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Coalbed Methane in the Rocky Mountain Region: Yesterday, Today and Tomorrow

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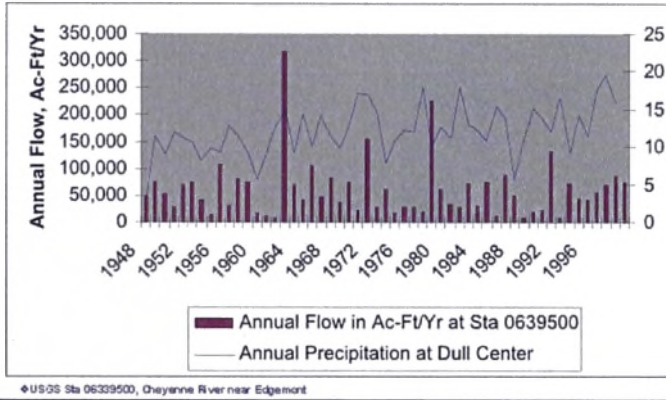
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Matthew R. Silverman, *Coalbed Methane in the Rocky Mountain Region: Yesterday, Today and Tomorrow*, in *COALBED METHANE DEVELOPMENT IN THE INTERMOUNTAIN WEST* (Natural Res. Law Ctr., Univ. of Colo. Sch. of Law 2002).

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Discharge in Cheyenne River vs Time



In fact, if you look at 1993 to 1999, you see the stream flow. This is at the same time we're seeing hundreds of coalbed wells coming online. Well, they organized sending the water to South Dakota and Montana. But look at the hydrographs. The hydrographs don't lie. Where is the water? The water is infiltrating, and it is, in fact, not leaving the state of Wyoming. I'm sure there's some of that that does get through to the Belle Fourche River in northeastern Wyoming from coalbed methane. Okay. If you look Caballo Creek and Highway 59, that's where the core areas are, and that's U.S. Geological Survey gaming station and there might be that much water crossing that.

This is a picture of the Belle Fourche down at Moorcroft. I could jump across the Belle Fourche here. Hundreds of coalbed methane wells contribute to coal

mines that are discharging to the Cheyenne River. In fact, you see the same kind of trend. Wildhorse Creek in Arvada, Wyoming has 32,000 barrels a day. They're dis-

BELLE FOURCHE RIVER AT MOORCROFT, WY



charging somewhere upstream at this location. Where's the water? It's not there.

In summary, I want you to take away from this that all CBM projects are not alike. Your water quality will define your approach, and your water management economics may determine if you have a coalbed methane project or not. And if there is a value net water resource, by all means you have to capture it. Water's too precious in the West not to. And it's not going to be a one size fits all. It's going to be an integrated approach on your operation.

Thank you.

COALBED METHANE IN THE ROCKY MOUNTAIN REGION: YESTERDAY, TODAY AND TOMORROW

MATTHEW R. SILVERMAN, *Consulting Petroleum Geologist*

Coalbed methane (CBM) resources are important in a number of different places in the Rockies. This paper is intended to provide a broad, geographic background on where those resources are and where they may be in the future.

Just a dangerous waste product a few decades ago, CBM now represents about seven percent of the natural gas production in the United States. Most of the coun-

try's gas, of course, comes from conventional gas production, but that seven percent is very important. It represents about 1.3 trillion cubic feet (TCF) of gas per annum, coming from about 15,000 coalbed methane wells. Most of those CBM wells are in the Rockies.

Today, those CBM resources are focused in four basins (Figure 1). The most important area in terms of production is the San Juan Basin of New Mexico and Colorado.

The other key producing basins in the region are the Powder River Basin in Wyoming and Montana, the Uinta Basin in Utah and Colorado, and the Raton Basin in Colorado and New Mexico. The CBM resources in each of these basins are summarized below.

