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COALBED METHANE IN VIRGINIA

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INTRODUCTION

Coal and some black shales are self-sourced (autogenic) reservoirs where methane gas is formed and stored in the coalbed or shales. The methane can be recovered as a fuel for commercial use by standard drilling and production techniques from these source beds.

Coalbed methane has been produced and utilized for many years in the southeastern and western United States, most notably in the Black Warrior basin in Alabama and the San Juan basin in New Mexico and Colorado. These basins presently are producing commercial quantities of methane gas from coalbeds. In Virginia, coalbed methane is present in the Valley coalfield, the Southwest Virginia coalfield, and the Richmond and Taylorsville basins (Figure 1). Five wells were drilled in the Valley coalfield; ten wells were drilled in the Taylorsville basin and thirteen wells in the Richmond basin all of which had non-commercial quantities of methane gas. Coalbed methane is being produced in the Southwest Virginia coalfield. In 1988, the first year of production, two wells produced 11,856 Mcf (1 Mcf equals 1000 cubic feet; 1993 average annual consumption per household was 95 Mcf) of methane (Figure 2). In contrast, in 1993, 19,923,463 Mcf of methane were produced from 465 wells. Cumulative coalbed methane production for the period of 1988 through 1993 is 28,700,917 Mcf. Coalbed gas in Virginia contains an average of 96.6 percent methane and has a heating value of about 990 Btu per cubic foot.

ORIGIN OF COALBED METHANE

Coalbed methane is formed as a by-product during the alteration of plant (organic) matter to coal. Throughout most of the Mississippian, Pennsylvanian, and Triassic periods in much of the area that is now the United States, climates were

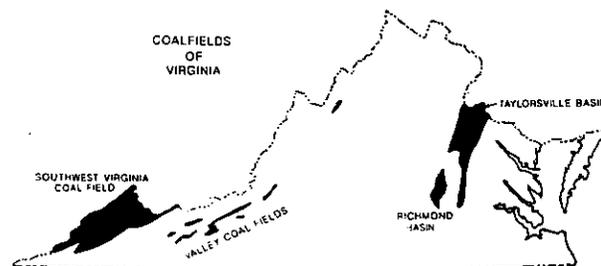


Figure 1. Location of coal-bearing areas in Virginia and current and potential coalbed methane production areas.

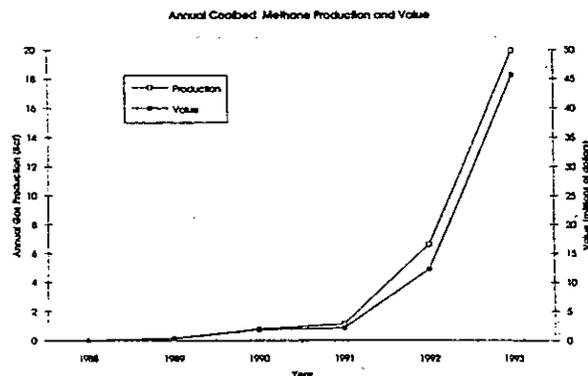


Figure 2. Annual production and value of coalbed methane in Virginia, 1988 to 1993.

moist and rainy, and temperate-to-cool, which furnished a suitable environment for plant growth and the accumulation of peat. Peat can form in tropical settings, but not on as large scale as in regions of lower temperatures. Plant debris decays

rapidly in the tropics, especially if there is an annual dry season, and organic material is not preserved except under extremely favorable circumstances. Extensive peat deposits are more indicative of high humidity and heavy rainfall than of high temperatures.

