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The Pennsylvania Anthracite District – a Frontier Area for the Development of Coalbed Methane?[1]

By Robert C. Milici[2]

Abstract[3]

The anthracite region of eastern Pennsylvania consists of four major coal fields that are within the folded and faulted Appalachians, in the Valley and Ridge and Appalachian Plateaus physiographic provinces. These are, from south to north, the Southern Anthracite field, the Western Middle Anthracite field, the Eastern Middle Anthracite field, and the Northern Anthracite field. Rank of the coal ranges from semi-anthracite to anthracite. In general, the anthracite fields consist of Pennsylvanian strata that are complexly folded, faulted, and preserved in structural synclines within older Paleozoic strata.

Published gas-in-place (GIP) data for Pennsylvania anthracite range from 6.4 SCF/ton (0.2 cc/g) for the Orchard coal bed to a high of 691.2 SCF/ton (21.6 cc/g) from a sample of the Peach Mountain coal bed that was collected in the Southern Anthracite field at a depth of 685 feet. This is the largest GIP value that the U.S. Bureau of Mines (USBM) (Diamond et al, 1986) reported for coalbed methane (CBM) nationwide. Of the 11 CBM analyses reported for the Southern Field by USBM, seven exceed 396 SCF/ton (12.4 cc/g) (average of 11 samples: 325.8 SCF/ton [10.2 cc/g]). In addition, adsorption isotherms for the Mammoth, Seven-Foot, and Buck Mountain coal beds in the Southern Field indicate that these beds have a very high capacity to hold methane under pressure (Lyons et al, 2003), with values that range from about 320 to 850 SCF/ton (10 to 27 cc/g).

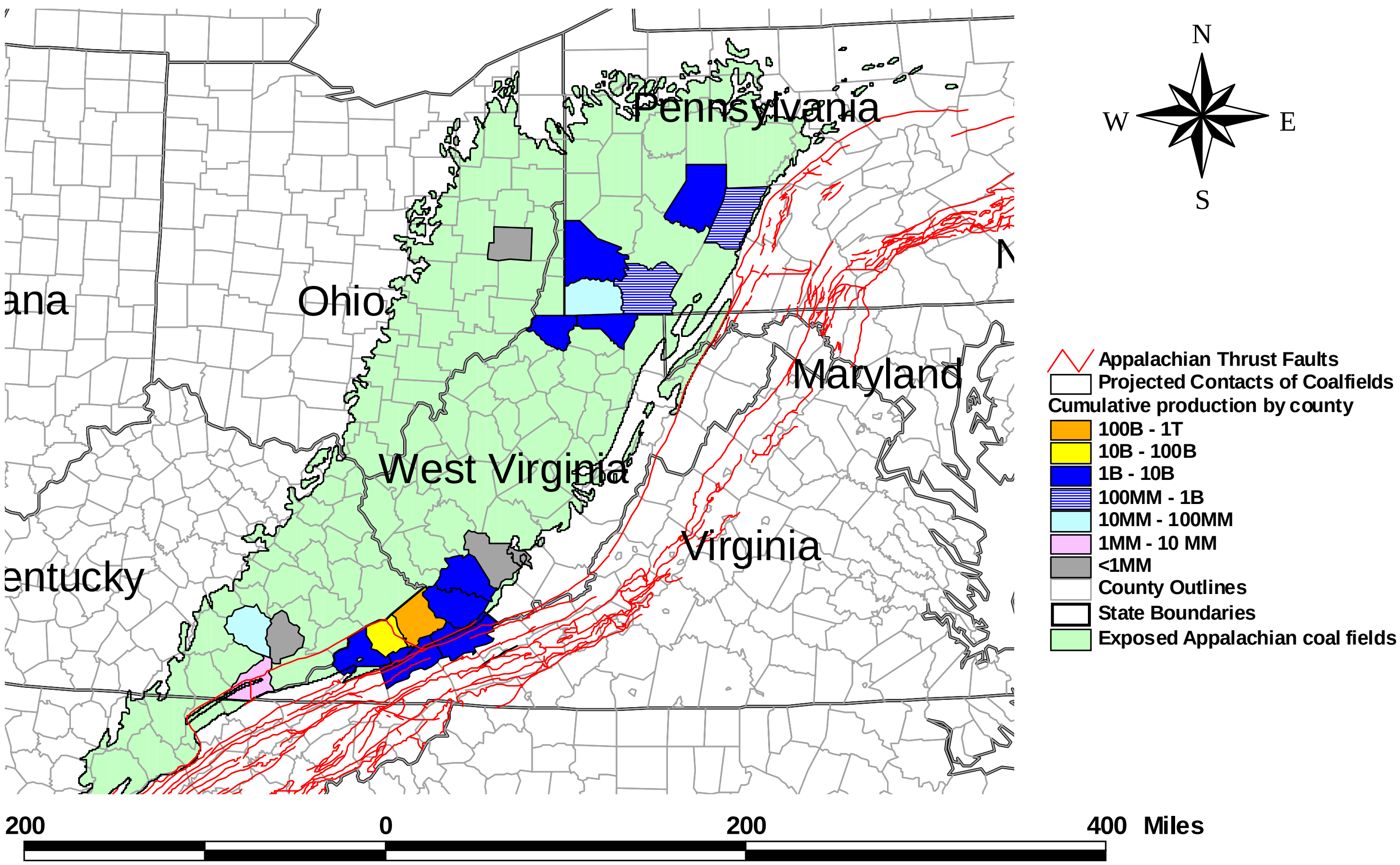
In spite of the complex geologic structures, there are several areas in the Southern Anthracite field where subhorizontal to moderately inclined coal beds may be accessed by the drill. For example, a detailed map and sections by Wood (1972) in Schuylkill County, Pennsylvania, has defined several areas of subhorizontal to gently inclined strata that contain 10 or more coal beds at depths of 500 to 2000 feet (150 to 600m), and with a cumulative coal thickness of 50 feet (15m), or more.

These data suggest that the Pennsylvania anthracite district is, at least, worthy of testing for CBM, using current desorption methodology and with coal samples collected from several coal beds in a single core hole.