Importantly, each of these basins is located in more than one state. Each of the basins is unique, and its coalbed methane resources are distinctive, but the basins share a number of characteristics. They are all interstate areas, and they will all require interstate solutions to

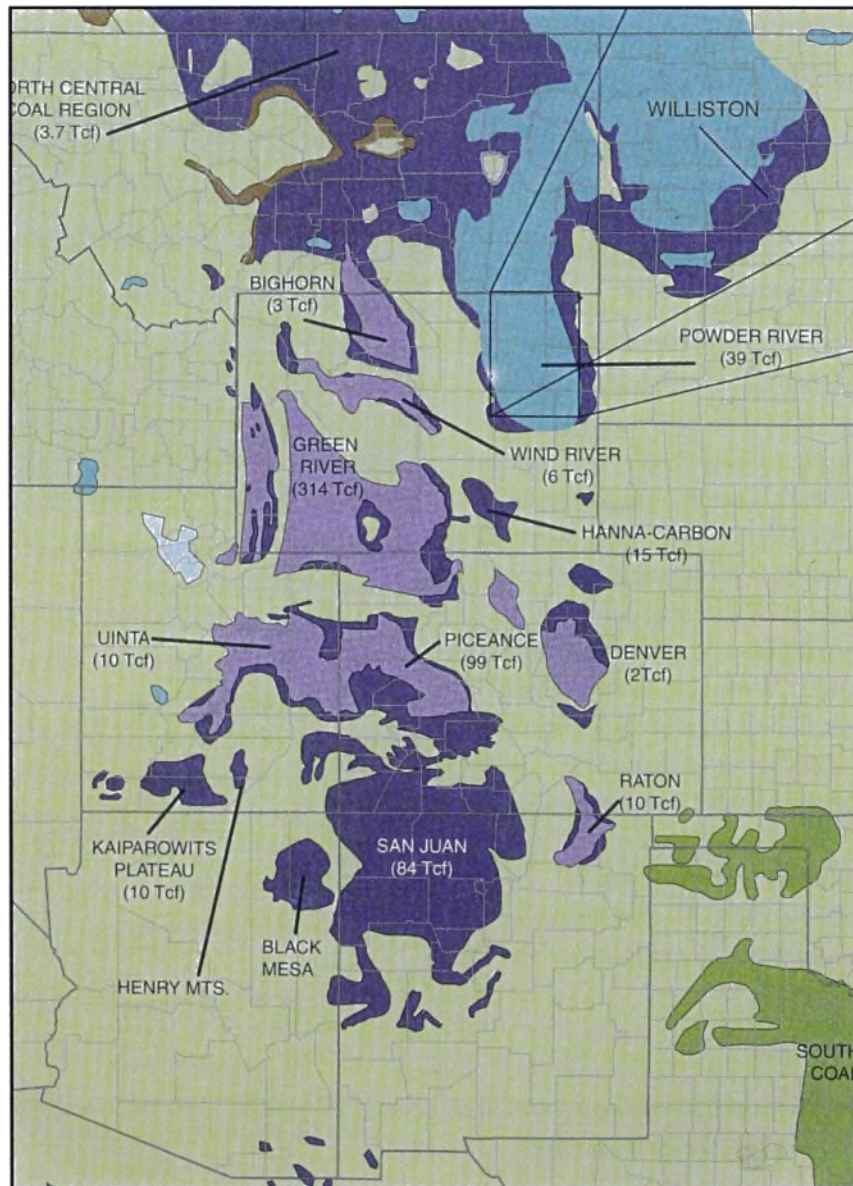


FIGURE 1 Coalbed methane basins of the Rocky Mountain region, after GTI, 2001; and Wood and Bour, 1988. The map is color-coded by the age of the coals that produce, or may produce, coalbed methane. The light blue areas represent Tertiary coals, which are the youngest coals in the Rockies. The lavender color represents Tertiary to Cretaceous coals, and purple represents Cretaceous age coals. The small areas in brown are Cretaceous-Jurassic, the oldest of the CBM coals in the Rockies. (Permian-Pennsylvanian coals in Texas and western Oklahoma are also shown.) The numbers in parentheses represent estimated resources of coalbed gas-in-place.

what are interstate problems. They share problems related to the environment, water quality issues, Federal access issues. They also share the requirement for resolving the infrastructure problems related to production, transportation, water management and local impacts. These are all issues that are common across essentially all coalbed methane basins.

Figure 2 provides a historical perspective, going back a little over ten years. Over the past decade, New Mexico, shown here in yellow, has been the dominant state. This CBM gas, of course, is from the San Juan Basin. But in the last few years, production has really come on strong from the Colorado portion of the San Juan Basin and from the Raton Basin, as well. Alabama has made a significant portion of the country's coalbed methane production and so have a few other states that are shown here as "Others". A very large portion of this production labeled "Others" comes from Wyoming, and that volume has grown dramatically in just a few years.

