A Supplement to

Oil and Gas Investor

OPPORTUNITIES IN **COALBED METHANE**

DECEMBER **2002**


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ABOUT THE COVER: The results of a fracture treatment performed by Schlumberger in an Alabama coalbed. The top of the fracture abruptly stopped as it hit a tougher layer of coal, but several thin vertical fractures broke through the boundary and propagated upward. (Photo courtesy of Schlumberger.)

OPPORTUNITIES IN **COALBED METHANE**

Coalbed-methane gas production is taking a bigger share of the North American energy supply mix at a time when conventional gas supplies are harder to find, more expensive to drill, and quicker to decline. Aggressive drilling, research into new technologies and federal tax incentives have made CBM plays increasingly viable from an economic and technical standpoint.

CBM development has taken off not only in the storied San Juan and Powder River basins of New Mexico and Wyoming, where there has been significant activity for 20 years. It has spread to 11 other U.S. basins where the potential is only starting to be realized.

Across the U.S., coalbed-methane production now accounts for close to 1.5 trillion cubic feet (Tcf) of gas per year—or 10% of total annual gas production—and 9.5% of proved U.S. gas reserves. Proved CBM reserves are estimated to total 17.5 Tcf, and the overall potential may be exponentially greater.

The future of CBM production looks bright. In Wyoming alone, where CBM occupies a position of true prominence, daily output could average 3 billion cubic feet per day by 2010. A wave of exploration is establishing new production in the Green River, Piceance and Cherokee basins. Some 20 independents are chasing these reserves in the Illinois Basin, and activity along the Texas Gulf Coast and in Alaska is set to take off.

Pilot projects are under way in Alberta, Canada, as well, as that country begins to explore the ramifications of declining conventional gas production and the potential for new CBM development.

Wyoming consistently ranks second only to Texas in the number of drilling permits issued per year, and the reason is the Powder River Basin.

Other U.S. basins may grow to exceed the production of better-known ones during the coming decade as gas demand increases and traditional Lower 48 supplies diminish. As long as the CBM business remains economic, there will be producers going after the once-neglected gas.

They will need technology and capital, and this report explains how today's CBM producers are accessing both, as well as describing where CBM producers may drive their stakes next.

—Leslie Haines, Editor

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MAKE THE MOST OF YOUR COALBED METHANE RESERVOIR WITH OUR COST-EFFECTIVE SOLUTIONS.

YOUR BOTTOM LINE WILL THANK YOU FOR IT.

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New Technology for CBM Production

Problems incurred, and lessons learned, are requiring new drilling, completion and operating practices in the coalbed-methane boom.

By W.H. Leach Jr.

Twenty-five years ago, coalbed methane (CBM) and unconventional gas production (UGP) were hardly household words, even among oil and gas industry principals. CBM, emitted from shallow coalbeds, was once deemed as totally useless and a hazard to the mining industry. It is impossible to measure the volumes of this gas that were literally blown out of mine shafts and adits utilizing huge fans. Ventilating gas from the last operating coal mine in Las Animas County, Colorado, cost the county $6,000 per day.

Contrast this to the position CBM occupies in the energy industry today. In 1990, CBM production totaled 196 billion cubic feet (Bcf) from approximately 3,000 wells. As of December 31, 2000, the Gas Technology Institute estimates 14,000 wells produced 1.3 trillion cubic feet (Tcf)—7% of total U.S. gas production for that year.

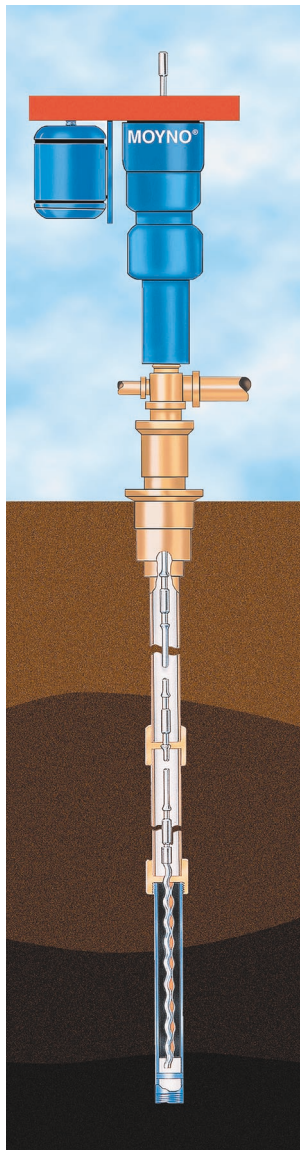
Currently, it is estimated CBM contributes 10% of domestic gas supply. Estimates of total recoverable reserves vary, but one source estimates CBM gas in place at 749 Tcf for the U.S. and 530 Tcf for Canada. In the Powder River Basin alone, the Wyoming Geological Survey estimates that by year 2010, daily CBM production could be averaging 3 Bcf. The number of new CBM drilling locations envisioned by the industry is staggering.

If the ratio of wells to production looks skewed, it must be remembered that CBM wells are basically water wells that produce gas. After a well is drilled, stimulated and completed, it must be dewatered. In simple terms this is an operation wherein pumping equipment is installed and the resident water is pumped from the formation. In reality, however, this operation is slow and may require a number of years before commercial gas production is achieved.

Initially, CBM development was fueled by Section 29 tax credits. Once that tax relief ended in 1992, operators began backing away from CBM operations, rationalizing that without the tax relief such activity was uneconomical. One reason for that opinion was the excessive amounts of water produced.

Awash in water

Early in the industry's experience with CBM, it learned that conventional downhole pumping equipment would not be adequate for the crucial job of dewatering. The huge volumes of water that must be lifted, without interruption or slowdown, were taxing to a traditional pumping system. The answer was progressing cavity pumps (PCP).



The progressing cavity pump (PCP) has lift capacities more than adequate to handle dewatering volumes.

The pump, while not specifically designed for CBM wells, is ideal for dewatering operations. Lift capacities are more than adequate to handle the required volumes. Its application to CBM wells is unique because, unlike conventional downhole pumps, it cannot gas lock. Another beneficial feature of the PCP is its ability to tolerate, without breakdown, cuttings and fines, materials often incurred after fracture stimulation treatments. Today, PCP manufacturing is one of the fastest growing segments of the gas-producing industry.

Disposal of produced waters continues to be the bane of CBM production, however. Just as produced water from deeper oil and gas formations can vary in amounts of contaminants, so does water produced with CBM. Some waters are fresher than others, but only a small amount may be potable for human consumption. As a result, adequate and safe disposal is a problem of considerable magnitude.

