits they have set cumulative footage records of 10,016 ft and 48,180 ft (3,054 m and 14,694 m) respectively, and boast ROP records of 179 fph with the insert bit and 200 fph with the PDC bit. Among other areas, the company has drilled wells in the Arkoma Basin, San Juan Basin, Black Warrior Basin, and Appalacian Basin. They core the coal seam and use a special core analysis trailer onsite to determine desorption properties of the coal samples.

By turning the traditional art of coalbed methane drilling and production over to the technologists, CDX Gas has solved the perennial problem of economics that has doomed earlier CBM projects. Although natural gas prices have been strong recently, it will take efficient drilling and production to sustain the business through a downcycle. With built-in efficiency, a scientific reservoir drainage plan, and with early positive cash flow assured, the company is positioned to weather any storm. E&P



US technically recoverable CBM resources.