[1] Presented at 2004 combined annual meeting of the NE/SE Section of the Geological Society of America
[2] U.S. Geological Survey, Reston, VA
[3] Reprinted from Milici (2004)

Appalachian Basin CBM Overview

Appalachian Basin CBM Production



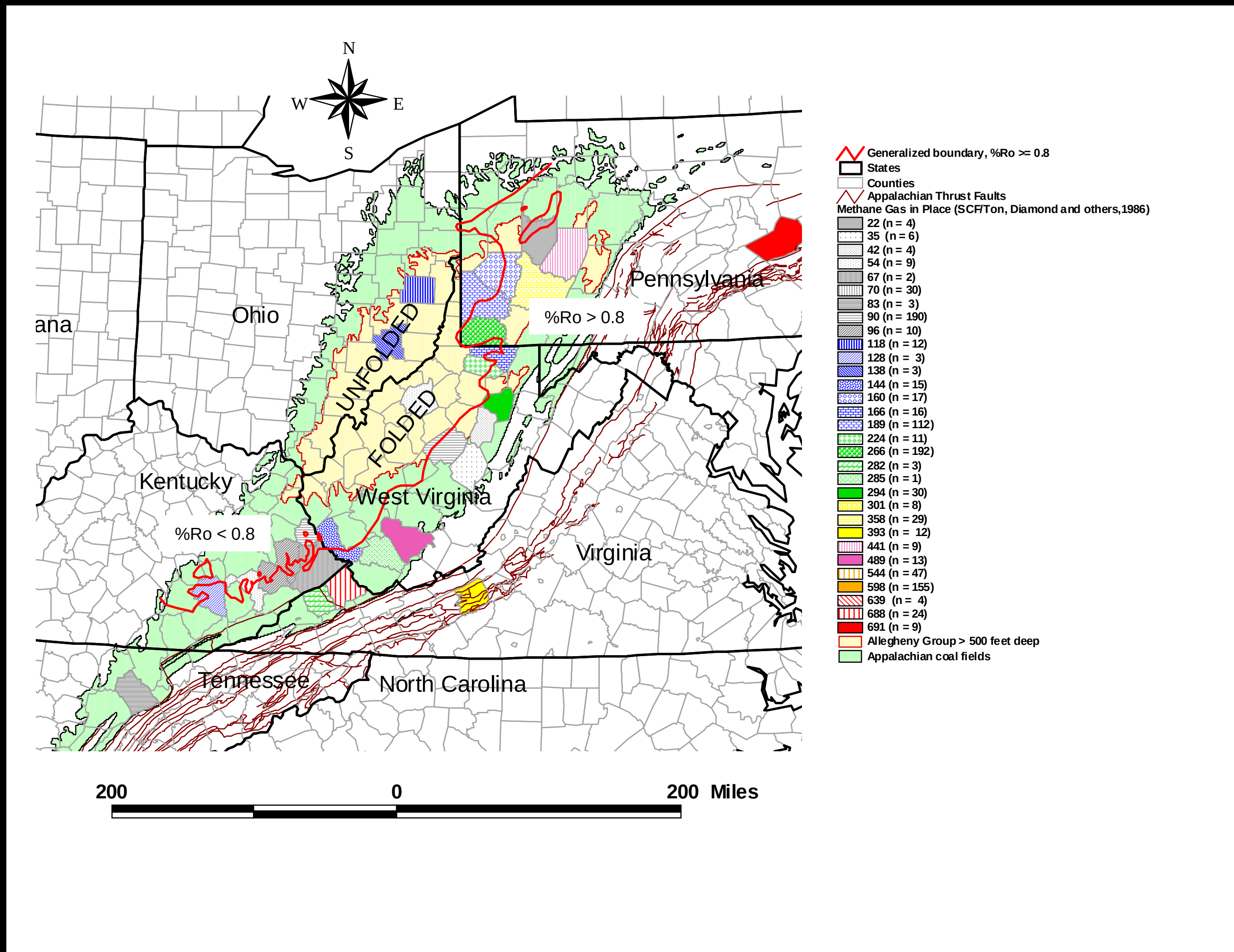
Cumulative coalbed methane (CBM) production by county in the northern and central Appalachian coal fields as of 2003. MM = million; B = billion; T = trillion. See next slide for data sources.

State	County	Date of first Production	Cumulative Production Date	No. Currently Producing Wells	CBM Cumulative Production (Mcf)
Alabama	Greene	1992	10/31/2003	0	99,565
	Hale	1990	10/31/2003	0	111,543
	Jefferson	1980	10/31/2003	655	184,658,319
	Pickens	1990	10/31/2003	0	1,873
	Shelby	1990	10/31/2003	0	3,969,067
	Tuscaloosa	1981	10/31/2003	3,096	1,310,241,313
	Walker	1989	10/31/2003	102	18,937,713
Alabama	Subtotal			3,853	1,518,019,393
Virginia	Buchanan	1992	2002	1,492	321,535,042
	Dickenson	1988	2002	474	71,810,618
	Russell	1990	2002	110	10,694,923
	Tazewell	1990	2002	93	5,620,269
	Wise	1990	2002	80	6,577,583
Virginia	Subtotal			2,249	416,238,435
West Virginia	Logan	2002	2002	1	157
	Marshall	ND	ND	ND	ND
	McDowell	1995	2002	40	3,571,128
	Monongalia	1992	2002	22	1,443,617
	Raleigh	1992	2002	2	62,811
	Wyoming	1994	2002	67	19,335,467
	*Wetzel	1931	2002	2	1,328,862
West Virginia	Subtotal			133	25,742,042
Pennsylvania	Cambria	1997	2002	Confidential	166,950
	Fayette	1999	2002	Confidential	199,718
	Greene	1988	2002	Confidential	774,910
	Indiana	1993	2002	Confidential	3,433,679
	Washington	1993	2002	Confidential	1,184,125
Pennsylvania	Subtotal			225	5,759,382
Kentucky	Bell	1998	2002	3	7,674
	Clay	1998	2002	5	56,478
	Leslie	2000	2002	1	
	Letcher	1997	2002	1	
Kentucky	Subtotal			10	64,152
Appalachian Basin Total				6,470	1,965,823,404
* Big Run and new unnamed fields, only					

