Unconventional Drilling Methods for Unconventional Reservoirs in the US and Overseas

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Abstract

Recent advances in drilling technologies have allowed some operators to re-evaluate the economic viability of developing unconventional low permeability reservoirs that had been previously discounted due to poor production performance. CDX Gas, LLC of Dallas, Texas has developed a patented drilling system that has dramatically enhanced production recoveries from tight coals and shales. The *Z-Pinnate Drilling and Completion Technology*™ (Pinnate Technology) employs horizontal drilling techniques in a multi-well pattern that create an efficient and environmentally friendly recovery method. CDX developed its Pinnate Technology during the mid 1990's as an extension of the underground horizontal drilling operations for coal seam degasification in advance of mining at the US Steel Company Pinnacle coal mine in Pineville, WV

Z-Pinnate wells drilled in a coal seam can drain up to 1200 acres from a single small well site and typically recover 85 percent to 90 percent of the gas in place within 3 to 6 years, depending on the reservoir characteristics of the coal. A pinnate pattern allows wells to reach maximum production rates in a matter of days by minimizing the dewatering period. This is a major advantage in light of the fact that many currently successful CBM plays, including the Raton and Powder River basins, initially were abandoned as failures during the early 1990's because of slow dewatering rates. Production profiles show that nearly 75 percent of cumulative production is recovered in the first 24 months, along with a dramatic increase in recoverable reserves.

By reducing the number of wells needed to deplete a project area, the Pinnate Technology reduces the surface disturbance caused by locations, gathering systems, and production facilities. This technique also reduces project development costs, thereby improving project economics and minimizing the impact on the environment. Pinnate Technology may also be applicable to low-permeability CBM plays outside the US, such as the anthracites of north-central China.

INTRODUCTION

Since 1990, coalbed methane (CBM) production has grown into a new $15 billion/year industry in the U.S. CBM currently supplies nearly 10% of our nation's natural gas production base and production continues to increase. Most of the production comes from the prolific San Juan Basin, the Warrior Basin and the Powder River Basin, the so-called Tier 1 Basins with annual production of more than 200 BCF [1]. Production in the San Juan Basin started to decline in 1999 while the Warrior Basin is holding steady at about 115 BCF/year. The PRB has been rapidly increasing since the late 1990's [2]. Due to the rapid production increase in the PRB, overall production from Tier 1 Basins is still climbing albeit at a lower rate.

As production from the Tier 1 Basins declines, exploration outside the San Juan Fairway and in Tier 2 and Tier 3 Basins with annual production from less than 100 BCF to 0.5 BCF per year has been intensifying. These areas often present special challenges for conventional drilling and completion technology.

CDX Gas, LLC developed a patented drilling system that has dramatically enhanced production and recoveries from low-permeablility coals and shales. The *Z-Pinnate Drilling and Completion Technology*™ (Pinnate Technology) employs horizontal drilling techniques in a multi-well pattern that create an efficient and environmentally friendly recovery method. CDX technology makes CBM production from challenging reservoirs viable. The company is a recognized leader in CBM development. As a fully integrated producer, the CDX group of companies can work an entire project from field exploration, to operating drilling rigs to production. The company operates throughout North America and uses environmentally friendly energy technology to extract methane gas from coal deposits on a commercial scale. CDX was started in 1991 to acquire oil and gas property interests. Since that time CDX has expanded operations into the Appalachian Basin, the Black Warrior Basin, the San Juan and the Arkoma Basin among other areas.

THE TECHNOLOGY

CDX developed its Pinnate Technology during the mid 1990's as an extension of the underground horizontal drilling operations for coal seam degasification in advance of mining at the US Steel Company Pinnacle coal mine in Pineville, West Virginia. By taking the drilling operation out of the coal mine, CDX essentially decoupled the drilling operation from the mining operation. This was done to enhance mine safety and mine productivity.

The technology has since been developed into a sophisticated, highly productive drilling and completion system. It involves drilling two wells from the surface. At first a "cavity" well is drilled, which is a conventional vertical well that is enlarged at the coal seam level to a diameter of 8 feet. The second well is directionally drilled to intersect the cavity at a predetermined point and extended to a length of up to 1 mile in the seam. From this main lateral numerous horizontal laterals are drilled to roughly cover a square area (Figure 1: Single Pinnate). The most notable aspect of the Pinnate system is the multilateral horizontal drainage network configured in the shape of a leaf (hence the name Pinnate). A single pinnate can cover an area of up to 320 acres (1.3 km^2). A single pinnate pattern can be drilled in 4 directions offset by 90 ^{o} each to cover an area of up to 1,200 acres (4.87 km^2) over 360^o. (Figure 2: Quad Pinnate). In the ongoing effort to save drilling cost more advanced horizontal drilling patterns have also been developed.