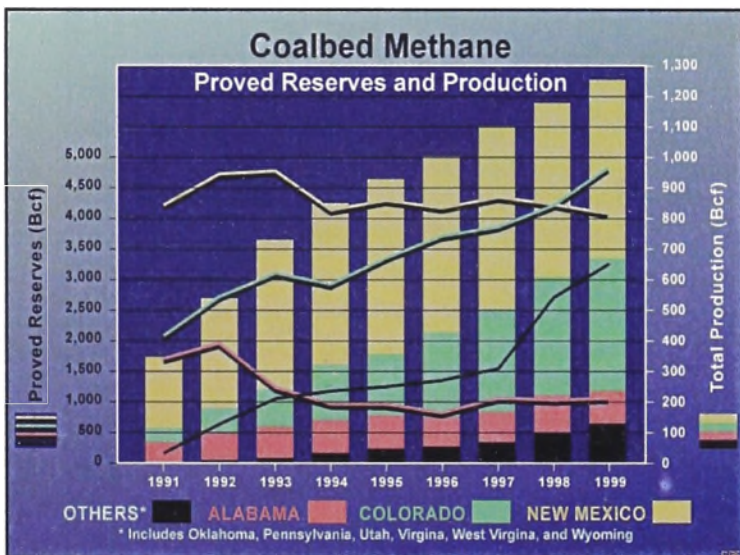


FIGURE 2 Coalbed methane proved reserves and production (courtesy Colorado Geological Survey). The bars represent coalbed methane production and the lines represent CBM reserves.

Two of the things that petroleum geologists and engineers are concerned with are: 1) the volume of gas that is in-place in any reservoir, including a CBM reservoir, and 2) how much of that is recoverable. Those are often two very different numbers, as Figures 3 and 4 illustrate.

Within the Rockies (Figure 3), over 50 percent of the coalbed methane gas in-place is in the Green River Basin. A lot of that is not recoverable by today's methods,

because it is deep, and because of economics, environmental considerations, access restrictions and other reasons. But this huge number provides a sense of the total size of the resource base. The Piceance Basin and the San Juan Basin also have very significant pieces of the pie. The other basins in the Rockies play a smaller role in terms of the resource base.

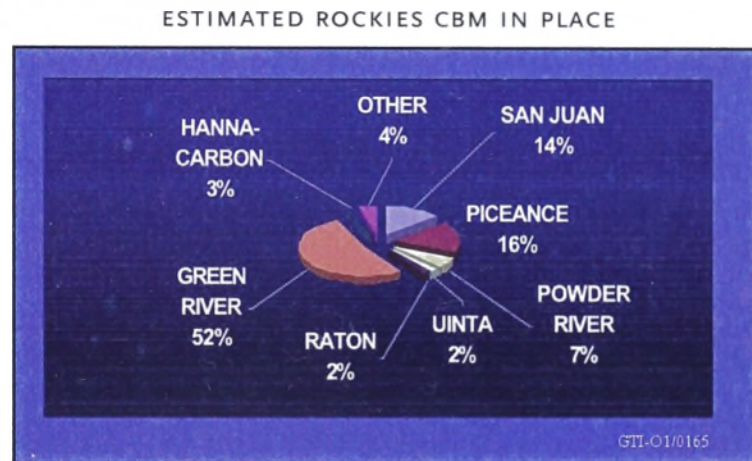


FIGURE 3 Estimated Rockies CBM in place. Estimates were derived from a variety of sources, principally GTI-01/0165.

Figure 4 shows the estimated volumes of recoverable coalbed methane, and this is a very different picture. The Powder River Basin takes the biggest piece of the pie at 43 percent of the coalbed methane that is recoverable under current technical and economic conditions. Again, the San Juan Basin and the Uinta-Piceance Basin play a big part in recoverable reserves as well.