In the three previously mentioned geologic periods peat was laid down just above sea level, within deltaic and tidally-affected, lagoonal-fill environments. In these environments coarse-grained sediments interspersed with finer sediments were deposited; the surface then stabilized and weathering of exposed sediments took place. Drainage was poor and clay formed from weathering or was transported in during flooding and deposited. A growth of heavy vegetation then covered the ground surface and also impeded drainage. Bushes, tree-ferns, and ferns grew rapidly within this swamp environment. As the dead vegetation accumulated, it produced an accumulation of peat. With further lowering of the land surface, the area became flooded and the peat was covered with fine mud, bearing organic matter and with woody plant fragments derived from the vegetation which persisted in the shallow waters of the lagoons and within the floodplains of the rivers and streams. With subsequent subsidence and flooding by marine waters the remaining plants were killed. With time, deposition, and subsidence, the organic matter and peat were buried deeper and deeper under accumulating sediments.

Through time this woody plant material was converted into coal (coalification), by an increase in temperature caused by deep burial, which drove off volatile matter. Methane gas was a primary component of this volatile matter. In addition, the conversion to coal also released carbon dioxide, nitrogen, and water. Because Appalachian basin coals were derived mainly from woody constituents of complex terrestrial plants, they are classed as dry-gas-generating source rocks.

During the early stages of coalification, biologically-formed methane is generated as a by-product of bacterial respiration. Aerobic bacteria first metabolize any free oxygen left in the plant remains and in the surrounding sediments. If sulfates are present, methane generation will not dominate over other gases until after sulfate-reducing bacteria have metabolized the sulfates. Where waters in the coalbeds are low in sulfates, methane production begins immediately after oxygen is depleted (Rice and Claypool, 1981). Other bacteria then reduce carbon dioxide to produce methane (methanogenesis). With burial, temperature rises and when a coal bed is held at a temperature above 50°C (122°F) for a period of time, most of the biologically-formed methane will have been generated. Also about two-thirds of the original moisture will have been expelled, and the coal rank will be approximately sub-bituminous (Rightmire, 1984).

By either increased burial or an increase in geothermal gradient, through time, the temperature rises above 50°C (122°F) and additional water, carbon dioxide, and nitrogen are generated and coalification proceeds to approximately the rank of high-volatile bituminous (Rightmire, 1984). Maximum generation of carbon dioxide (with little methane generation) occurs at about 100°C (212°F). Thermogenesis of methane begins in the higher ranks of high-volatile bituminous coal. At about 120°C (248°F), the approximate boundary between high

and medium volatile bituminous coal, generation of methane exceeds generation of carbon dioxide (Rightmire, 1984). Maximum generation of methane from coal occurs at about 150°C (302°F).

METHANE OCCURRENCE IN COALBEDS

The methane gas generated in coalbeds may escape directly into the atmosphere, migrate into adjacent rocks, or may be retained within the coalbed. The actual amount of methane retained by coal can be less than 10 cubic feet per ton to more than 600 cubic feet per ton (Meissner, 1984).

Methane is present in coal as both adsorbed and absorbed molecules on the surface of pores in the coal, and ninety percent or more of the total methane retained by a coal is probably adsorbed on the coal pore surfaces or absorbed within the molecular structure of the coal. It is found as free gas existing within fractures (cleats) or pores, and as dissolved gas in water present in the coal (Rightmire, 1984). Meissner (1984) believes that coal acts as a molecular sieve or solid solvent that absorbs, rather than adsorbs, methane molecules.

Coalbed methane reservoirs typically have low matrix permeability generally less than 1 millidarcy and permeability is produced by cleats and/or fractures. According to Petroleum Information (1986), desorption and gas flow through water-saturated coalbed reservoirs during methane production occurs in three stages: 1) single-phase flow, where gas is completely saturated in the water retained in the coal bed; 2) unsaturated single-phase flow, where methane desorption begins as reservoir pressure drops; and 3) two-phase flow, where gas and water are present and are mobile and gas saturation is increased.

The amount of methane in a reservoir is dependent on the depth of burial, coal rank, and hydrogeologic setting (Petroleum Information, 1986). The ability of a gas to flow through a reservoir is dependent on such factors as structural setting, depth, variations in coal maturation history, and the water saturation. Depth is extremely important in the producibility of a coalbed reservoir because permeability decreases more rapidly with depth in the coal reservoirs than in conventional clastic or carbonate reservoirs. On the positive side, coalbed methane reservoirs may exhibit negative decline curves as they are produced; because, as coal is dewatered and reservoir pressure is lowered, gas flow (desorption) and permeability to gas increases (Petroleum Information, 1986).