Cumulative Production of CBM in the Appalachian Basin

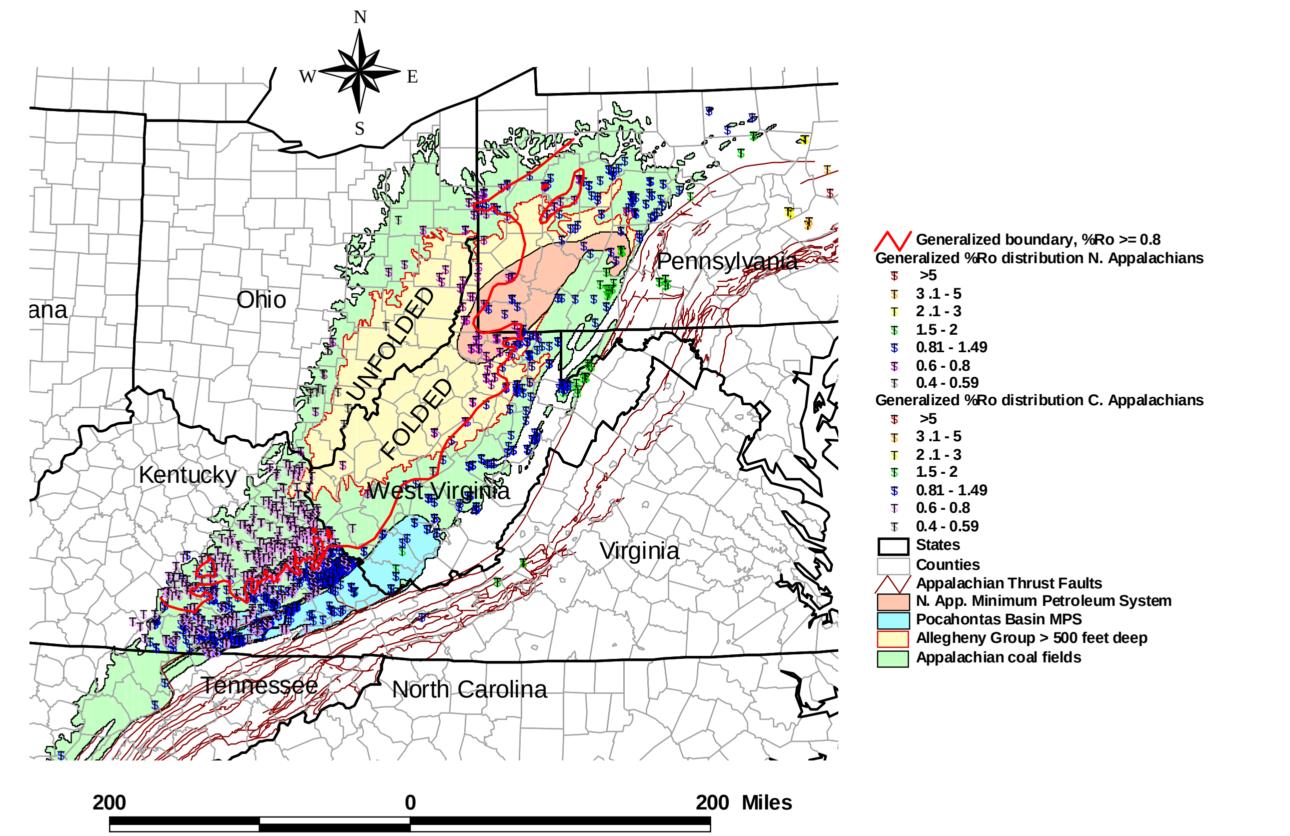
Cumulative production of CBM from the Appalachian Basin (1999-2003 data). Source of data: Alabama State Oil and Gas Board (2004); Kentucky Division of Gas and Oil (2004); Markowski (2004); Virginia Center for Coal and Energy Research (2004), and Avary (2004).

USBM Gas-in-place Values



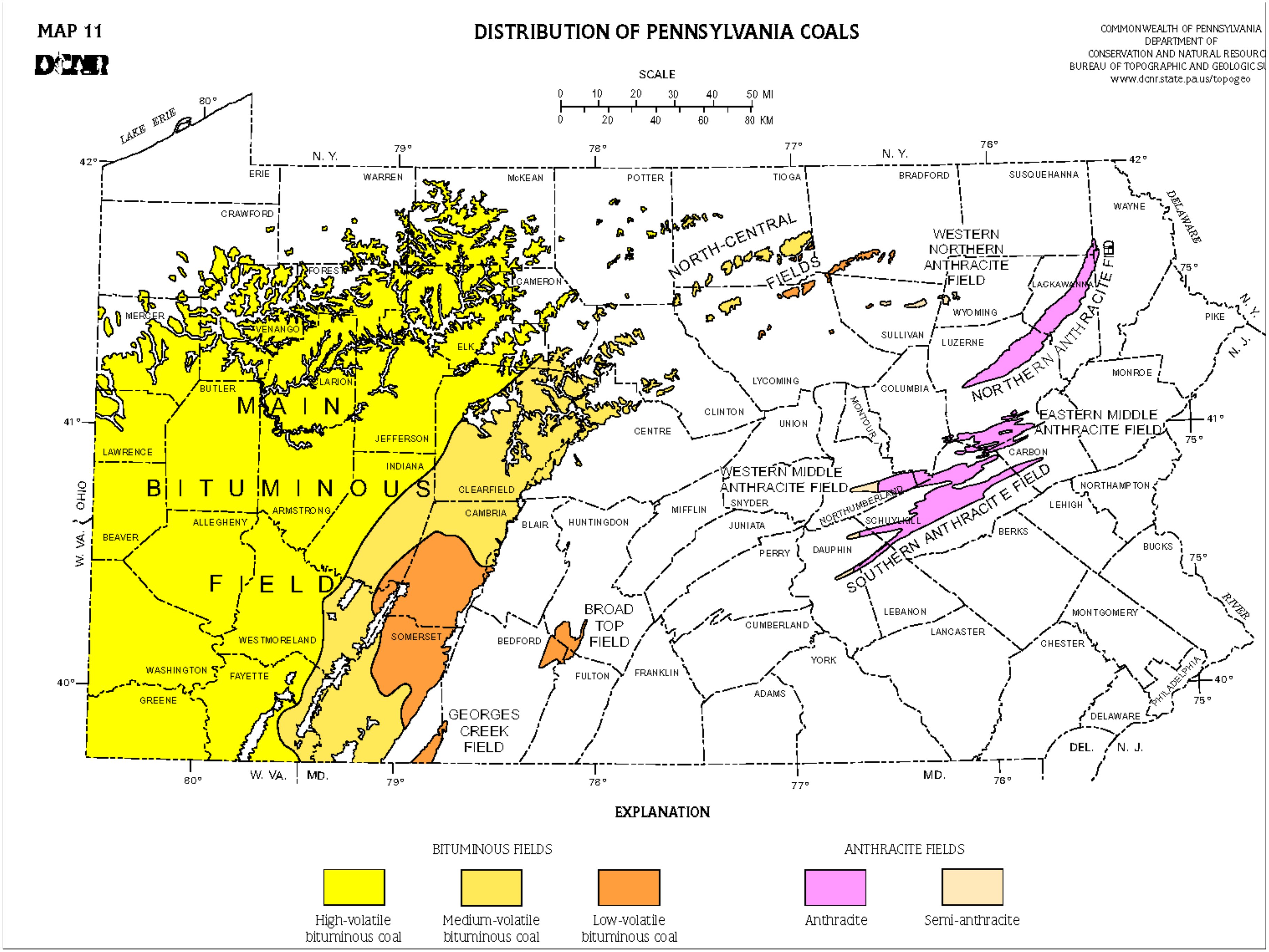
In-place gas values by county in cubic feet per ton (Diamond and others, 1986; in CF/TON). N = number of samples in the county; the values presented are the largest for each county represented. USBM = U.S. Bureau of Mines. Vitrinite reflectance line of 0.8 %Ro separates relatively immature region on the west from mature region on the east, similar to thermal maturation patterns in Alabama (Pashin and Hinkle, 1997).