In certain areas, produced CBM water is being transported away from producing locations and commingled into surface-water systems where such a practice is feasible. As an example, in Wyoming's Powder River Basin, Laramie-based WWCengineering has designed and is currently permitting several alternative trans-basin pipelines to move CBM water to river systems that are able to receive significant quantities of the water without injuring existing irrigation practices.

The concern of local residents over water problems is growing and is not easily addressed. In the Rocky Mountain region, operators often dis-

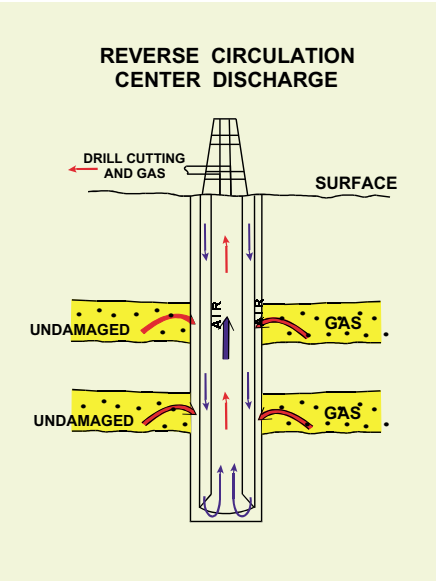
pose of their produced CBM water by underground injection. Many residents fear that this practice may be leading to contamination of fresh water aquifers and wells. Currently, in Delta County, Colorado, the Board of Commissioners is challenging the right of the Colorado Oil & Gas Conservation Commission to mandate the drilling of CBM wells on private property, despite valid leases.

One innovation in CBM technology sparked by water concerns is a unique drilling program developed by Calgary-based K2 Energy Corp. The process is called "reverse circulation center discharge" (RCCD). The company, in conjunction with Midnight Sun Drilling of Whitehorse, Yukon, has recently completed nine CBM wells in northern Montana. RCCD creates minimum drilling damage to the formation, thus allowing CBM gas to flow to the surface during drilling operations.

RCCD drilling consists of three basic components: double-wall drillpipe, an air hammer, and a downhole blowout-prevention system. The drillpipe has a 4.5-inch outer and 2.875-inch inner. Air circulates between the two strings, drives the air hammer, and reverse circulates the formation cuttings back up the inner pipe to the surface.

K2 reports that the wellbore is perfectly straight from top to bottom, with no fill at the bottom of the well. The well can flow gas as it is drilled. And, it adds, besides greatly reducing drilling damage, the technology is cost competitive to conventional rotary drilling.

K2 has applied for a patent on RCCD. Moreover, the U.S. Department of Energy has witnessed an RCCD operation and has expressed interest in a possible cost-sharing joint venture to further improve the technology.



Reverse circulation center discharge (RCCD) creates minimum drilling damage to the formation, thus allowing CBM gas to flow to the surface during drilling operations.

Doing It Right

Denver independent Evergreen Resources Inc. is a large-scale producer of coalbed methane (CBM) in the Raton Basin of southern Colorado. The company has prospered since venturing exclusively into CBM, delivering both compound annual production growth and compound returns to shareholders exceeding 20%. Notably, it has accomplished all of this in a basin previously devoid of commercial hydrocarbon production.

Evergreen's entry into CBM exploration and production was primarily influenced by its president, Mark S. Sexton. A member at one time of Amoco Production Co.'s CBM development task force, Sexton was an early pioneer in recognizing the potential of CBM in the Rockies.

Today, Evergreen has more than 675 active CBM-producing wells in the Raton Basin, as well as CBM projects in Alaska and several foreign countries. Its average CBM production is 140 million cubic feet per day. Current reserves, calculated by independent petroleum engineers, are 1.13 trillion cubic feet (Tcf), and are expected, due to current drilling activity, to be 1.2- to 1.25 Tcf by year-end.

"By doing it right, we became the first company to make CBM operations work efficiently without Section 29 tax credits," says Sexton. Evergreen also consistently ranks among the lowest lifting-cost producers in the industry.

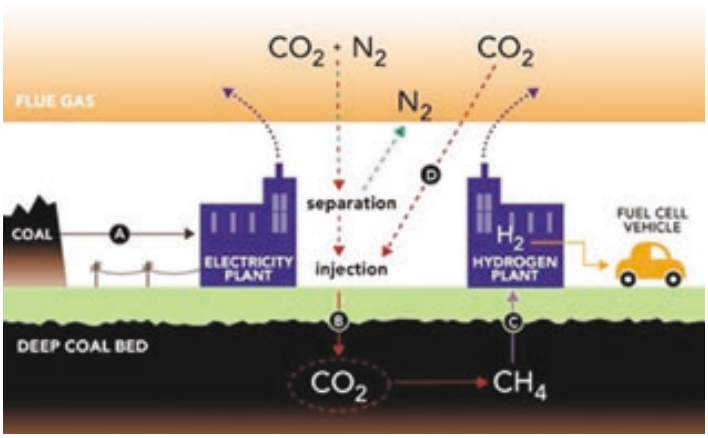
The company has been an innovator in CBM technology and practices. To optimize efficiency, Evergreen is vertically integrated. It owns its drilling rigs, cementing trucks, stimulation units and workover/completion units. "When we are ready to do something we can get it done without waiting," says Sexton.

Evergreen designs its own stimulation programs. Rather than a blanket formula, each fracture stimulation job is tailored to individual well conditions. By placing an emphasis on rheology, the company has been able to learn more about, and utilize, less invasive frac fluids. Because the CBM reservoirs are underpressured, the company is experimenting more with air drilling as well as underbalanced mud systems. It also was among the first CBM producers to use coiled tubing.

The Raton Basin wells are drilled in two days and stimulated and completed in 30 days. Once placed on pump, gas production begins to increase, as water production decreases. Evergreen has been a long-time proponent of progressing cavity pumps. Usually three to four years of dewatering are required before a well establishes a stable production rate. Once dewatering operations are initiated, the well is not shut down, even if the gas-gathering system is shut down. Rather, the gas is vented or flared until normal operations can be restored.

The produced water in the Raton Basin is potable for wildlife and livestock, but not quite of a quality for human consumption. To help solve this problem, Evergreen headed up the construction and operation of a new water facility in the Purgatoire River Valley, where access to potable water is limited. The water tap was opened in December 2001, providing potable water to more than 100 families.