DRILLING AND COMPLETION

The following discussion is a summary of information provided by Sexton and Hinkle (1984). Coalbed methane wells are drilled using air-rotary drill rigs. Since extremely low formation pressures and fracture gradients are characteristics of coalbeds, drills using circulating drilling fluids to remove drill cuttings and control formation pressures are not used because the fluid can seal pores and can have an adverse effect on production of gas (Graves and others, 1983). Therefore, air

is used to prevent contamination of coalbeds by drilling fluid. Also, drilling time and costs are less for air-rotary drilling.

Coalbed methane wells are typically completed as cased open-holes. Using the cased open-hole method, production casing is set or cemented in place immediately above the uppermost producing coalbed and the lower portion of the hole is uncased. Many of the wells in the eastern Buchanan County field have been completed by cased open-holes. Wells completed as cased open holes primarily tend to prevent cement from damaging producible coal beds as well as to reduce the cost of drilling and completion. A disadvantage to completion as a cased open hole is the general difficulty in isolation of the zones or intervals during hydraulic fracturing to increase production. Caving has also been a concern in completion of a well by this method, although this problem is minimal.

In cased hole completions, production casing is set through the productive coalbed(s) that are penetrated by the wellbore. When this method is employed, the casing is selectively perforated or slotted to provide paths for the methane to come out of the coalbed and into the wellbore. Advantages to cased hole completions include better isolation of productive intervals and the elimination of problems associated with caving of sides of the wellbore. Disadvantages are the additional completion cost and the potential damage to minable coalbeds from the casing cement. Cement damage can be minimized by the use of light-weight cements such as spherulite or possibly foam cement (Graves and others, 1983).

Wells associated with underground mining are of three types: gob holes, vertical-ventilation holes, and horizontal-ventilation boreholes. Gob holes are vertical wells designed to draw off the coalbed gas that has accumulated in debris resulting from the collapse of the mine roof following underground mining. Vertical-ventilation holes are drilled to degas the coalbed prior to mining. Horizontal ventilation boreholes are drilled into the coal face in underground mining operations. This technique is used to degas the coalbed prior to mining. This method decreases the amount of methane gas at the mine face, thereby providing safer working conditions for underground miners.

STIMULATION TECHNIQUES TO INCREASE PRODUCTION

It is well known that secondary fracturing of coal beds increases the flow of gas into a well. "Hydraulic fracturing" involves injection of fluids and a propping agent (such as sand) under high pressure into a coalbed. The application of pressure injects fluids into the coalbed thereby widening natural fractures and creating new ones that are held open by a propping agent after the pressure is released. As a result, these fractures provide path-ways for gas migration to the wellbore, thus stimulating the flow of gas. It has been demonstrated that gas flow rates from a coalbed can be increased twentyfold by hydraulic fracturing (Elder and Deul, 1975).

Experience with coalbed methane production in the Appalachian basin and other basins has shown that coalbeds must be dewatered before a significant amount of gas can be

produced. Dewatering of the coalbed is accomplished by pumping water up the tubing string, thereby allowing methane to flow up the casing-tubing annulus. The majority of coalbed methane wells are equipped with rod pumps powered by a "walking beam." Water produced along with the gas is disposed of by injecting it back into the subsurface through an approved Class II D injection well, or by shipping it to an acceptable disposal or treatment plant.

Gas-water separators are normally connected to individual wells to remove moisture from the gas when it reaches the surface. The gas must be compressed and additional water removed by a dehydrator before entering the gas transmission line.