The technology requires accurate pressure management during the drilling operations to minimize formation damage, while mitigating borehole stability problems. Over-balanced drilling reduces

potential problems with borehole stability and resulting stuck down-hole tools, but can lead to significant formation damage. Under-balanced drilling minimizes the potential for formation damage, but requires close attention to the safe handling of the produced gas. Pressure management is carried out by controlling the amount of air injected into the drilling fluid during drilling operation. CDX uses a Dual Well system (Figure 3: Dual Well System with Air Injection) to reduce the weight of the fluid column. The air is injected into the drilling fluid at the cavity elevation of the vertical well. This allows for maximum control over the pressure environment in the horizontal well bore.

Production Characteristics of Horizontal CBM Wells

One of the unique features of the far-reaching CDX Pinnate drilling system is accelerated gas recovery and increased ultimate resource recovery compared with conventionally completed wells. Figure 4 shows simulated production decline curves for a horizontal well and conventionally completed vertical wells in the Central Appalachian Basin. It may be noted that the decline curve for the vertical (conventional) well represents production from 15 wells drilled on 80-acre spacing needed to cover the 1,200-acre area.

An unusual characteristic of the CDX decline curve is its almost immediate gas production. This virtually eliminates the typical lengthy dewatering period of conventional CBM wells prior to significant gas production. Furthermore, the production decline is steep; usually 75 per cent to 85 per cent of the recoverable gas is produced in only two to three years.

Another feature of the CDX drilling and completion system is its ability to accurately control direction and length of the horizontal laterals in the coal seam. All laterals are carefully planned in advance of drilling, production forecasts are made using a calibrated reservoir model to achieve uniform drainage and maximize recovery of the resource throughout the reservoir. This procedure virtually eliminates “hot spots” and guarantees a more complete resource recovery than conventionally completed wells can usually achieve. Because reservoir parameters and geologic conditions vary by basin, CDX develops calibrated reservoir models and procedures for each area in which it operates.

BENEFITS OF THE CDX PINNATE TECHNOLOGY

The Technology offers significant benefits over conventional drilling and completion technologies both for the environment and for project economics, as follows:

Environmental Benefits

CDX is committed to environmentally responsible energy production. The CDX drilling equipment has been reduced in size and leaves a “smaller foot print” on the surface that takes up considerably less space than conventional drilling and completion equipment (Figure 5: CDX Drilling Rig on Location in Central Appalachian Basin). The reason for the reduced space needs lies in the fact that with the Pinnate Technology hydraulic fracture stimulation is not required eliminating the need for the large frac equipment and tankage.

CDX Pinnate wells drilled from one location on a 1,200-acre drilling unit replace up to 16 conventional well sites that are drilled on 75-acre spacing (Figure 6). Not only does the Pinnate Technology require considerably fewer well locations for a given area, but each well site also needs less space than a conventional drill pad. As a result fewer drill pads, fewer roads and pipelines need to be laid to drain the same area as conventionally developed CBM fields thus lessening the environmental impact of the drilling and production operation. The cumulative footprint of a Pinnate development is roughly 10% as large as that required for conventional vertical CBM wells.

By employing Pinnate Technology to extract CBM gas ahead of coal mining operations, CDX maximizes gas recovery from the coal as a result of the far reaching drainage pattern, and consequently minimizes emission of methane into the atmosphere. Methane is known to be a potent GHG, with 23 times the radiative forcing potential of carbon dioxide.

CDX has also developed a technology to dispose produced formation water underground without the need to lift it to the surface, assuming the water is unfit for surface disposal.

The Pinnate Technology is ideal for delicate terrain around environmentally sensitive areas such as forests, reservoirs, inaccessible canyons and mountains due to its ability to its ability to reach out in any direction for a mile or more.

Pinnate wells potentially could produce water for local irrigation needs of populations in remote areas with little infrastructure if the water is of sufficient quality. The technology typically produces copious amounts of water from the network of far reaching horizontal holes.

The depleted network of drainage holes is an ideal receptacle for CO_2 sequestration applications, when drilled in coal seams that are not suitable for mining.