Sexton believes the oil and gas industry must work with landowners and others outside of industry to better relationships; he talks to landowners and local politicians on a regular basis. Evergreen enjoys a very favorable relationship with its landowners, which is another key component of "doing it right."



A fuel source—in this case, mined coal—is burned (A) to produce electricity and flue gas. The carbon dioxide (B) is captured from the flue gas (comprised mainly of CO_2 and N_2) and injected into deep unmineable coal beds. Once there, the coal adsorbs the CO_2 releasing methane (C) from the coal. The methane gas (CH_4) is produced and is reformed in H_2 and CO_2. The H_2 can be used to fuel the next generation fuel-cell vehicles and pure carbon dioxide (D) is injected back into the coal bed.

Close and closer

Well spacing is becoming an increasing problem in certain areas. Because of the low permeability of the coal, wide spacing such as is common in deeper gas and oil wells is not adequate, despite stimulation, to effectively recover the reserves. As operators have discovered this, many new locations are being spaced closer together. Furthermore, because much previous drilling was done on wider spacing, considerable infill drilling is now being contemplated.

This trend toward more wells is not being met kindly by local residents. As the Rocky Mountain News pointed out in a story on October 5, 2002, "A lot of anxious citizens (again in Delta County, Colorado) are concerned that the drilling has the potential to contaminate groundwater and create an unsightly skein of roads and wells across the landscape."

One approach that could alleviate the spacing issue is being pioneered by the privately held CDX Cos. The Dallas-based group has patented its Z-Pinnate horizontal drilling and completion system. Using horizontal laterals, CDX can access up to 1,200 acres from a single wellsite, significantly reducing surface impacts. (In contrast, vertical CBM wells are often drilled on 80-, 40- or even 20-acre spacing.)

CDX's pinnate drilling pattern also accelerates gas recovery, allowing as much as 85% of the gas in place to be produced within 36 months. Another benefit of the system is that production and dewatering are integrated, so wells begin producing gas immediately at high rates.

CDX currently has projects in 14 states and two Canadian provinces. Recently, its CDX Gas LLC affiliate announced a venture with Penn Virginia Corp. The companies established an area of mutual interest covering 16,000 square miles in the central Appalachian Basin, for exploration and development in CBM and Devonian Shale. Horizontal laterals from one well site drilled last year with CDX continue to produce more than 2 million cubic feet of gas per day; typical production from a vertical Appalachian Basin CBM well ranges from 50,000 to 100,000 cubic feet per day.

Although horizontal drilling is often considered to be more expensive than vertical drilling, CDX notes that economies of scale are rapidly achieved with a horizontal drilling process that reduces total development cost. The rapid rate of recovery from drilling tens of thousands of feet, reaching out over hundreds of acres, from one site, creates a higher return on investment. In addition, because there are fewer pipelines, power lines and roads required, CDX's process becomes even more efficient and cost-effective.

Enhanced recovery

A consortium of American and Canadian companies was recently formed by Computer Modeling Group (CMG) of Calgary to develop a technology called "enhanced coalbed-methane recovery" (ECBM). ECBM is a novel process of injecting carbon dioxide into

Evergreen Resources is converting CBM-well water into potable water and providing it via a new water facility in the Purgatoire River Valley.

CBM beds to release the methane. The CO_2 is absorbed by the coal and stored in the pore matrix of the coal seams, releasing the methane. The potential benefits are higher production rates and greater total recovery. In addition, CO_2 storage is established in the coalbed, virtually eliminating any release of CO_2 to the atmosphere.

Although the technology is being developed in North America, its greatest application is expected to be in China, Poland and India, as well as in South American countries, where coal is abundant and conventional gas supply is not.

Full-service firms

Additionally, the larger service and supply companies all have a number of programs tailored to specific CBM situations and needs. Each program is designed on an as-needed basis.

Schlumberger, as an example, now offers a comprehensive range of cased and openhole logging services giving data on coalbed thickness, depth, quality and gas content as well as the permeability and mechanical properties of the target coal seams and surrounding beds. These services can be adapted to meet the changing needs of a given CBM region based on existing knowledge. Two cased-hole tools in particular, the ECS (elemental capture spectrometer) tool and the RST (reservoir saturation tool), increase operational efficiency by providing CBM evaluation information without the need for openhole logging. These tools directly measure the chemical makeup of coal and ash mineralogy and are used to estimate the discrete coal-gas volume and the degree of cleating.

One service company, *Layne Christensen Co., likes CBM so much it formed an alliance to develop and produce for its own account.*

One service company recently changed its philosophy regarding CBM. Layne Christensen Co., in a recent annual report to shareholders stated, "Late in fiscal 2002, after extensive market study, we concluded that we have more opportunity to participate in CBM as a developer and producer than we do as a drilling contractor."

The company formed a strategic alliance with Mohajir Engineering Group Inc., in January 2002. With more than 13 years experience, Mohajir is a key player in the discovery and development of unconventional gas throughout the U.S., positioning Layne Christensen as a low-cost player in the CBM market.

A large part of CBM development does not require totally new technologies and/or techniques, but rather the application and innovation of known methods combined with certain new technologies and new thinking. □

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CBM Investors Keep Their Guard Up

Financing is available to CBM projects, which have often proven themselves to be high-return investments.

Article by David Wagman

Coalbed methane (CBM) is an easy investment—like going a few rounds in a championship prizefight. Round One is all adrenaline. After all, coal reserves are plentiful, easily found and close to the surface, so close that a gas well usually can be drilled in a single day.

Those factors help drive CBM development costs toward zero, leaving what looks like plenty of upside potential, especially with pro formas based on gas prices of $3 per thousand cubic feet (Mcf). By one estimate, the internal rate of return on a CBM investment can hit 50%. One financier reports seeing 18% to 20% returns on drilling programs in the Black Warrior and Cherokee basins. Go the distance? Piece of cake.

The going gets tougher in Round Two. For one thing, almost every CBM well needs to be dewatered before production can start. Figure on six to 12 months of pumping water, not gas, out of the hole. Cash flows are negative during this time, and related environmental costs can mount if complications crop up over disposing of the water, which may have an elevated sodium content.

Savvy investors also must beware of varying degrees of CBM engineering expertise when it comes to reviewing production estimates and production-decline curves. CBM is still a relatively new unconventional gas play and engineering expertise may be spotty. The gas can be susceptible to coal fine movement and geologic formations may not be consistent across a basin.

One financial expert cautions investors to be mindful of CBM's "many ubiquitous characteristics," which make it possible for unscrupulous operators to, say, take two promising data points and imply that everything between is proved. "It isn't always so," the source says.