OWNERSHIP AND LEASING OF COALBED METHANE

Coalbed methane presents special problems for ownership and leasing because coal is both the source and the reservoir for the gas, as well as being a separate leasing entity in itself. Coal rights reserved for the Federal government do not include coalbed methane, but oil and natural gas rights reserved for the Federal government do. The Virginia Code, Title 45.1, Mineral and Mining, Chapter 22.1, the Virginia Gas and Oil Act sets the laws pertaining to General Provisions, Gas and Oil Conservation, and regulations of gas and oil development and production. The Gas and Oil Regulations was set forth on September 25, 1991. Part II of this regulation pertains uniquely to coalbed methane wells, although the permittee must also comply with Part I the Standards of Applicability. The regulation contains information for permitting wells, well-casing requirements, wellhead equipment, and for plugging wells, among other regulations. The Virginia Gas and Oil Act provides for the establishment of the Virginia Gas and Oil Board. This Board has the authority to issue rules, regulations, and orders pursuant to the provisions of the Administrative Process Act. On March 20, 1989, the Board ordered the establishment of field rules, including well spacing and drilling unit size in the Nora gas field as proposed by Equitable Resources Exploration, Inc. Equitable was granted a 60-acre drilling unit. Following this order, the Board established the rules for the Oakwood coalbed gas field I (OGCB 3-90) on May 18, 1990 as proposed by OXY USA, Inc. Then May 28, 1992, the Virginia Gas and Oil Board established drilling units for the Oakwood Coalbed methane field II (VGOB 91-1119-162) which is for production from gob gas, horizontal boreholes (short hole gas), and any drilling unit which contains an existing well. The boundaries of the Oakwood coalbed methane field II were extended by the Board order 92-0216-0336/93-0316-0349 on June 23, 1993. The VGOB Order 93-0316-0348 modified and expanded the Oakwood coalbed methane gas field by combining the boundaries of the field I and II, with exceptions of lands operated by the Pocahontas Gas Partnership. The drilling unit established for the Oakwood coalbed methane field is 80 acres per well.

On August 9, 1991 and August 15, 1991, the Board established rules for production units BUN1 (VGOB Order 0618-127) and BUS1 (VGOB Order 0618-128) for the production of

sealed coalbed methane gob gas as proposed by Pocahontas Gas Partnership. The Pocahontas Gas Partnership was allowed to permit and convert a minimum of 8 vertical ventilation holes to coalbed methane wells in these units. The Board ordered the creation of the production unit for BUS2 by Order 91-1119-0160 and 91-1119-161. The Board granted the application of Pocahontas Gas Partnership to establish drilling units identified as SLW5, SLW6, SLW7, SLW8, SLW9, SLW10, SLW11, and SLW12 by Order 92/01/21-0180. Order 93-0216-0325 extended the boundaries of the Oakwood coalbed methane field I and established drilling units for the Hurricane extension.

As an incentive to develop alternative fuel resources in the United States, the Crude Oil Windfall Profit Tax Act of 1980 contained provisions for the Internal Revenue Service (IRS) to give tax credits to producers of nonconventional fuels, including coalbed methane. These tax credits were designed to help producers of nonconventional fuels remain competitive during times of low oil and natural gas prices. Calculation of tax credits uses an inflation adjustment factor (based on the gross national product implicit price deflator as determined by the IRS) and a phase-out factor based on domestic crude oil prices (Soot, 1988). The tax credit is only applicable for production from new wells on previously undeveloped property and only applies to wells drilled after December 31, 1979, and before January 1, 1991. Coalbed methane production in 1986 was eligible for a tax credit of \$0.75 per million Btu of gas sold; in 1987, the tax credit was \$0.77 per million Btu of gas sold (Soot, 1988). The latest available tax credit value is for 1990 in which it was \$0.87 per million Btu of gas sold. By the year 2000, the tax credit could be as much as \$1.34 per million Btu (Soot, 1988) depending upon the rate of inflation, among other factors.