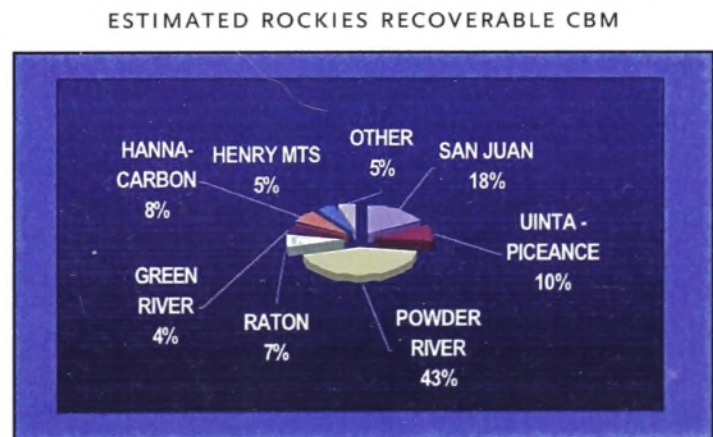


FIGURE 4 Estimated Rockies recoverable CBM. Estimates were derived principally from the potential gas committee, 2000, as given in GTI-01/0165.

KEY PRODUCING BASINS

SAN JUAN BASIN

The San Juan Basin (Figure 1) has an estimated 84 trillion cubic feet of coalbed methane gas in-place. The San Juan Basin has been and continues to be the world's number one area for CBM production. But the San Juan is now in a relatively mature stage of development for CBM. Coalbed methane production has probably peaked there, and, while the basin is still very active, the focus of new drilling and new activity has now gone elsewhere.

Of the basin's estimated 84 trillion cubic feet of CBM in-place, about 12 TCF is recoverable. Almost 8.5 trillion cubic feet of CBM has already been produced (IHS, 2002). The San Juan Basin represents 80 percent of all the CBM production in the United States, and is currently making

where rates are typically 200 to 500 thousand cubic feet (MCF) per day. There is much tighter spacing in the Powder River Basin than in the other basins, reflecting the shallow depths and low per-well recoveries.

The typical depths for CBM wells in the San Juan Basin are 2,000 to 3,000 feet; whereas, in the Powder River Basin, over 10,000 much shallower wells have been drilled. In the Uinta and Raton Basins, well depths vary greatly, but typically, they are much deeper than the wells in the Powder River Basin. Coals are thickest in the Powder River and San Juan Basins, and richest (measured in standard cubic feet of gas per ton of coal) in the San Juan and Uinta Basins. Finding costs for CBM reserves in the San Juan Basin have been less than half those in the Powder River and Uinta Basins, and about 60% of those in the Raton Basin.

	SAN JUAN BASIN	POWDER RIVER BASIN	UINTA BASIN	RATON BASIN
Daily production/well	2,000 MCF	200 MCF	500 MCF	300 MCF
Spacing (acres)	320/160	80	160	160
Number of wells	3,500–4,000	+10,000	450	800–1,000
Typical well depth (ft)	2,000–3,000	300–700	1,000–4,000	500–3,500
Net coal thickness (ft)	70	75	24	35
Gas content (scf/ton)	430	60	400	300
Finding cost (\$/MCF)	0.11	0.25	0.25	0.18

Table 1. Comparison of key producing basins, after GTI and McMichael et al., 2001.

about 75 percent of all the CBM gas in the country. The reasons for that include the presence of thick, rich coals with high permeability and a play that has been extensively developed. Among the top operators in the basin, in terms of both historic production and total well permits, are well established, very large to super-major oil companies, including Burlington, Amoco (now BP) and Phillips.

Table 1 compares the San Juan Basin with three of the other key CBM basins in the Rockies. Typical production per well per day in the San Juan Basin is relatively high, often 2 million cubic feet (MMCF) per day. This is ten times what is being produced per well in the Powder River Basin and four times greater than the Uinta Basin,

POWDER RIVER BASIN

In terms of well permitting, current drilling, and the growth in production, the Powder River Basin is the most active coalbed methane play in the Rockies. Figure 5 illustrates the CBM basins of Wyoming, including the Powder River Basin in the northeastern part of the state. CBM targets which are shallower than 5,000 feet are shown in red. This depth is a traditional cut-off, above which, coalbed methane targets are thought to be currently viable. Shallow coalbed methane plays are present in the Powder River Basin, of course, and in the Wind River Basin, shallow portions of the Hanna Basin and the Big Horn Basin, and a couple of places in the Green

River Basin. Deeper targets (shown in orange) represent a resource base for the future. Those targets are present in a number of areas, but the key for the future is the huge, deep coalbed methane potential in the Green River Basin. If this becomes economically viable and technically feasible, it could dwarf everything else that is being done in the region.