Round Three can be punishing for investors, particularly those with programs in the Powder River Basin of Wyoming and Montana. That go-go region, with more than a hint of the Wild West about it, is saddled with a lack of take-away pipeline capacity. The problem ranks second only to water as a primary concern among producers.

The basin's shortage of pipeline capacity is one reason why the region's basis differential blew out last summer by $2 to $2.50 per Mcf when compared with Nymex prices, which are based on gas delivered to the Henry Hub in Louisiana.

Wellhead prices fell below $1 per Mcf at one point, leaving "very, very small margins" according to one producer. Little wonder many of the basin's smaller developers are hoping pipelines and other deep-pocketed white knights will build transportation capacity to ease the Powder River bottlenecks, particularly at Cheyenne.

If you're still in the ring, the notion of easy money from an investment in coalbed methane may have evaporated entirely.

Internal capital

With coalbed methane "you never can let your guard down," says Cameron Smith, founder and senior managing director of New York City-based Cosco Capital Management, a firm that hooks energy-sector capital-seekers up with capital providers. "The risks from an economic point of view are very much on the operations and production side rather than on the geologic or exploration side."

The commodity's relatively low margins make it particularly vulnerable to operating-cost creep. That means infrastructure costs, if improperly managed, can cut margins to the bone. What's more, because the wells tend to be relatively small-rate producers with steep decline rates, lenders frequently expect producers to protect the pricing downside with hedges. One mezzanine lender is adamant in requiring hedges on 50% to 75% of projected production.

Much of the current CBM-development work is funded from internal cash. That's because relatively little money is necessary to get a development play started. Stuart Wagner, principal in Denver-based Petrie Parkman & Co., an investment-banking firm, says a well may be drilled and completed for as little as $100,000. With drilling depths generally less than 1,000 feet, wells can be drilled quickly, sometimes in a day.

With good management, Wagner says, an investment in CBM can become a strong cash flow machine with internal rates of return on pretax

Cameron Smith

cash flow in excess of 50% based on $3 gas at the Henry Hub.

John K. Castleberry, president and chief executive officer of Bismarck, North Dakota-based WBI Holdings, sounds more conservative. A business unit of oil and gas producer MDU Resources, WBI funds its 800-well Powder River Basin development play with a combination of internal cash and corporate equity and debt.

When WBI expects to see a return in excess of investment isn't clear, however. Because CBM is still in its infancy "no one knows how long the play will last in commercial production," Castleberry says. Wells producing in the Powder River Basin for two to three years have generally exceeded expectations, he says. Based on those results, production could last for 10 to 20 years.

Gas Reserves at Supply Basins in the Rockies

State/Region	Recoverable at <$2/Mcf	at $2-$3.34	Total (MMcf)	Recoverable (MMcf)	Total Gas Resources (MMcf)
Colorado-DJ Basin	1,327	1,797	3,124	768	3,892
Colorado-Piceance/Sand Wash	1,887	4,263	6,149	9,558	15,707
Colorado-Raton	696	3,032	3,728	108	3,836
Montana-Williston/PRB	3,897	3,472	7,369	40,847	42,216
N. Dakota-Williston	257	1,141	1,398	1,064	2,462
Utah-Uinta/Paradox	1,964	4,747	6,711	10,725	17,437
Wyoming-Powder River	15,220	3,544	18,764	5,891	24,655
Wyoming-Big Horn/Wind River	403	1,875	2,278	1,009	3,287
Wyoming-Green River	5,286	8,495	13,782	146,068	159,850
Total	30,937	32,366	63,303	216,039	279,342

Source: Platts Research and Consulting

Mezzanine capital

Virtually every professionally managed energy-specific fund is willing to look at CBM business plans, says Smith. ARC Financial Group, Natural Gas Partners and EnCap Investments have interest in the sector. So do UBS Warburg, Morgan Stanley, First Reserve Corp. and JP Morgan.

Mezzanine capital sources include Wells Fargo, Prudential, JM Huber Corp. and, more selectively, Duke Energy Capital.

Houston-based Wells Fargo Energy Capital is particularly bullish on nonconventional gas plays. The company has financed two CBM programs in recent years, committed to a third and is currently submitting for approval an Antrim Shale development-drilling program.

The first program, in the fall of 1999, was a $9-million senior secured debt financing with an equity kicker, says Gary Milavec, senior vice president. The commitment funded drilling 33 infill wells in Alabama's Black Warrior Basin. The financing has since been paid off and generated a nearly 20% return. "We achieved our rate-of-return objective," says Milavec.

The second drilling program, in the summer of 2001, was a $7.5-million commitment for an Oklahoma City-based company working the Cherokee Basin CBM play, in southeastern Kansas and northeastern Oklahoma. That financing also combined senior secured debt with an equity kicker, and is generating close to a 20% return. The borrower is currently merging with a Kansas-based company also active in the Cherokee play. Wells Fargo Bank will provide a $7.5-million conventional revolving credit facility for the merged entity and Wells Fargo Energy Capital will provide a $7.5-million subordinated credit facility. Proceeds from the subordinated facility will be used to continue the development-drilling programs already initiated.

"I like unconventional gas," Milavec says. By focusing on proved undeveloped infill wells in established basins, by requiring aggressive hedging, by building economies of scale and by being particular about the engineering studies [i.e. looking for engineering expertise in each basin], a CBM investment becomes almost like a manufacturing operation rather than a conventional gas play, Milavec says.

"The relatively low-risk nature of CBM lends itself to mezzanine financing. If you drill in established areas, you can create a lot of value."

Virtually every *professionally managed energy-specific fund is willing to look at coalbed-methane business plans. Rates of return of 20% and more have been reported.*

Institutional investors

Institutional investors may be scarce (Section 29 tax credits expire at the end of 2002), but they are not entirely out of the market. Detroit-based Everest Energy has structured a $60-million program with a number of publicly unidentified pension funds to develop 47,000 net acres in the Powder River Basin. Everest forecasts annualized internal rates of return from 25% to 35%.

Because the company is drilling into blanket formations of coal its prospects of hitting gas are high, says Vincent J. Brennan, vice president.

Coal seams tend to thin out at the fringes of a basin, leading to potentially higher levels of risk compared with the center of a basin. So far, data from Everest's properties suggest that coal—and CBM—is present in its acreage, he says.