OCCURRENCE AND PRODUCTION OF COALBED METHANE IN VIRGINIA

The release of methane gas from coalbeds is a serious safety hazard in underground coal mining. In Virginia, methane associated with coalbeds is well known. These coalbeds are Mississippian, Pennsylvanian, and Triassic in age and occur in a variety of stratigraphic and structural settings. Evidence for methane occurrence is shown by direct measurements in wells and coal cores, surface venting of gas from coal mine vertical ventilation shafts, gas-related explosions and fires in underground coal mines, inferences from coal rank, and finally from the thermal history of the coalfields.

Mississippian coals in the Price Formation crop out in the Valley and Ridge physiographic province in Montgomery and Pulaski Counties ("Valley coalfields"). There are generally two thick coalbeds in the Price Formation, these are the Merrimac and Langhorne coalbeds. The Merrimac and Langhorne coalbeds are found at depth below a thick overthrust sequence of Cambrian and Ordovician dolomite and limestone. The Merrimac coal ranges from 5 to 12 feet in thickness and the Langhorne, which is located about 20 feet below the Merrimac, ranges from 1 to 3 feet thick (Stanley and

Schultz, 1983). In 1982, the Division of Mineral Resources received a grant from the U.S. Department of Energy to assess coalbed methane resources in a part of the Valley coalfield. Three core holes were drilled during the program. These wells were completed as dry holes. In 1987 and 1988, Valley Basin Associates (New River Gas Company) drilled four wells for coalbed methane in Pulaski County. These wells were also completed as dry holes.

Generally, the rank of Mississippian-age coals in Virginia is relatively high (low volatile bituminous or semi-anthracite). Several now-abandoned underground mines in the Valley coal fields were reportedly gassy (Stevens, 1959). Explosions related to either methane gas or possibly coal dust occurred in the Parrott (1915 and 1932), Great Valley (1928 and 1946), and Hard Coal (1939) Mines in Montgomery and Pulaski Counties (Stevens, 1959; Stanley and Schultz, 1983). Stevens (1959) also reported that several gas ignitions occurred in the Merrimac mine; but listed no dates.

Pennsylvanian coals in the Pocahontas, Lee, and Norton Formations crop out in the Appalachian Plateaus physiographic province in the southwest Virginia coalfield (Figures 1 and 3). Figure 4 shows the coalbeds associated with coalbed methane production. The thickness of the rocks between the Jawbone coalbed and the Mississippian Bluestone Formation averages 1500 feet. Generally the coalbeds in the Pocahontas, Lee, and Norton Formations range from less than one foot to as much as 5 feet.

In general, the rank of Pennsylvanian-age coals in the southwest Virginia coalfield is low- to medium-volatile bituminous. In the southwest Virginia coalfield (Figures 1 and 3), direct and indirect evidence exists for the presence of coalbed methane. An explosion occurred in the South Mountain Coal Co., Inc. Mine No. 3 in the Imboden coalbed in western Wise County in 1994. The mines of the Island Creek Coal Company, in Buchanan County, located in the Pocahontas No. 3 coalbed are very gassy. Explosions related to methane or coal dust have occurred in a mine at Deskins in 1983 and at Keen Mountain in 1994. In 1978, the Island Creek Coal Company designed a project to recover methane from vertical ventilation holes that were drilled into the Pocahontas No. 3 coalbed in order to degas the coal prior to mining. They also have utilized the horizontal borehole system. It has been shown that significant quantities of methane gas can be produced. In 1991, OXY USA, Inc. drilled 72 coalbed methane wells. Pocahontas Gas Partnership drilled one coalbed methane well, and Virginia Gas Company drilled five coalbed methane wells all in central Buchanan County. In 1991, Island Creek Coal Company and Consolidated Coal Company applied for permits to convert vertical ventilation holes to coalbed methane wells. They were granted permits in 1992. Cumulative production of coalbed methane in Buchanan County through December 1993 was 19,584,006 Mcf.