WYOMING CBM TARGETS

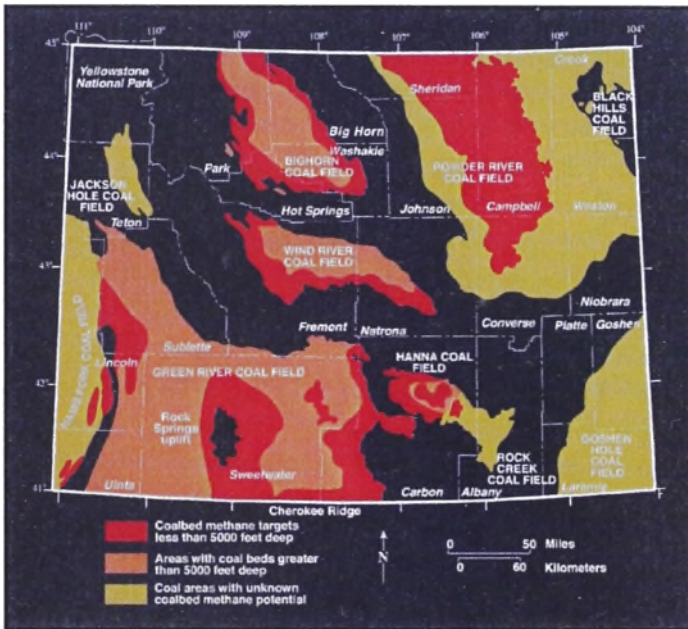


FIGURE 5 Wyoming coalbed methane potential includes the producing Powder River Basin and several other basins, some with targets deeper than 5,000 feet (courtesy Wyoming State Geological Survey).

Historical and projected growth in CBM development in Wyoming is shown in Figure 6. Most of this growth is projected to come from the Powder River Basin. Before five years ago, there was essentially no CBM production in the Powder River Basin, but the basin has now produced about 400 billion cubic feet of coalbed methane. Figure 6 illustrates how that production is projected by the Wyoming State Geological Survey to ramp up over the next 20 years. The number of producing wells has also grown explosively here since the mid 1990s and is projected to grow at a very high pace over the next five years, as well.

WYOMING CBM PRODUCTION

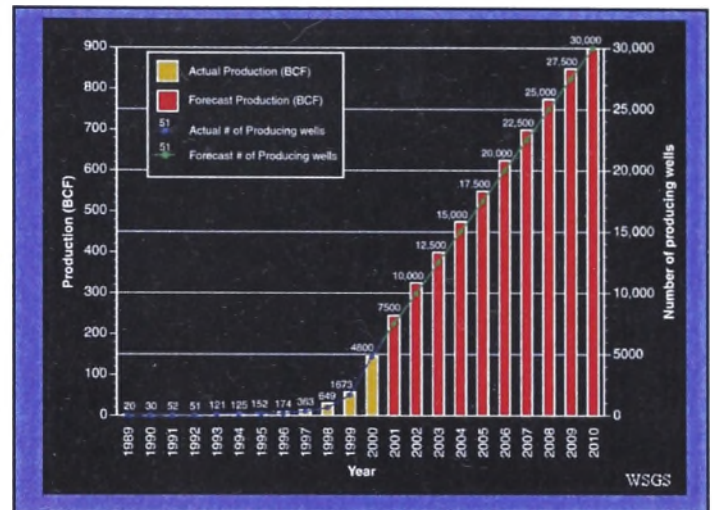


FIGURE 6 Actual and projected growth in Wyoming coalbed methane production and producing well count (courtesy Wyoming State Geological Survey).

This is a developing resource and also a developing problem that concerns people throughout the region today. Much of the impact has been felt in the eastern part of the basin near Gillette in an established coalbed methane fairway. Drilling has now been extended to the western part of the basin near Buffalo and Sheridan. Due to governmental restrictions, activity in the promising northern part of the basin in Montana has moved forward less rapidly.

Published estimates suggest the presence of at least 40 trillion cubic feet of gas in-place in the Powder River Basin, and approximately 10 TCF is thought to be recoverable. As more pilot projects are undertaken and more data are gathered, these numbers have been revised upward several times. We may expect to see future upward revisions as well. The Powder River Basin has a relatively low gas content per ton of coal, but the coals are thick, shallow and permeable. The basin enjoys very large CBM resources because the thick coals have a huge areal extent. The favorable economics are related in part to low costs associated with shallow drilling and permeable reservoirs that do not require expensive fracture treatment.