Thermal Maturation Values (%Ro) in the Dunkard and Pocahontas Basins



Location and vitrinite reflectance values (%Ro) for coal samples studied courtesy of Leslie Ruppert, USGS. Illustration shows the minimum petroleum system boundaries for the Dunkard (Northern Appalachian) and Pocahontas basins, the folded and unfolded parts of the Dunkard basin, and a generalized boundary between thermally mature and immature coal beds. C. = Central, N. = Northern, App. = Appalachian, MPS = Minimum Petroleum System.

The Anthracite Region



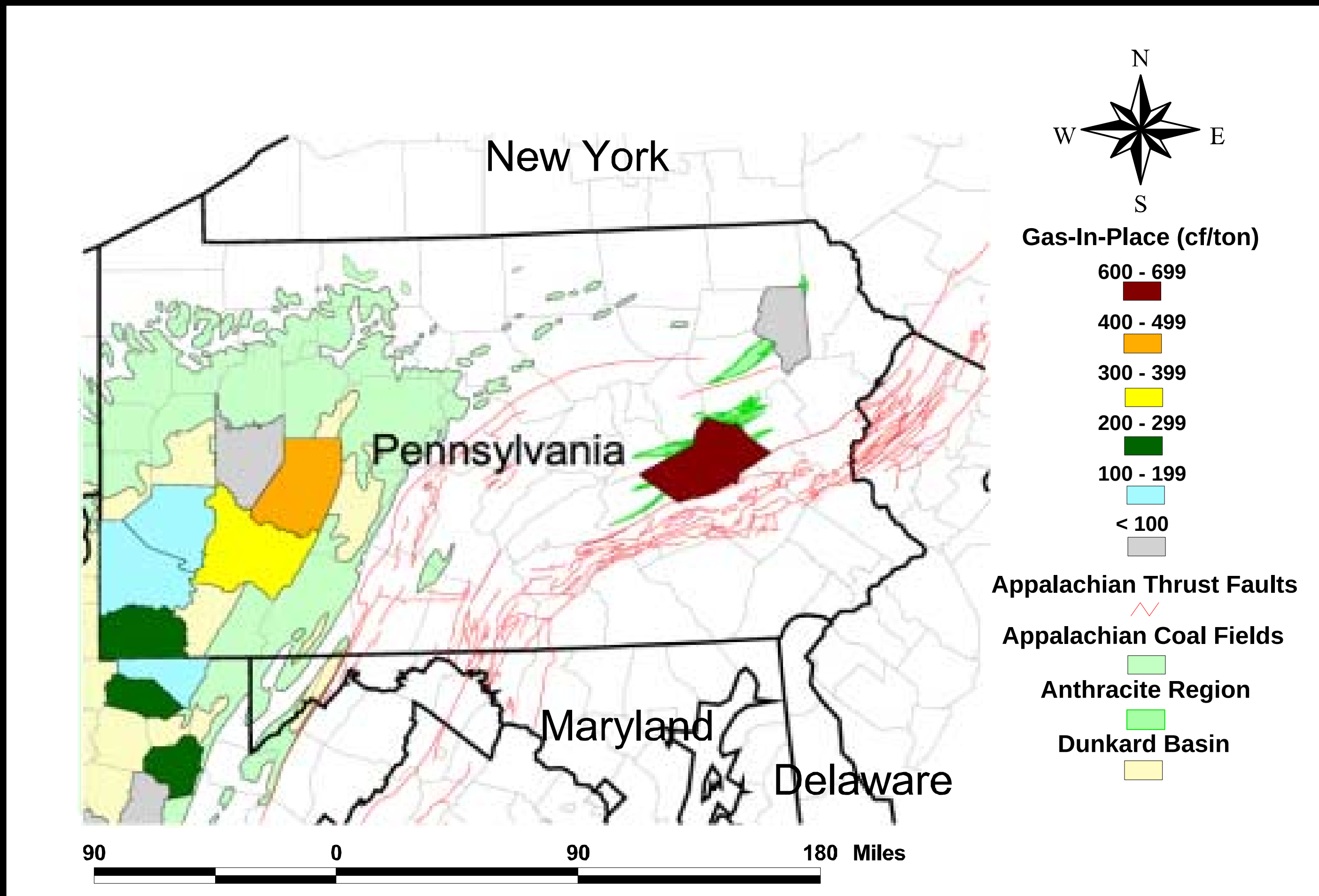
Map 11, Pennsylvania Bureau of Topographic and Geologic Survey, http://www.dcnr.state.pa.us/topogeo/maps/map11.pd.

Comparison of Pocahontas Basin and Anthracite Region

	Pocahontas Basin	Anthracite Region
Geologic Structure/ porosity/ permeability	Deep basin; bedding-parallel faulting in coal	Complex folding and faulting; conchoidal fracture in coal
Amount of Water	Generally low	Probably moderate to high
Gas-in-Place	688 cf/ton	691 cf/ton
Coal rank	Low-volatile bituminous to semianthracite	Bituminous to anthracite
Depth of overburden	About 2000 feet (max)	Maximum unknown, but > 1000 feet
Coal Quality	Low ash, low sulfur, high rank coal	Low ash, low sulfur, high rank coal