The company claims a 100% success rate on its drilling. Everest is currently dewatering a number of wells, and expects to start producing gas in the first quarter of 2003, ramping up to include 100 wells by year-end 2003. Everest Energy plans to invest in excess of $150 million in the Powder River play.

Indeed, the Powder River Basin is among the hottest current development plays. Robert Downey, president of Denver-based Energy Ingenuity, a CBM engineering consultancy, says the basin has an estimated 37 trillion cubic feet (Tcf) of gas in place and 25 Tcf of recoverable reserves. To date, production has amounted to just under 1 Tcf, he adds.

One major risk facing producers and investors alike in the Powder River play is the outcome of a federal environmental impact study due soon and to be made final early next year. With 55% of the basin's acreage owned by the federal government, many developers holding leases have been unable to drill while the study has been completed. "If you are a small company with 10,000 acres of federal leases, you can't drill," Downey says, because of uncertainty surrounding the impact study.

Transportation problems

But assuming drilling can ramp up next year, producers wonder if enough take-away capacity will exist to move the commodity to markets. "We hope the E&P companies will put their heads together to solve the take-away problem," says Brennan.

Infrastructure investments are under way but whether the new pipelines prove adequate to solve the Powder River's capacity problem remains to be seen. One source of relief may come next spring when the Kern River pipeline expansion becomes operational. The expansion is expected to handle an additional 1.75 billion cubic feet (Bcf) per day of capacity from the hub at Opal, Wyoming, heading west. Kern River will primarily serve basins in western Wyoming, doing little to ease constraints on the east side of the state, including the Powder River Basin, however.

Among the projects proposed for gas headed into the Midcontinent is the $60 million, 16-inch Grasslands pipeline being developed by Williston Basin Pipeline, another unit of MDU Resources. The pipeline, which would be funded internally, would initially carry 40 million cubic feet per day north to the Ventura hub, relieving some congestion at the Cheyenne hub, says Michael P. Batzer, vice president of Williston affiliate Fidelity Resources, based in Denver.

A second phase would increase the pipeline's capacity to 60 million cubic feet per day while a third phase would add another 20 million of capacity. With additional compression, the pipeline eventually could carry as much as 200 million cubic feet per day out of the Powder River Basin.

That sort of commitment to building infrastructure may help ease the transportation crunch and reduce the basis differential that otherwise would threaten to become a problem each summer.

Battling the 'conflict industry'

One issue that can't be financed away so easily is environmental concern—primarily concerns related to dewatering wells. It's almost a no-win situation for CBM developers. Some landowners complain dewatering depletes aquifers, which would be tapped for crop irrigation. But still other landowners complain the water pumped from the wells is too salty to be used, forcing developers in some cases to build evaporation ponds.

The rise of what some see as a virtually permanent "conflict industry" involving environmentalists and landowners has almost certainly affected CBM economics, says Castleberry.

Environmental issues are inherent to almost every CBM development play, Smith adds. That includes not only U.S. fields, but also emerging Canadian CBM fields where government ownership through Crown landholdings is extensive and where environmental impact statements are a regular part of most development schemes.

Despite running the risk of being knocked out of the ring by one of CBM's potential pitfalls, the nonconventional gas play still proves financially attractive to many investors. After all, says Smith, coal formations largely are blanket deposits that carry fewer geologic variables than conventional gas deposits. The greatest risk, he says, appears to lie more in successfully managing the operations side of the business.

"There is no reason why a well-conceived CBM project—absent unforeseen environmental costs or price disturbances—can't produce returns that are at least comparable to conventional gas at significantly lower geologic risk," he says.

Sentiments such as that keep investors climbing into the ring for a shot at the prize purse. □

***While plenty** of capital is available for funding CBM drilling, one issue that can't be financed away easily is that of environmental concerns such as water disposal.*

CBM: Coming to a Basin Near You

The coalbed-methane industry is enjoying yet another remarkable growth spurt in its brief history. Experienced CBM operators are looking to repeat their success in other areas, and companies new to the field are adding CBM to their portfolios.

Article by Stephen D. Schwochow

Thirty years ago, no one had really heard of "coalbed methane." Today, no one can doubt its importance to our country's domestic gas supply. Annual CBM production from 11 coal basins now tops 1.5 trillion cubic feet (Tcf) and CBM proved reserves total 17.5 Tcf, or 9.5% of U.S. proved gas reserves.

From what areas can the industry expect to see production growth in the next several years? To answer that, here's a look at three "generations" of CBM plays: the mature stalwarts; the younger, established plays; and the frontier basins.

Two "first-generation" plays, San Juan and Black Warrior, have matured. Annual production from each remains high but has begun to plateau. Future production growth in New Mexico's San Juan play could come from development of lower-rank Fruitland coals, from widespread application of horizontal drilling and enhanced recovery procedures, or from development of the deeper Menefee coals.

For Alabama's Black Warrior Basin, no new-field development is on the horizon. Proved reserves have declined since 2000, and no substantial production growth is likely unless Pottsville coals are developed in the deeper part of the basin in Mississippi.

The second-generation

Second-generation plays were developed in the late 1980s and early 1990s. Little need be said about the three hottest CBM plays in the Rockies: Powder River, Raton and Uinta. Annual production from these high-profile plays is climbing almost exponentially. Play characteristics have been well documented, and areas of expansion are well known.

This is not to downplay the ongoing problems with leasing, well-permitting and water production in the Powder River Basin. These issues are vitally important to the entire industry.