The list of top operators in the Powder River Basin includes some of the industry's established independents like Devon and J. M. Huber, as well as companies that have traditionally been midstream or transportation companies like Western Gas and Williams. Companies

ranging from smaller majors, like Marathon, to some regional independents are represented, also. Many of these strong positions in Powder River Basin CBM (and in other CBM plays) were created by recent acquisitions.

UINTA BASIN

The prolific Ferron coalbed methane play in east-central Utah (Figures 1 and 7) is the third largest CBM play in the Rockies. The volume of estimated CBM resources in-place in the Uinta Basin is about 10 TCF, of which roughly half is thought to be recoverable. The play is currently producing about 300 MMCF of gas per day, of which roughly 250 MMCF comes from the Drunkard's Wash Field. Approximately 300 billion cubic feet (BCF) of gas has been produced from this basin since the early 1990s (Lyons, 2002).

Gas content in the coals in some parts of the Uinta Basin rivals that in the San Juan Basin. Per well recoveries are relatively high in the northern part of the play where well control and the pipeline infrastructure have been located. Over 400 wells are producing, but published estimates suggest the play could ultimately support eight times this many CBM wells. Top operators in the Uinta Basin include major oil companies and large independents such as ChevronTexaco, Phillips, and Anadarko.

RATON BASIN

The Raton Basin in southeastern Colorado and northeastern New Mexico (Figure 1) is fourth in terms of CBM production in the Rockies. There are over 10 trillion cubic feet of gas in-place in the Raton Basin, and about 3.5 to 4 trillion cubic feet of that gas is considered recoverable. Cumulative CBM production is about 130 BCF (IHS, 2002). Although these are big numbers, the Raton Basin's production so far represents less than two percent of the gas that has been produced in the San Juan Basin. The Raton Basin's current production is about 110 MMCF of gas per day. This total comprises about three percent of all of the coalbed methane gas that is being produced in the United States.

Ten years ago, coalbed methane gas represented approximately 10 or 15 percent of all of the gas being produced in Colorado. Now, utilization of this important resource has increased dramatically. Coalbed methane now represents more than half of the gas being produced in the state, and most of this growth comes from CBM from the Raton and San Juan Basins. The top operator in the Raton Basin by far, is Evergreen, which is the domi-

nant company, especially on Colorado's side. The other key companies include Devon, El Paso, Williams, and other independents.

NEW COALBED METHANE RESOURCES

FUTURE SOURCES OF CBM

Parke A. Dickey said, "We usually find oil in new places with old ideas. Sometimes, also, we find oil in an old place with a new idea, but we seldom find much oil in an old place with an old idea. Several times in the past we have thought that we were running out of oil, whereas actually we were only running out of ideas." The same is true for gas, including coalbed methane.

In the coming years, CBM production will be generated from a number of new ideas, sources and areas (Figure 1), including the following:

- New Economics
- New Plays and/or Areas in Producing Basins
- New Technologies
- Deep Plays
- New Basins

First, new economics could mean not just higher prices for the producers, but as new pipelines come into the Rockies, new markets are developed. Markets in the future will become available for gas that has been stranded, and CBM resources will be used locally and sub-regionally for electric power generation.

Second, a key method by which people have traditionally found oil and gas is by exploring in new plays or new areas in producing basins. The Powder River and San Juan Basins, for example, have been traditional conventional gas producing areas for many years. In the last decade or two, both have become very important coalbed methane producers, generating huge volumes of new resources.

Third, new technologies that will be important for CBM development include exploration and evaluation techniques, horizontal and slant-drilling, multiple-seam and thin-zone completions, enhanced fracturing methodologies, and advances in water treatment, disposal and re-injection. All of these will be called upon to enable new coalbed methane resources to be brought to life.

Fourth, we also will have new production from deep plays in which huge gas resources are stored throughout the Rockies. These will be developed in the future as

technological advances and market conditions permit. Finally, we can expect to see coalbed methane produced from new basins, in other words, basins that are not producing now at all, as in western Washington, for example.