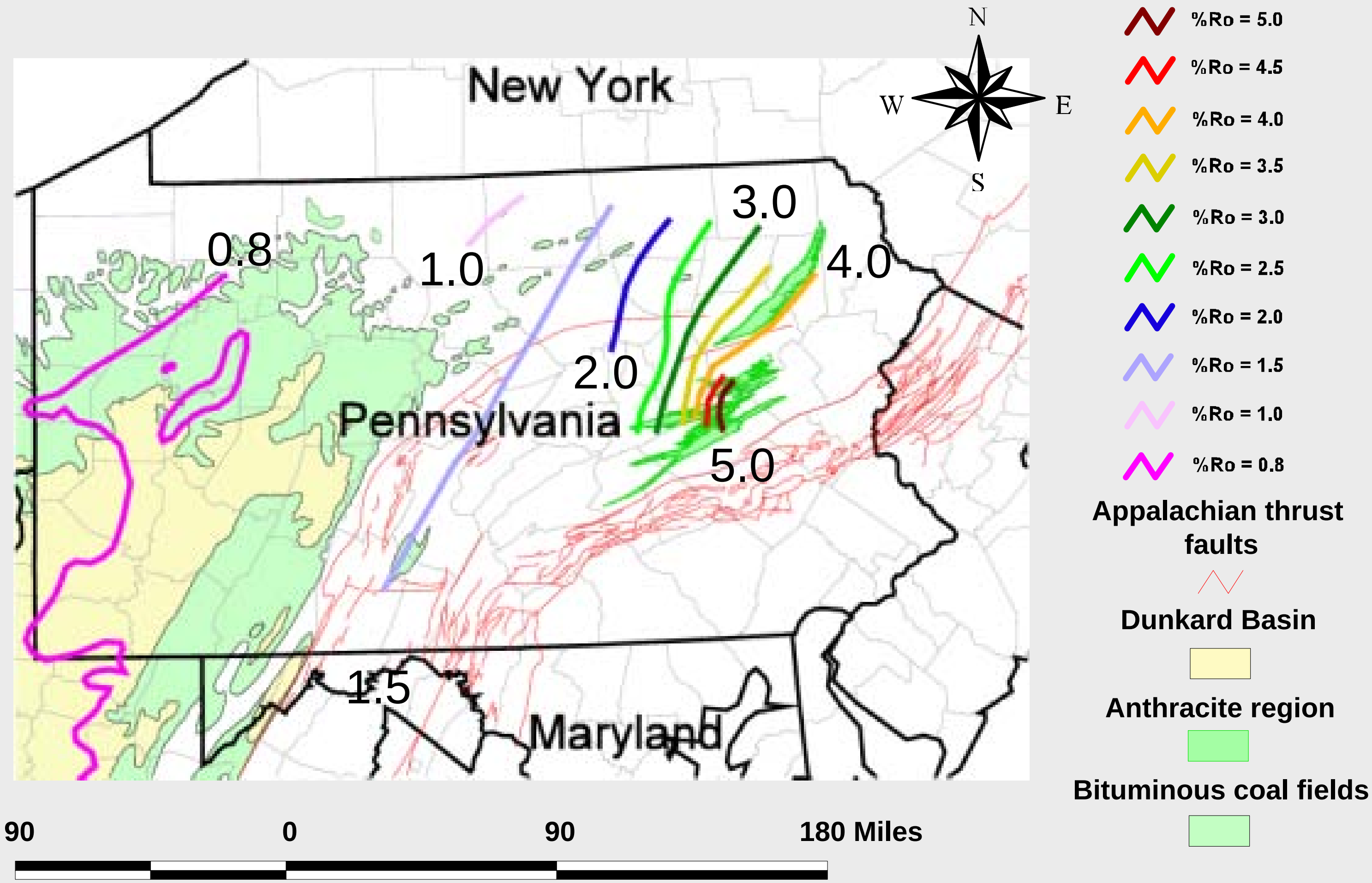
Although there is a great deal of difference, geologically, between the Pocahontas basin and the Pennsylvania anthracite district, the regions do exhibit some common characteristics. Gas-in-place data, the maximum for each basin (Diamond and others, 1986), in cubic feet per ton (cf/ton) were obtained from desorbing coal core samples under ambient conditions. Max = maximum.

Northern Appalachian Coal bed Gas-In-Place Data



Data from Diamond and others (1986). Gas-in-place data were measured under ambient conditions. See earlier slide for number of samples per county.

Thermal Maturation of Northern Appalachian Coal Fields in %Ro



The slide shows increase of thermal maturity from west to east across the northern part of the Appalachian coalfields. %Ro values range from about 2 on the western side of the anthracite region to 5, or more, in the Southern Anthracite Coalfield (data from Ruppert, written communication, 2002, and Hower and others, 1993).

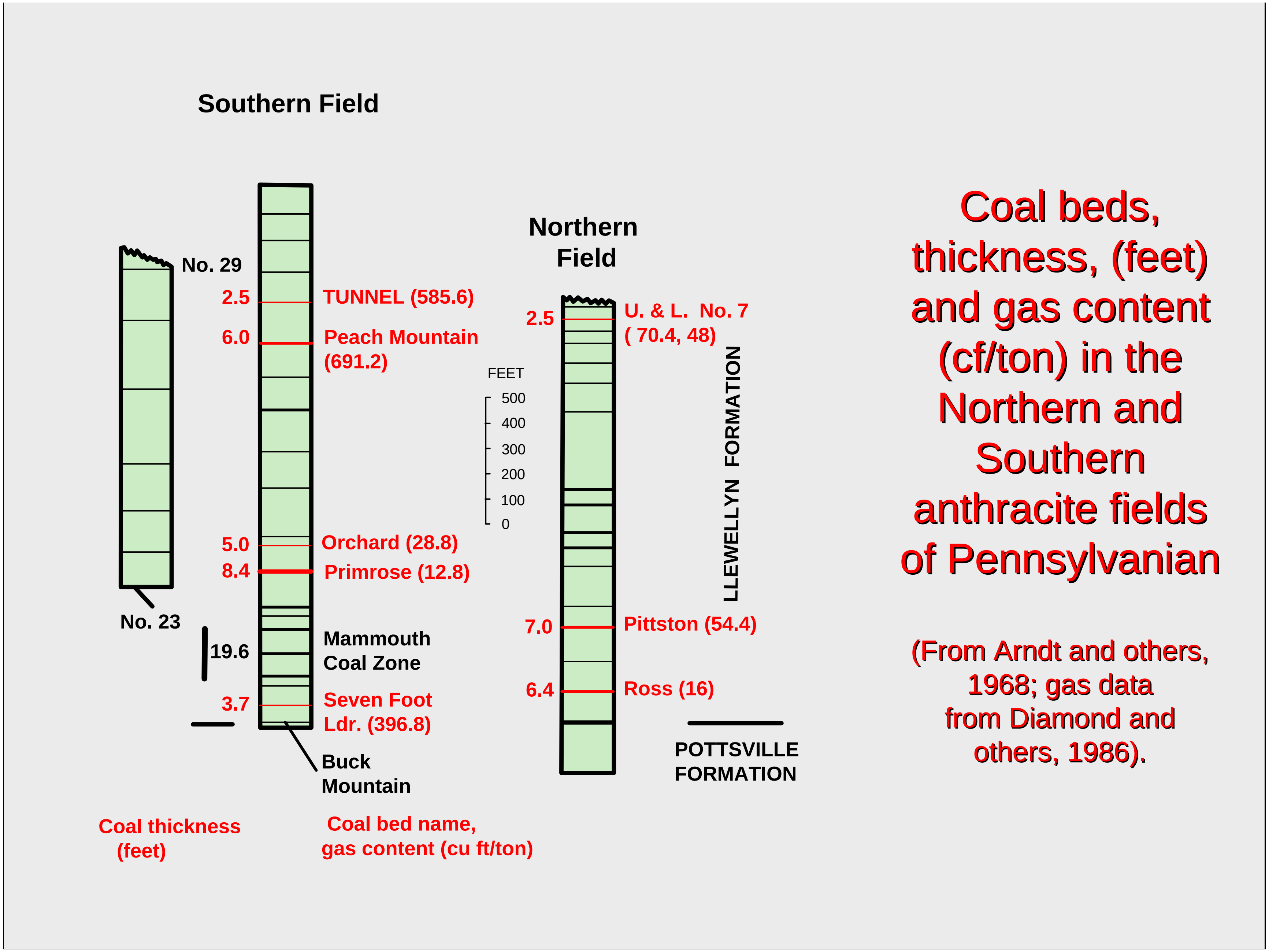
Northern Anthracite Field	Southern Anthracite Field
Total gas (cf/ton)	Total gas (cf/ton)
U. New County	Tunnel
70.4	585.6
54.4	482
L. New County	448
48	403.2
41.6	Peach Mountain
32	691.2
28.8	640
25.6	601.6
16	Orchard
Big Bed (Pittston)	28.8
64	6.4
54.4	
44.8	Primrose
32	12.8
28.8 (2)	
Clark (Ross)	Seven Foot Leader
16 (2)	396.8 (2)
12.8	
9.6 (2)	