The Clinchfield Coal Company, in cooperation with the U.S. Bureau of Mines, began a similar program in 1978 to drill vertical ventilation holes into the Jawbone coalbed in Dickenson County. In 1979 four holes were drilled to degas the coal in advance of mining. Explosions related to methane or coal dust occurred in a mine in the Jawbone coal near

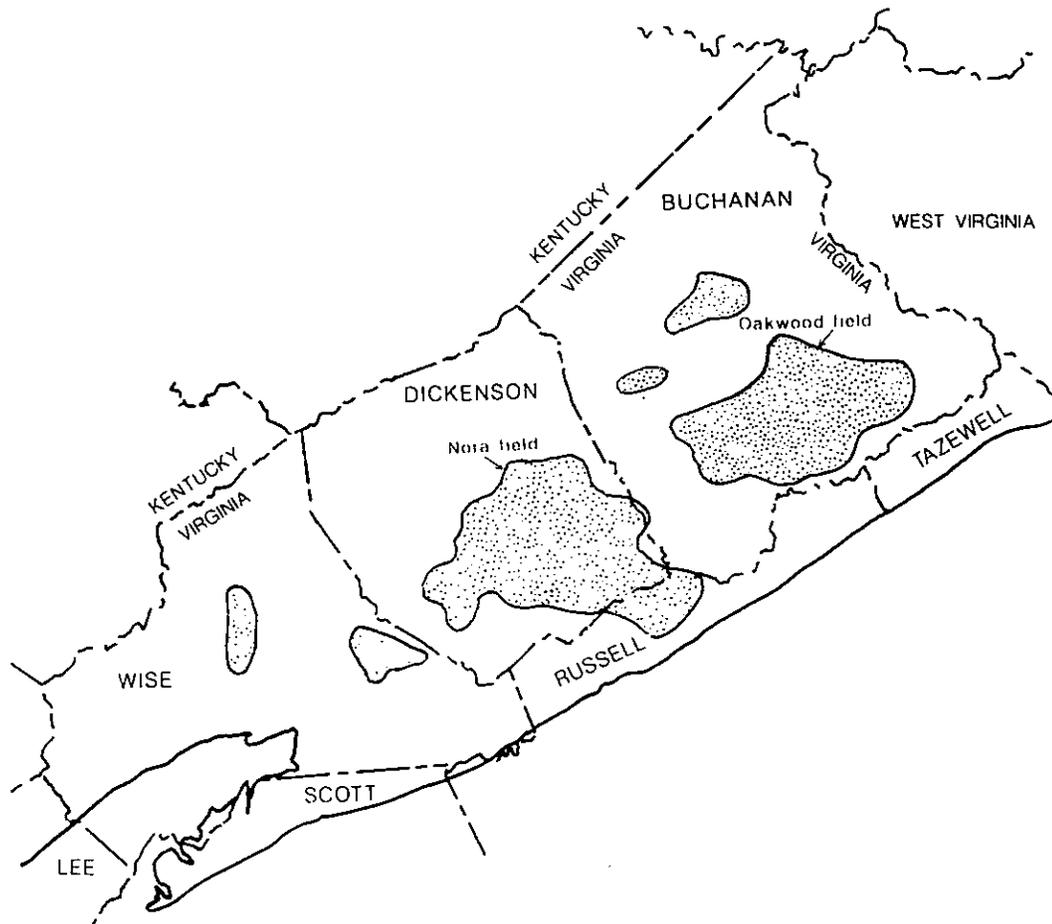


Figure 3. Location of area where current coalbed methane production is taking place.

McClure, Dickenson County in 1983.

Equitable Resources Exploration, Inc. (EREX) drilled two exploratory wells in 1988 in the Nora gas field in Dickenson County to test coalbeds in the Pocahontas and Lee Formations for methane (Figure 4). The first well was completed on September 13, 1988 and in October 1988 it produced 26 Mcf of gas on a daily basis. Total production for this well through December 1993 was 245,540 Mcf. The coalbed methane wells yield an average of 122 Mcf per day of methane gas along with 4 barrels of water per day. Water produced with the gas is disposed of by pumping into a deeper formation, in this case the Price Formation, via an approved injection well. Cumulative production of coalbed methane in Dickenson County from September 1988 to December 1993 is 7,735,207 Mcf. Equitable also produces coalbed methane in Russell and Wise Counties. Cumulative production through December 1993 for these counties are 1,359,550 Mcf and 22,154 Mcf, respectively. Cumulative coalbed methane production in the Commonwealth from 1988 through 1993 was 28,700,917 Mcf with a cumulative

value of \$62,321,551.