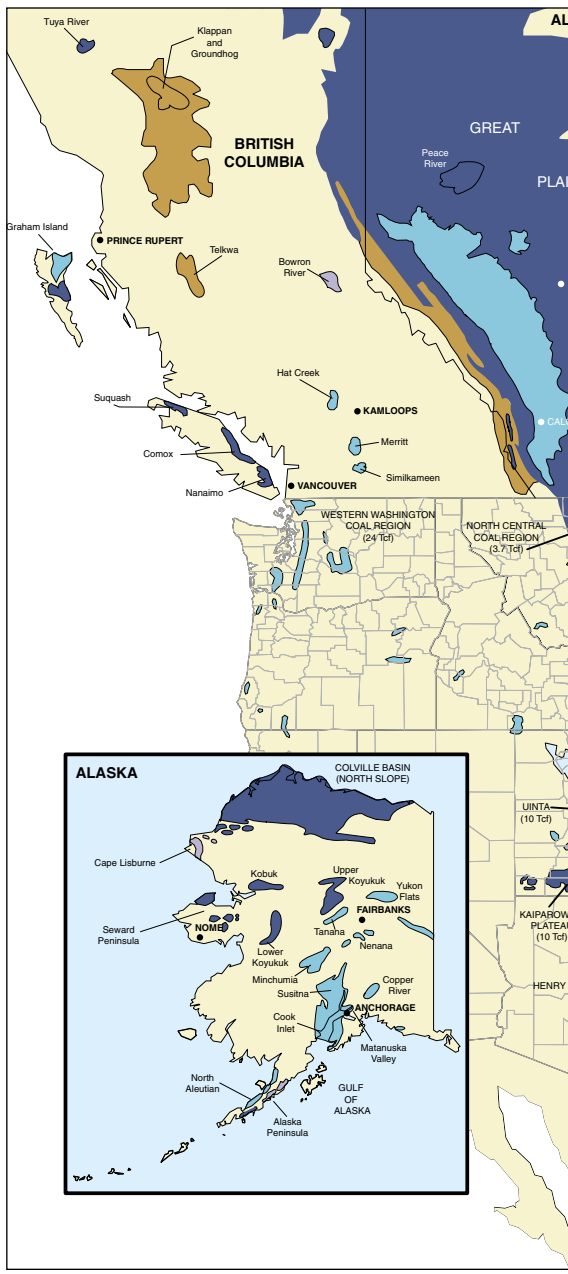
Green River Ironically, the Lower 48 coal region with the highest in-place CBM resource has produced the least. Cretaceous and Tertiary coals of the Greater Green River region may hold 314 Tcf of methane. Yet, annual production through the 1990s was practically nil.

One of the limitations is that a substantial part of the resource lies within deep coals, which drillers have been reluctant to pursue. A turnaround is at hand, however.

Research has given us a clearer understanding of the relationships among structure, coal properties and hydrodynamics in this complex basin. The information undoubtedly has proved useful in selecting sites that possess optimal coal parameters while avoiding areas of anticipated excessive water production.

Although operators, understandably, are still seeking shallow objectives, deep drilling may be warranted where higher gas content and the right combination of structure, pressure, water flow and permeability exists.

A wave of new exploration projects has established shallow Mesaverde coal production on the flanks of the Washakie Basin. Infinity Inc. of Chanute, Kansas, and Casper, Wyoming-based Double Eagle Petroleum Co. are the first with projects to have come online. Dolar Oil Properties, North Finn LLC, Stone & Wolf LLC and Rocky Mountain Energy



have multiwell projects in various stages of completion.

To the west, in the Green River Basin proper, Infinity Inc. has established production at another pilot project situated on the Labarge Platform, where the target coals range in depth from 1,800 to 3,200 feet.

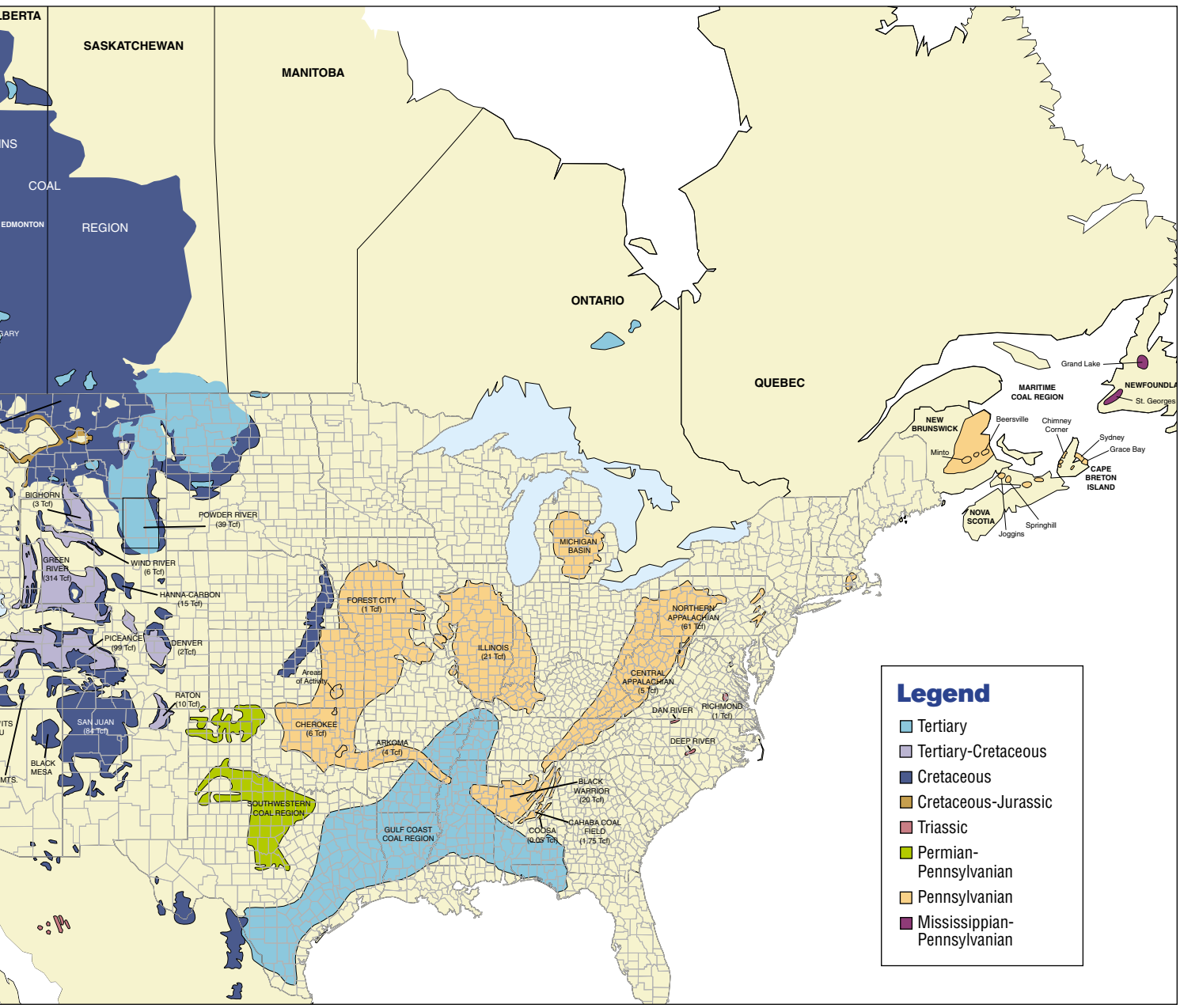
In the Sand Wash Basin of Colorado several large leaseholds have been assembled over a potential production fairway related to a deep-seated fault system in the basin interior. Infinity Inc., Tipperary Corp., Patina Oil & Gas Corp. and KLT Gas Inc. are working this area.