Gas-in-place data for the Northern and Southern Anthracite fields

(Diamond and others, 1986; Trevits and others, 1988)

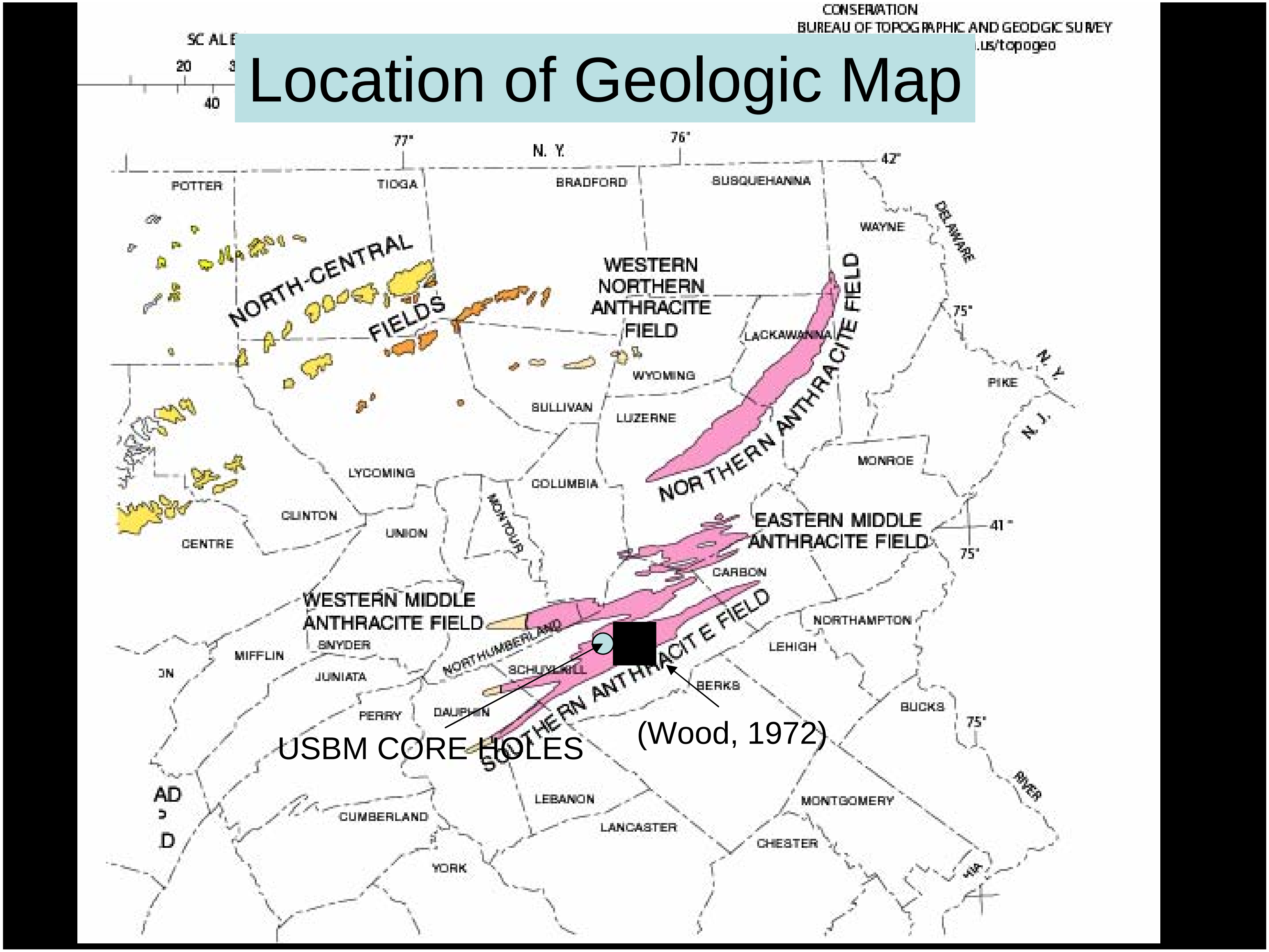
cf = cubic feet; L. = Lower; U. = Upper.

CBM desorption values, in ambient cubic feet per ton, obtained by the U.S. Bureau of Mines for the Northern and Southern Anthracite fields in Pennsylvania (Diamond and others, 1986).