The Triassic-age coals in the Richmond and Taylorsville basins are high-volatile bituminous-rank coals. During 1981-1982 Merrill Natural Resources encountered coalbed methane while drilling in search of oil. Not all of the wells intersected coalbeds; they were abandoned as dry holes. Coal was mined in the Richmond basin from 1748 to 1927 and during the period from 1810 to 1912 there where at least 28 explosions related to either methane gas or coal dust in these mines (Wilkes, 1988).

Texaco USA, in search of conventional gas, completed six exploratory wells in the Taylorsville basin during 1986. They also completed one well in 1989 and two wells in 1992 in this basin. All nine of these wells were completed as dry holes. Completion reports filed with the Virginia Division of Gas and Oil do not describe the presence of coalbeds, although geophysical logs of several of the wells indicate the presence of coalbeds.

Series, Formation		Coalbed
Early Pennsylvanian	Norton	Jawbone
		Tiller
	Lee	Upper Seaboard
		Greasy Creek
		Middle Seaboard
		Upper Horsepen
		Middle Horsepen
		C
		War Creek
		Beckley
		Lower Horsepen
		Little Fire Creek
	Pocahontas	Pocahontas No. 9
Pocahontas No. 8		
Pocahontas No. 6		
	Pocahontas No. 5	
	Pocahontas No. 3	
Late Mississippian Bluestone Formation		

Figure 4. Formations and coal beds typically fractured for production of coalbed methane in the Southwest Virginia coalfield.

COALBED METHANE POTENTIAL IN VIRGINIA

Most methods used to determine methane content of coalbeds are dependent on sampling of the coal and measurement of gas given off. To estimate the probable methane content of coals like those in the Appalachian Plateaus area, theoretical models can be applied. A coal-resource estimate should be used as a guide to the relative abundance of coalbeds typically fractured for methane recovery, and not as an absolute quantity. The areas of the plateau capable of producing methane gas are limited to those coalbeds that are greater than 500 feet below the surface. Because a minimum depth of 500 feet is generally required for coal to contain any appreciable amount of gas in place. Within the Pocahontas, Lee, and Norton Formations, a 1500-foot thick interval, there are as many as 17 coalbeds (Figure 4). Seven coalbeds in the Pocahontas and Lee Formations are most commonly hydraulically fractured. The area used for the coal resources of the Appalachian Plateau is rounded to the nearest acre (Figure 3). The area contains about 797,248 acres. The average thickness for these coalbeds that underlie the area is 2.5 feet (280 thickness measurements). The area is multiplied by the aver-

age thickness of the coal beds to obtain acre-feet of coal. Acre-feet of coal is then multiplied by 2000 tons/acre-feet to get the estimated tonnage. The coal resources for these seven coalbeds is estimated at 3.98 billion short tons. The next step is to determine the probable range of gas contents for the coalbeds. Gas content in these coal beds is determined to range from 249 to 408 cubic feet/ton. Using these two figures, multiplied by the estimated tonnage, indicates that the total gas in place for the Appalachian Plateaus seven target coalbeds is between 0.9 and 1.6 trillion cubic feet of methane.

Kirr (1980) calculated a conservative estimate of 2 billion short tons of coal in the Richmond basin. Using his calculated gas contents of 175 to 465 cubic feet/ton yields an estimate of 0.3 to 0.9 trillion cubic feet of methane present in the basin.

Henderson (1983) provided a preliminary estimate of coal resources in the Valley coal field as 1.19 billion short tons. Gas content values for the coals in this coalfield, as determined in the Sunnyside and Merrimac test wells average 176 cubic feet/ton (Stanley and Schultz, 1983). These yields indicate that 0.2 trillion cubic feet of methane might be present in the Valley coalfields. The preliminary estimates of coalbed methane resources presented here indicate that at least 1.2 to 3.3 trillion cubic feet of methane might be present in the coalfields of the Commonwealth.