Piceance Basin The Piceance Basin of western Colorado is another Rocky Mountain anomaly—a large in-place resource (99 Tcf) but minimal production.

Like the Green River region, a large share of the Piceance resource lies within Cretaceous coals below 5,000 feet. Unfortunately, low permeability and regional hydrocarbon overpressuring severely limit gas producibility in most areas. Three fields—Grand Valley, White River Dome and Pinyon Ridge—do produce CBM and—at 5,000 to 8,000 feet—represent the deepest known productive coalbed completions.

At White River Dome, Tom Brown Inc. last year completed 27 new coalbed wells below 7,000 feet and effectively boosted the field's previous output from deep coals and tight sandstones tenfold. Although the production mechanism (fracture-enhanced permeability) is not yet entirely understood, the results apparently indicate that coal reservoirs may, indeed, be producible at depths considerably greater than believed possible. But at a price—Tom Brown's wells cost more than $800,000 apiece.

Another characteristic of deep CBM production in these fields is the



occurrence of recoverable light oil; unfortunately, the gas stream also contains inordinately high amounts of carbon dioxide.

In light of new insight into the complex hydrodynamics, transitionally pressured areas of modest historical CBM production in the southeast part of the basin merit reexamination.

Arkoma Basin Since 1989 the Hartshorne coalbed play generally has followed the productive Ouachita foldbelt structures within the established gas fields in eastern Oklahoma.

According to the Oklahoma Geological Survey's database, more than 700 coalbed completions have been reported by 50 operators.

Typical Hartshorne completions range from 600 to 2,500 feet deep and yield average initial rates of 10,000 to 120,000 cubic feet per day. The OGS' study of Spiro Southeast Field in Le Flore County demonstrated that wells recompleted with freshwater/sand fracs achieved stabilized gas rates of 1 million cubic feet per month or more, with minimal water volumes, after one year.

Three signs point toward a promising future for CBM. First, because the Hartshorne appears to be gas-productive across the basin, substantial prospective acreage along the structure outside the conventional gas fields remains to be explored.

Second is the successful application of horizontal drilling. Since 1998 six operators have drilled more than 110 lateral completions, principally in the Kinta Field area of Haskell and Pittsburg counties. The laterals have been driven up to 5,300 feet. Half of them reported initial potentials of 200,000 to 600,000 cubic feet per day. Seven others, all completed by Mannix Oil/Williams, each came in at more than 1 million per day with little or no water.

Third is the first confirmed CBM well, a Hartshorne lateral, drilled in Arkansas. Using its proprietary multiple-lateral drilling technique, Dallas-based CDX Gas LLC completed the Sebastian County well in 2001 at less than 1,000 feet true vertical depth. The company is developing other shallow coal prospects in the low-volatile bituminous coal area on both sides of the state line.

Cherokee Basin Availability and the low cost of acreage, the absence of federal lands, and a low gas-price differential helped set off a leasing boom in 1999 that has resulted in the addition of several hundred new coalbed wells in southeast Kansas and northeastern Oklahoma.

Large-diameter cased holes, air drilling, freshwater/sand fracs and low pumping rates generally have been found to work best with the Pennsylvanian Cherokee Group coals. Three of the thickest and most widespread—Riverton, Weir-Pittsburg and Mulky—are most commonly completed in Kansas; 10 seams produce in Oklahoma, up to four of which may be commingled in a given well.

Produced water is manageable, but its high salinity requires disposal by reinjection.

Two of the active developers provide an interesting contrast in CBM development and strategy.

Long-time local operator, Quest Resource Corp. of Benedict, Kansas, took advantage of its own gathering lines by acquiring producing properties around Thayer Field. The company has completed about 60 Mulky wells producing an average 25,000 to 60,000 cubic feet per day. Expansion plans call for 40 wells a year during the next five years

Devon Energy, on the other hand, has gone directly to multiple-seam completions for higher flow rates—300,000 cubic feet within a year. The company has amassed 420,000 net acres in Kansas and Oklahoma. With 125 wells drilled in 2001, Devon was on track to have drilled 400 wells in 2002, toward a target of 2,500.

The Kansas Corporation Commission has proposed new rules to ease certain requirements on coalbed well-testing, flaring and venting.

Forest City Basin CBM exploration in the Forest City Basin in northeast Kansas is a natural extension of the Cherokee Basin play, based on continuity of structure and a comparable package of coal seams. In fact, structural and thermal settings may exist here similar to those that account for the coal rank, permeability and high thermogenic gas content found in southeast Kansas.

One of the largest new land positions has been assembled by Vancouver-based Heartland Oil & Gas Inc. The 160,000-acre Soldier Creek prospect is spread across seven counties west of Kansas City. Heartland has drilled stratigraphic tests in the deep basin adjacent to the Humboldt Fault and Nemaha Uplift.

Illinois Basin Coal-mine methane (CMM) in the Illinois Basin has been recovered sporadically since the 1960s, and some success was achieved tapping CBM from virgin seams in the mid-1990s. The flurry of new well permits and completions since 1998 could finally establish commercial production in the basin, whose resource potential is estimated at 21 Tcf. About 20 independents—more than ever—are active, pursuing both CBM and CMM.

Most projects target, individually, the Herrin, Springfield-Harrisburg or Murphysboro seams in Illinois, and the Springfield or Seeleyville seams in southwestern Indiana. Gas in these Pennsylvanian-age seams is producible at remarkably shallow depths—250 to 700 feet. The deepest

The "newer" CBM basins *offer exciting potential. Devon Energy may drill 2,500 wells in Kansas and Oklahoma. Some 20 firms are drilling in the Illinois Basin.*

coals tested to date lie at about 1,600 feet.

Not coincidentally, many of the Illinois CBM and CMM projects are situated over the southern deep end of the basin, known as the Fairfield Basin, whose complex structural and thermal history has contributed to the high coal rank, high gas content and other coal conditions observed there.

Among the multiwell project developers are Berry Petroleum, BPI Industries, DeMier Oil, Peabody Natural Gas LLC and USA Coalgas LP in Illinois, and Pulse Energy Systems LLC, Robinson Engineering and Mountain Petroleum Corp. in Indiana.

It is premature to characterize what will be the optimum completion and production strategies for these coals, which reportedly tend to desorb gas slowly and retain a comparatively high residual gas content.