Economic Benefits

Benefits of accelerated gas production rates, higher resource recovery and reduced construction cost include expedited return on investment and higher project net present value (NPV) as illustrated in the following table.

Table 1: Comparative Economics for a 1,200-acre CBM Project

	Vertical	Horizontal
Revenue-PV(10)	**$3,676,000**	**$6,689,000**
CAPEX	**($2,420,000)**	**($1,635,000)**
Lease Operating ($0.55/mcf)	**($751,000)**	**($934,000)**
Interest	**($746,000)**	**($66,000)**
Severance Tax (3%)	**($185,000)**	**($201,000)**
G&A	**($500,000)**	**($500,000)**
Profit & (Loss)	**($926,000)**	**$3,353,000**

These data were generated based on the following assumptions: Coal thickness – 6 ft. (single seam); overburden thickness - 1,000 ft.; gas content - 200 ft^3/ton; permeability - 5 md; gas production was based on the decline curves indicated in Figure 4.

Operational Benefits

The Pinnate Technology offers a high degree of directional control and repeatability in placing horizontal laterals due to state of the art MWD technology employed. It also requires fewer roads, pipelines, compressor stations and drill pads thereby reducing up-front expenditures.

It is particularly well suited for thick, tight coals where conventional completion technology yields low initial production (IP), requires long production intervals to depletion and has generally poor resource recovery.

Pinnate Technology is characterized by high IP, rapid resource recovery and uniform reservoir depletion is believed to represent a break-through technology for many CBM reservoirs around the world

that have eluded commercial CBM production so far. An example of such reservoirs that show great promise but have not yet reached commercial scale are the high-rank semianthracite coals of the Peoples Republic of China.

HORIZONTAL DRILLING IN ANTHRACITE COALS – CHINA

China has large (>1,000 Tcf) CBM resources but has not yet achieved commercial production, despite over $100 million invested during the past decade in conventional vertical-well production technology by foreign CBM companies [3]**.** If a breakthrough in CBM production can be achieved, the China CBM industry could emerge as a major investment and export market for U.S. companies.

Anthracite deposits, such as found in north-central China, represent a promising target for advanced horizontal pinnate drilling technology. Extensive high-rank anthracite coal deposits with CBM potential are located close to China's industrialized heartland west of Beijing. These anthracites -- concentrated in the Qinshui coal basin of Shanxi Province -- contain an estimated 100 Tcf of CBM gas in place with high resource concentrations of more than 30 Bcf/mi^2.

The underground anthracite coal mines in north-central China rank as some of the world's gassiest. Many mines emit more than 10 MMcfd of waste methane (recalculated @100% CH_4). Several multi-well CBM pilots have been tested recently in Qinshui anthracites by Chinese and foreign operators. Although a few of these wells produced gas at low rates, significant commercial production has not yet been established.

China anthracites have several promising geologic and operational features that make them particularly prospective for development using horizontal pinnate drilling:

- **Geology.** The geological conditions may be favorable for horizontal drilling. Anthracite seams average 4 to 8 m thick, are around 200-600 m deep, have high gas contents approaching 1,000 scf/ton. Faulting in the Qinshui basin is rare and dips are gentle (generally <5 degrees).

- **Permeability.** Permeability is relatively low compared with most USA CBM areas (around 1 md), but may still be adequate given the high gas-in-place concentration and the extended borehole length of horizontal drilling. In contrast to the anthracites of Pennsylvania, which formed mainly from high pressure, China's anthracites were mainly thermally generated. This low-stress history has helped to preserve coal cleating and permeability.

- **Well Stimulation.** Hydraulic fraccing capability is still at an early phase in China. Fraccing in China is much more expensive and often less effective compared with the USA. Horizontal pinnate drilling in the anthracites could obviate the need for expensive and operationally complex well stimulation.

- **Longhole Boreholes.** Several underground anthracite coal mines in the southern Qinhui basin are starting to implement longhole horizontal degasification boreholes, mainly for safety reasons. They have drilled boreholes as long as 500 to 1,000 m, the longest achieved to date in China and much longer than the standard short-hole technology. These boreholes are drilled into a 6-m thick coal seam from the mine gateways using directional drills. Successful implementation and operation of long horizontal boreholes indicates that the anthracite coal seams in this area may have sufficient strength and stability to support horizontal drilling from the surface.

- **Mine Degasification.** Horizontally deviated surface wells show great promise for controlling methane emissions into the anthracite mines. This could improve mine safety and productivity.