FUTURE EXPLORATION FOR COALBED GAS

Exploration targets for coalbed methane can be defined by (but are not limited to) the following criteria: 1) the presence of thick, abundant, and continuous coalbeds (source rocks); 2) coal-bearing areas containing coals of appropriate rank (determined directly from coal analyses or by inferences about probable subsurface coal rank); 3) adequate conditions for accumulation and preservation of coalbed methane (a favorable reservoir); 4) appropriate depth to the coalbed methane reservoir (depth places economic and mechanical limits on development); and 5) other factors that affect exploration, target identification such as degree and location of faulting and fracturing, the nature of the geothermal gradient, the presence of high pressure or overpressured areas in the subsurface, and the presence of conventional gas fields that derive their production from coal-bearing rocks.

The southwest Virginia coalfield contains numerous, thick, laterally continuous, relatively shallow (less than 2500 feet) Pennsylvanian-age coalbeds that are a large source of biogenic coalbed methane. In Virginia these major targets for coalbed methane are the Pocahontas, Lee, and Norton Formations. The development of coalbed methane as a resource in the southwest Virginia coalfield area will continue to grow at the present rate for the next few years. Exploration targets for coalbed methane in the Valley and Ridge province of Virginia are defined primarily by coalbeds in the Price Formation that are under less than 1000 feet of overburden.

Coalbed methane within the Triassic basins will remain a mystery until they are more extensively drilled. The estimate of at least 0.3 trillion cubic feet of gas within the Richmond basin constitutes a considerable potential energy resource

for the Richmond metropolitan area. The present database is insufficient to evaluate the resource potential of the Richmond basin. More information on the geology and methane characteristics of the coalbeds within the basin is needed for a better evaluation of the resource available.

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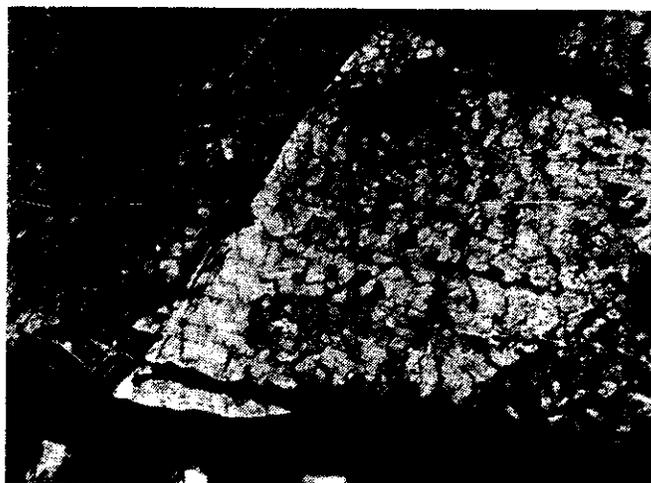
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INTERESTING GEOLOGIC FEATURES FROM VIRGINIA



Flute casts in the base of graywacke (sandstone) bed in the Martinsburg Formation, State Road 684, approximately 4.2 miles northeast of Bixler Bridge, Page County, Virginia.



Ripple marks in limestone bed with calcite filled joints; U.S. Highway 58 west of Gate City and east of Speers Ferry, Scott County, Virginia.

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NEW RELEASES

Publication:

Publication 136 Coal beds, coal zones, and key stratigraphic names in the Pennsylvanian of Southwestern Virginia
by Jack E. Nolde, chart with text, 1994. Price: \$6.50

Brochures:

Virginia Diamonds by Palmer C. Sweet, 1994. Free
Virginia Division of Mineral Resources, Products and Services, 1994. Free
Earthquakes by Stanley S. Johnson, Matthew S. Sibol, and Martin C. Chapman, 1994. Free