Most operators are set on supplying gas to the Chicago market. However, infrastructure must be expanded so prospects can be developed beyond the interstate pipeline corridors.

Central Appalachian Basin What began for Consol Energy Inc. as a need to improve safety and productivity at its underground coal mines has evolved into a multifaceted commercial gas recovery operation. At Oakwood Field in Buchanan County, Virginia, Consol has mastered three CMM strategies—vertical degasification wells drilled in advance of mining, degas boreholes drilled inside the mine, and "gob" wells that drain residual methane from the fractured and collapsed roof strata left behind an advancing longwall mining machine.

Consol has become the leading CBM producer in the Central Appalachians with 1,100 wells. A portion of its gas stream is now diverted from pipeline sales into the country's first power plant fueled entirely with coal-seam gas. The 88-megawatt "peaker" facility, operated by Consol and Allegheny Energy Inc., opened in June.

The company has also won a U.S. Department of Energy grant to demonstrate slant-hole drilling for multiseam degasification followed by carbon dioxide sequestration with simultaneous enhanced methane production.

Equitable Resources specializes in multiple-seam completions—as many as 10 of the 30 seams in the section. The company is the leading operator in Nora Field in Dickenson County, and in Bradshaw Field in McDowell County, West Virginia, where the Virginia plays have expanded. Some Nora Field wells are dual completions in Devonian shale or Mississippian limestone.

The third generation

Of the dozen or so remaining undeveloped coal regions, the Gulf Coast and Alaska stand out as candidates for the "third generation." And they're as different as hot and cold—literally.

Gulf Coast Until the late 1990s, no one had seriously considered Gulf Coast coals as potential sources of methane because of their apparent low rank—lignite—and presumably, therefore, negligible gas content. Indeed, lignites of the Lower Tertiary Wilcox, Claiborne and Jackson groups predominate at the surface, cropping out in bands stretching more than 900 miles from the Rio Grande to southern Alabama. Downdip (coastward) from the outcrops, these coals apparently attain sufficiently high rank to have generated methane.

The Basin Research Institute at Louisiana State University delineated a CBM-prospective area in the Central Louisiana basin in which the gas produced from Wilcox sandstones apparently is biogenically sourced from subbituminous Wilcox coals. Devon Energy has assembled 230,000 net acres in this area and plans a five-well pilot project.

In south Texas, The Exploration Co. (TXCO) of San Antonio is working a multiple-formation oil and gas prospect in the Maverick Basin, where anomalously high-rank coals of the Cretaceous Olmos formation were found at depths to 2,200 feet on the Chittim Anticline. TXCO has recompleted 34 conventional wellbores, which are undergoing dewatering and testing. In the interim, the produced water is reinjected as a waterflood for secondary oil recovery from the underlying San Miguel Formation.

The U.S. Geological Survey has very conservatively estimated 4- to 8 Tcf of CBM in place within the region to a depth of 6,000 feet.

Alaska Tapping even a fraction of Alaska's estimated 1,000 Tcf of CBM is a tantalizing prospect, but it will be a costly venture. A large part of the resource is in remote areas inaccessible by roads and far from pipelines, and key coal characteristics remain unknown in most basins.

What likely will become the state's first CBM field is in the northern Cook Inlet Basin just 30 miles north of Anchorage. Denver-based Evergreen Resources has begun evaluating high-volatile bituminous coals underlying 63,000 acres of the Pioneer Unit (acquired from Unocal in 2001) and adjoining tracts in the Matanuska coal field. The company expects to begin drilling two four-well pods by year-end 2002. Evergreen believes about 1,000 wells would be required to recover a targeted 1 Tcf of gas from its acreage.

CBM is particularly attractive here because conventional gas reserves in the Cook Inlet Basin overall are declining. Actually, according to a recent investigation at Kenai, what is produced as "conventional" gas may be largely CBM that has migrated into the producing zones. Middle Tertiary coal measures underlie the entire basin, onshore and offshore, and contain an estimated 230 Tcf of gas.

Even the North Slope figures into Alaska's CBM picture. Regional coal studies suggest the presence of a potential fairway that stretches across 40,000 square miles of the Colville Basin, where Cretaceous and Tertiary coals contain a staggering 800 Tcf of methane to depths of 6,000 feet. Fortuitously, much of it underlies the National Petroleum Reserve-Alaska. Even at 10% recovery, coproducible CBM would be attractive to the companies gearing up for new natural gas development within the petroleum reserve.

On a smaller scale, the Alaska Division of Geological and Geophysical Surveys continues its field studies to

Running hot and cold: *Intriguing plays are being investigated in Louisiana and Texas. Evergreen Resources sees up to 1,000 wells near Cook Inlet, Alaska.*

assess the potential for developing shallow CBM (at less than 3,000 feet) for use in rural communities.

Canada onstream Canadian coalbed methane has finally become a reality after a quarter century of exploration. The country's first commercial production has come online in southern Alberta. A joint venture of EnCana and MGV Energy Inc., a Canadian subsidiary of Fort Worth-based Quicksilver Resources Inc., has drilled 100 exploration and pilot wells on the immense Palliser Block; 14 wells are producing gas into sales lines on an extended test basis.

Exploratory drilling and field investigations continue at many other sites in Alberta and eastern British Columbia. But the large capital outlays and extensive landholdings that are necessary at this early stage has somewhat limited the participants to large independents with deep pockets. Active players include Anadarko Petroleum, Burlington Resources, Devon Energy, EnCana, Koch, Nexen Inc. and Penn West Petroleum Ltd. Some junior companies have gained footholds through existing holdings or established production and facilities.

Canada's potential CBM resource rivals that of the entire continental U.S. One estimate, from the Canadian Gas Potential Committee, pegs in-place resources of the Western Canadian Sedimentary Basin at 304-to 543 Tcf. The Geological Survey of Canada estimates that another 79 Tcf may exist in the Maritime provinces onshore and offshore.

Three potential play types are being investigated in the basin—shallow foreland basin, deep foreland basin and foothills/mountains.

In an effort to bolster its competitive position with Alberta, the British Columbia Ministry of Energy and Mines has proposed four royalty initiatives specifically to encourage CBM development.

Overall, coalbed methane was a technology-driven play from the start, and advanced drilling and production technologies will be integral to future development—no two plays are alike. For newcomers, then, the learning curve will be steep. Successful development demands careful analysis and synthesis of many geological, hydrological and engineering factors, not just coal rank and gas content. □

November 8, 2002

ArcLight Energy Partners Fund I, L.P.

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