- **GHG Capture.** The horizontal pinnate wells could capture methane prior to mining and thus reduce GHG emissions from the mines. The World Bank's Carbon Fund is currently evaluating its first coal mine methane capture and utilization project, which is located in the Qinshui basin.

Pilot Study

In order to determine the commercial CBM potential of these low permeability coals in China it is necessary to carry out one or several pilot studies to demonstrate that the CDX horizontal drilling technology is a viable method to produce CBM gas at commercial rates. It is also necessary to verify critical reservoir and cost parameters in order to make valid economic projections for potential CBM projects in that area. CDX is currently in discussion with interested parties to define and carry out such a test program.

CONCLUSIONS

The paper describes the CDX *Z-Pinnate Drilling and Completion Technology*™, which is based on a Dual Well system that allows for effective pressure management during drilling operation. Z-Pinnate wells drilled in a coal seam can drain up to 1200 acres from a single small well site and typically recover 85 to 90 percent of the gas in place within 3 to 6 years. Subject to carrying out extensive pilot tests, the technology appears well suited for the thick, low-permeability, semianthracite seams in north-central China.

References Cited

1. Samuel H. Limerick, Energy Information Administration 2003, unpublished
2. idid.
3. Stevens, S.H., “China Coalbed Methane Reaches Turning Point.” Oil and Gas Journal, January 25, 1999, p. 101-106.