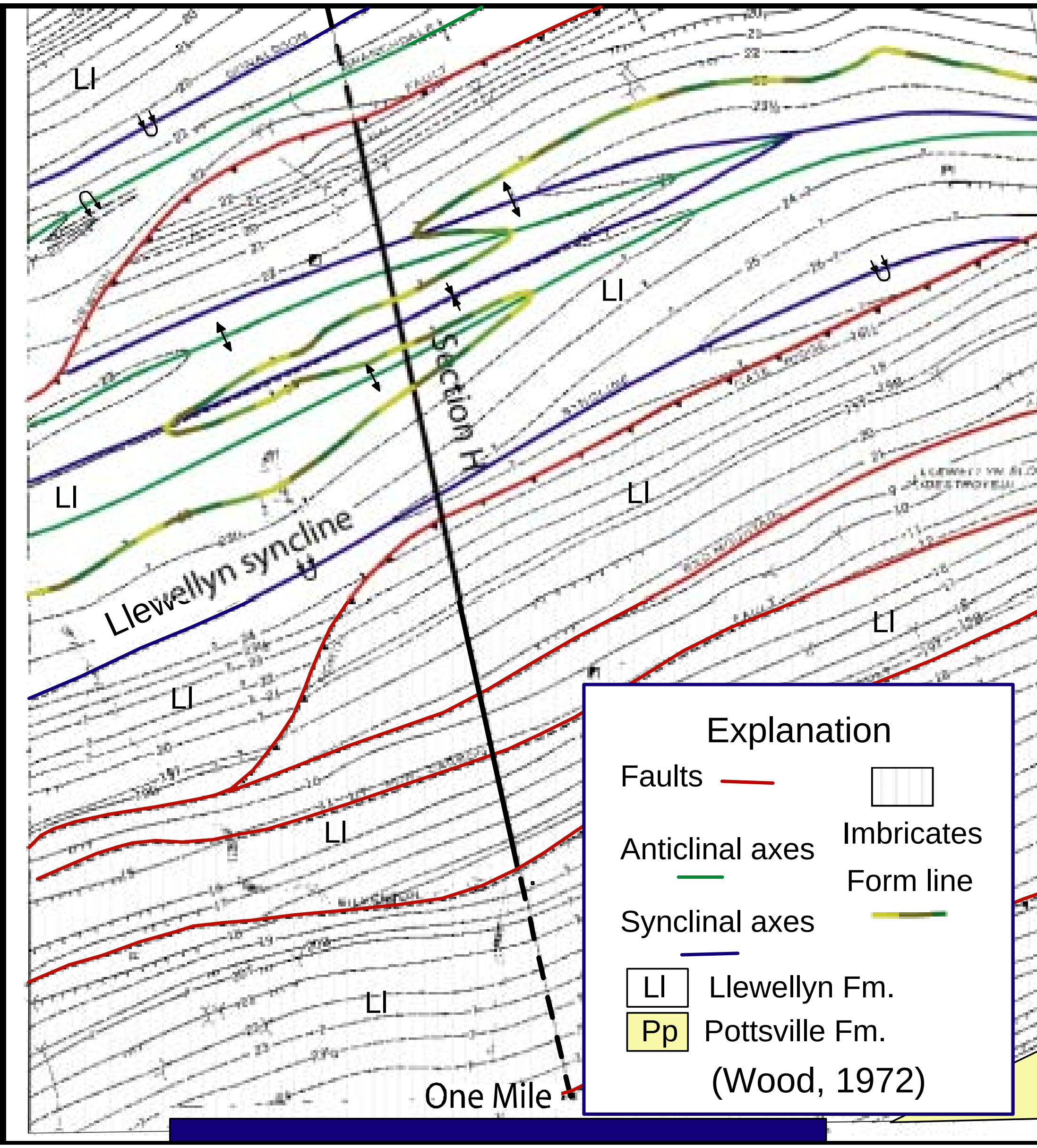


Generalized stratigraphic column for the Northern and Southern Anthracite fields (adapted from Arndt and others, 1968; gas data from Diamond and others, 1986). Coal bed names are shown generally on right of column, together with maximum tested values for gas content; names or numbers in red are for coal beds for which there is gas-in-place data. Numbers on the left side of columns show the average thicknesses of the coal beds.

Location of Geologic Map

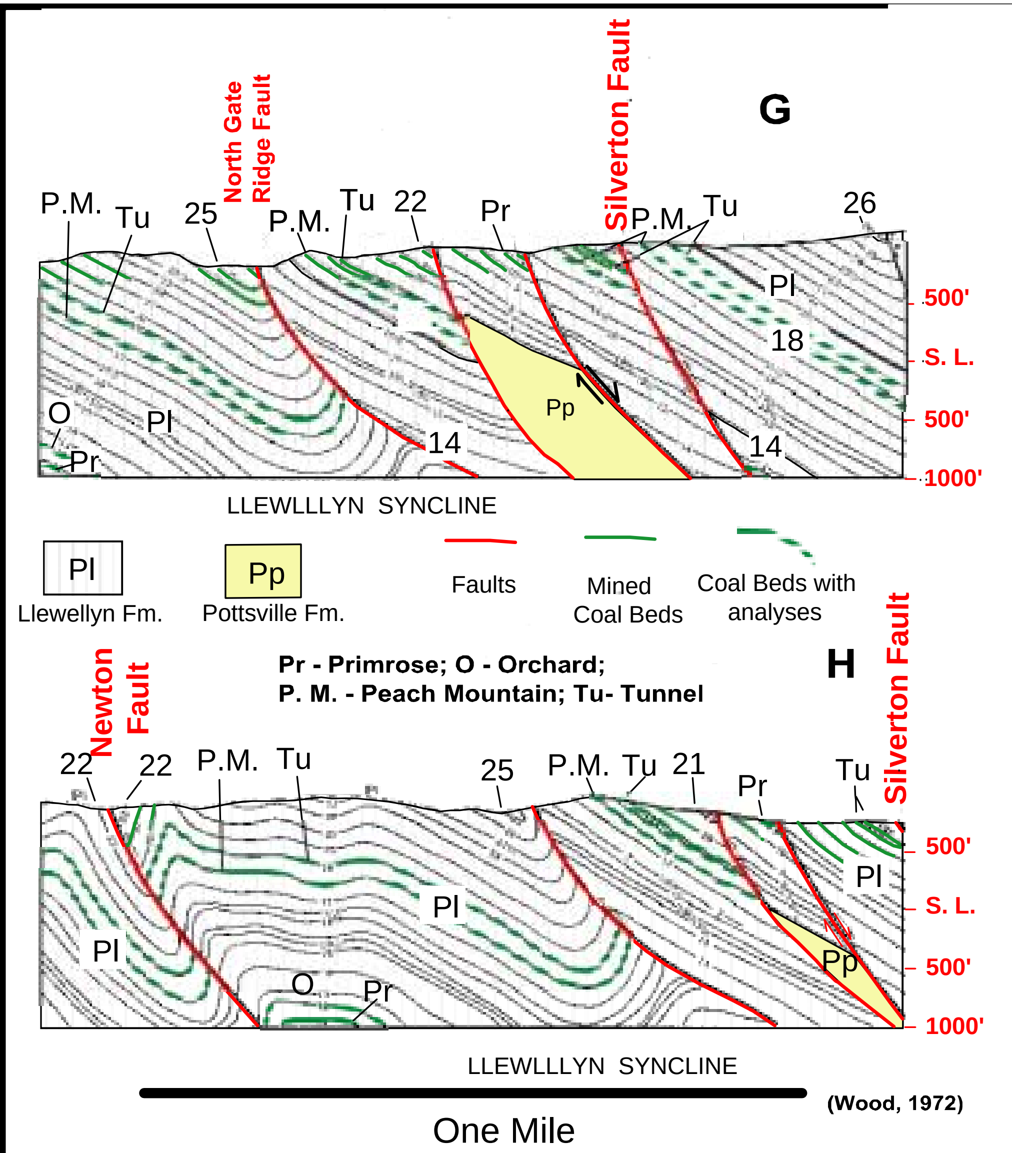


Part of Pennsylvania Topographic and Geologic Survey Map 11, showing the general location of the Schuylkill quadrangle (Wood, 1972) and two closely spaced USBM core holes (Trevits, and others, 1988). See earlier slide for explanation of colors.