TECHNOLOGY

The Uinta Basin provides an example (Lyons, 2002) in which application of seismic technology has made a positive difference in the reserves base and in project economics. New advances in geophysical techniques will also play a vital role in the development of coalbed methane resources in the future. Near the top of the seismic line (Figure 7), two gas wells with poor production are labeled in red. An excellent producer is labeled in blue. The significance is that the seismic line shows the presence of prominent faulting in the CBM interval. Black vertical lines in the center of the seismic data panel show the faults. Generally speaking, faulting and associated folding produce fractures, and fractures may yield higher permeability. Higher permeability results in wells that produce more efficiently. Use of this technology leads to the identification of sweet spots, relatively small areas of higher production. By focusing on the sweet spots, operators may be able to drill fewer wells and still drain the same volume of gas. This tends to result in better profitability and in less surface disturbance. Seismic in this area helped not just to identify faults and predict a high-productivity fairway, but also to:

- Map the extent of the producing coals more precisely

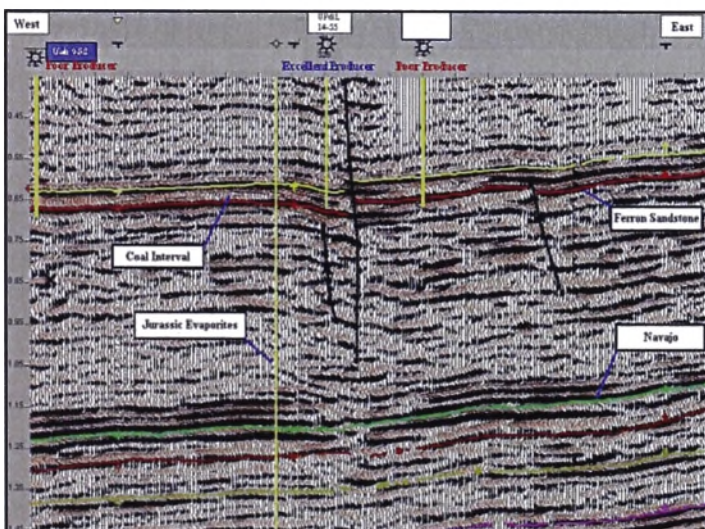


FIGURE 7 Buzzard Bench seismic line 4, showing the relationship of faulting to a narrow fairway of higher production, Uinta Basin, Utah (after Lyons, 2002).

- Understand coal facies changes
- Improve the interpretation in sparsely drilled areas
- Assess other formations for water disposal or hydrocarbons production

DEEP COALBED METHANE

An example from which we may begin to see the potential of deep CBM production is offered by the Piceance Basin of Colorado and Utah (Figure 1). In the Piceance Basin, approximately 99 trillion cubic feet of coalbed methane gas is in-place. Of that, 84 TCF is in deep coalbeds, that is, coalbeds deeper than 5,000 feet. One example of deep CBM production there is the White River Dome Field, which is producing coalbed methane from depths of 5,000 to 8,000 feet. Sixteen wells drilled in the late 1980s and early 1990s cut 25 to 85 feet of net coal, with gas contents measured at 547–621 scf/ton. This field has produced over 10 BCF of coalbed methane (Murray and Perlman, 2002).

Other examples of basins with deep CBM potential (SPE 26196, GTI-01/0165) include:

- The Green River Basin, in which only 48 of the 314 trillion cubic feet of gas resources is estimated to be actually in coals that are shallower than 6,000 feet.
- The Uinta Basin, where a majority of the CBM resources are thought to be deep.
- The Tertiary basins of western Washington, in which 50–80% of the estimated 24 TCF of CBM in-place is below 5,000 feet.
- The San Juan Basin, in which 17 trillion cubic feet of CBM is estimated to be reservoir in Menefee coals that are deeper than 5,000 feet.
- Alberta, Canada, where at least 50 TCF is present in coals from 5,000 to 11,000 feet deep.

NEW PLAYS IN PRODUCING BASINS

A final example of potential future CBM sources is the Williston Basin of North Dakota and Montana (Figure 1). There, the U.S. Geological Survey (Ellis et al., 1999) has mapped the presence of coals near the heart of the traditional oil and gas play (Figure 8, for example). These coals are considered prospective for coalbed methane.