Figures

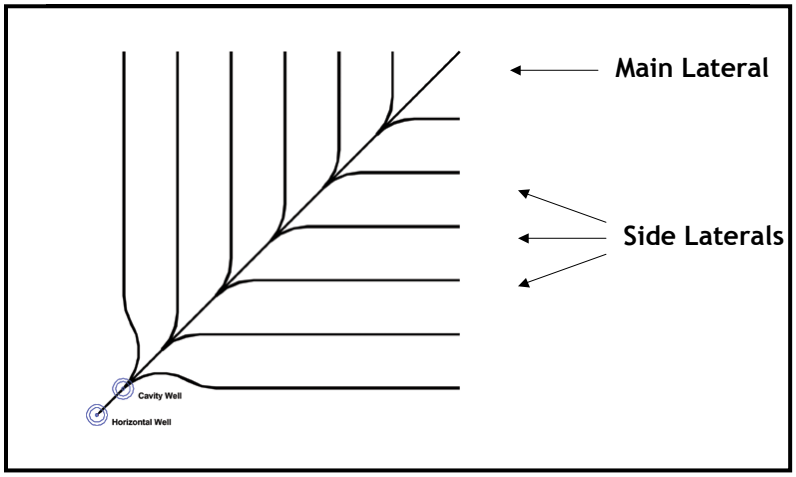

Figure 1: Single Pinnate

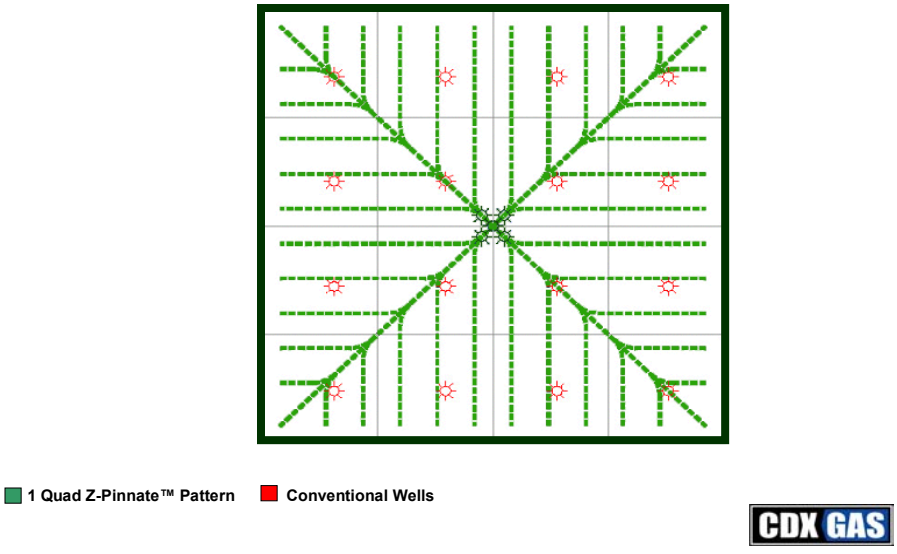

Figure 2: Quad Pinnate

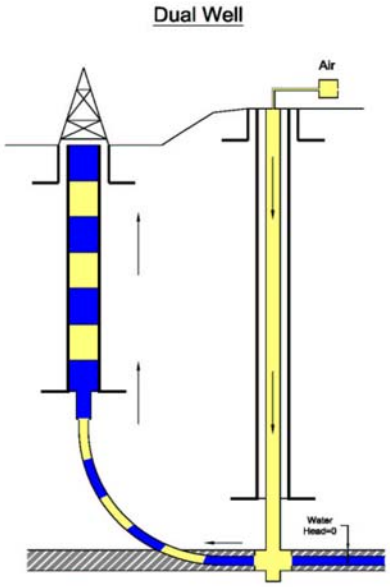

Figure 3: Dual Well system with Air Injection

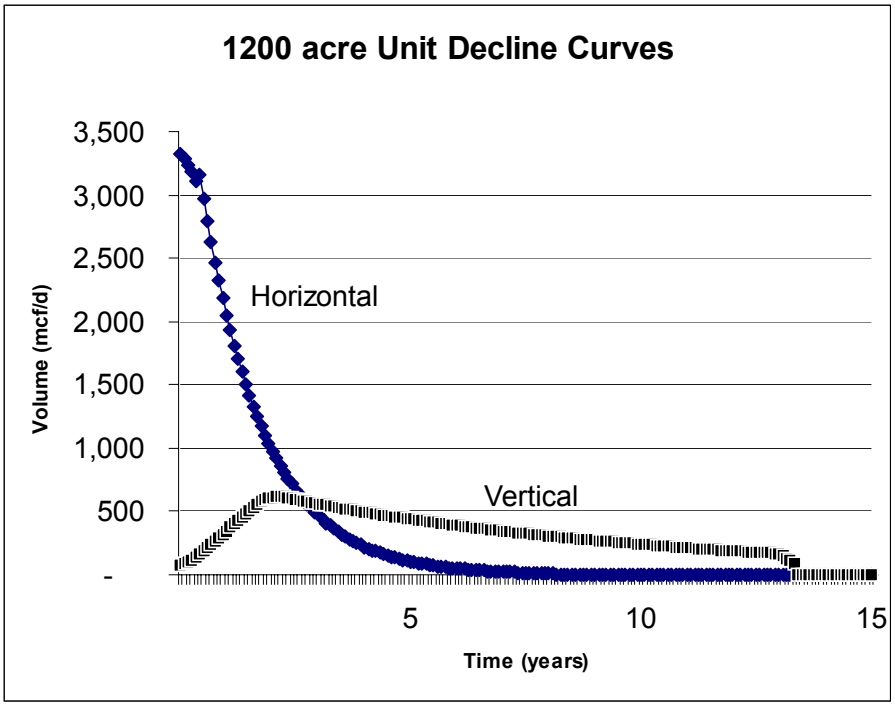

Figure 4: Producti0on Decline Curve Comparison Horizontal Versus Vertical Wells For 1,200 Acre Unit

Figure 5: CDX Drilling Rig on Location in the Central Appalachian Basin

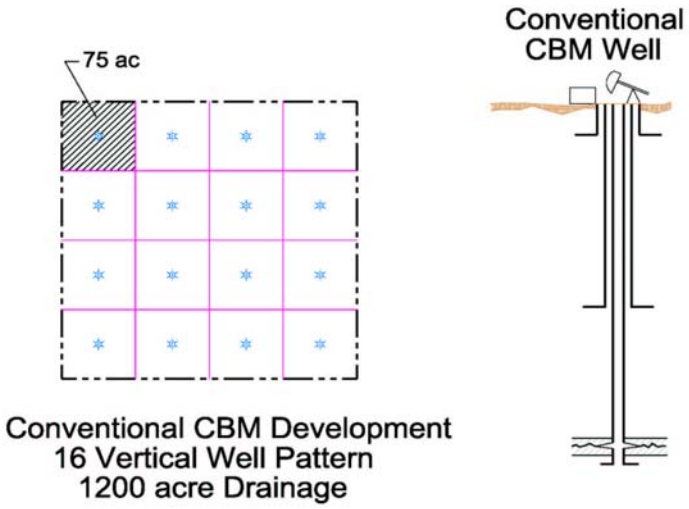

Figure 6: CDX Z-Pinnate Site Replaces 16 Conventional Well Sites on 1,200 Acre Unit