Coals in both the Williston Basin and the Powder River Basin are from the Tertiary Fort Union Formation. The Williston Basin's coals are relatively low rank and have produced biogenic gas, as in the Powder River

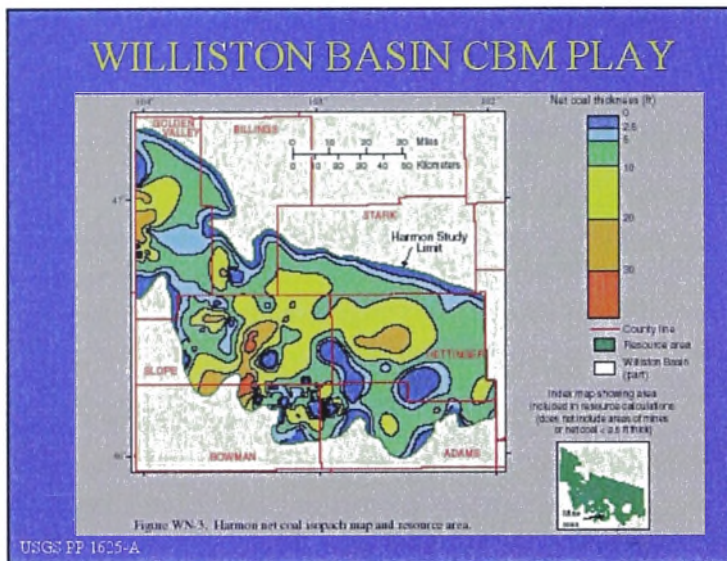


FIGURE 8 Net isopach map of the Harmon coal, Williston Basin, North Dakota (from Ellis et al., 1999).

Basin. They are 20 to 50 feet thick and continuous over a large mapped area. Fifteen years ago, many people said that no coalbed methane play in the Powder River Basin would ever work because of the low gas content of the coals. Now, we can all see the enormous size of the resource base that has been developed there. The question is open: Is there a CBM play in the Williston Basin?

CONCLUSIONS

Figure 9 is the coalbed methane resources pyramid for the Rockies. The volume of 7 TCF at the apex of the pyramid suggests the amount of coalbed methane gas that has been produced so far, although actual numbers are somewhat higher. This is the gas that has proven easiest to find and produce, and includes the most highly economic resources. Below this is a level of proved reserves at about 11 TCF. As one looks down the pyramid, the volume increases dramatically to where the total resource base may be as much as 536 trillion cubic feet of coalbed methane in the Rockies. However, costs increase, the requirements for new technology increase, the environmental considerations increase, and the uncertainty also increases, all in the same direction towards the base of the pyramid.

Therefore, the future level of coalbed methane production in the Rockies may ultimately approach the huge numbers at the bottom portion of the pyramid. But this entire volume of gas at the pyramid's base is unlikely

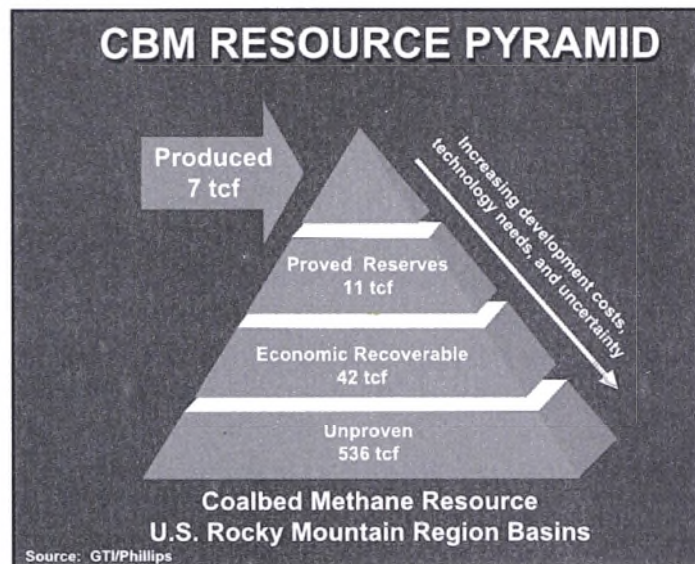


FIGURE 9 Coalbed methane resources pyramid for the Rocky Mountain region, after Bowles, 2001, from GTI. The 42-TCF level reflects the resources that are considered technically feasible and economically viable today. The pyramid is actually broader at the base than represented here.

to be produced. It is essential to keep in mind all of these difficult factors that must be dealt with before these resources can be brought to the market.

ACKNOWLEDGMENTS

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