South-west Corner of the Pottsville Quad-rangle, PA (Wood, 1972)

In this illustration, the faults are shown in red and the coal beds in black, except for Coal bed 23, which is colored blue and yellow. Synclinal axes are shown in blue and anticlinal axes in green. The location of the cross section partly illustrated in the following slide (Wood's Section H) is shown by the straight blue line. The part of the section shown is indicated by the solid line. Note that the mapped area may be divided into an imbricate thrust-faulted zone, with strata that are moderately inclined to the southwest, and the Llewellyn syncline, which contains beds that are tightly folded. The scale of Wood's (1972) published map is 1:12,000.



Parts of G and H Cross Sections, Schuylkill Co., PA (Wood, 1972)

Note that the Pottsville Formation (Pp) is shown in yellow, and the Llewellyn Formation (Pl) with vertical ruled lines. The Primrose (Pr), Orchard (O), Peach Mountain (PM), and Tunnel (TU) coal beds are high-lighted in dashed green. Solid green-colored coal beds along the surface of the section have been mined. Section G is one mile northeast of section H.

USBM Boreholes

- Two holes drilled in Minersville Quadrangle in 1975 (Trevits and others, 1988)
  - 1. Drilled to 1,948 feet, stuck, flooded; 6 coal beds perforated, stimulated; Peach Mountain had 640 cu ft/ton, low porosity and permeability; little gas.
  - 2. Drilled to 2,355 feet; 8 coal beds perforated and stimulated; Tunnel coal 482 cu ft/ton, low porosity and permeability; little gas.

USBM Section, Southern field

(Trevits and others, 1988)

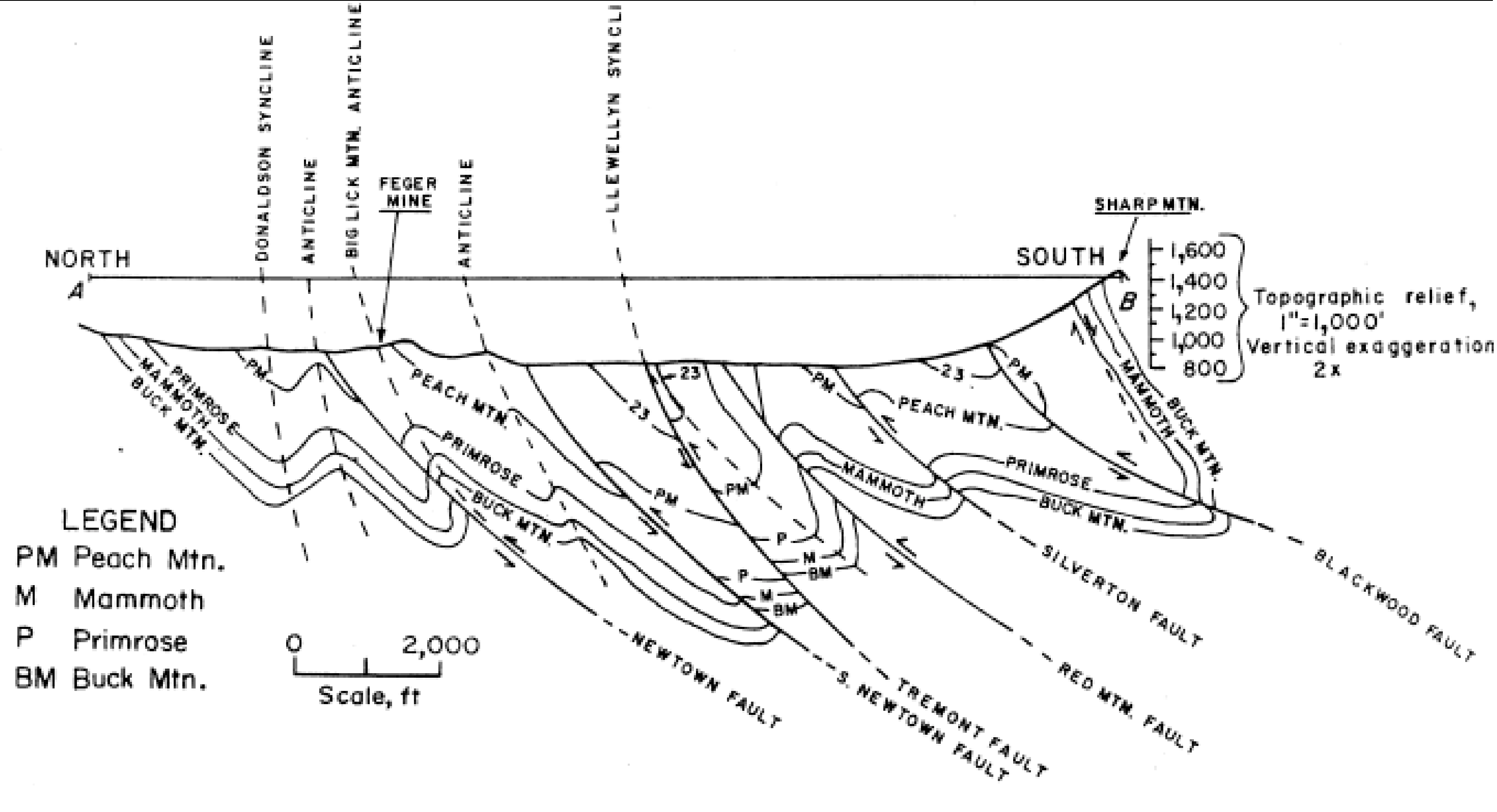


Figure 9-17.—Generalized cross section of coalbeds in anthracite region.

Cross section from Trevits and others, 1988, Figure 9-17.

Is there gas?

Explosions of fire-damp (CH_4)
in Anthracite coal mines 1870 to 1880

YEAR	NUMBER
1879	100
1878	29
1877	71
1876	65
1875	59
1874	77
1873	74
1872	81
1871	83
1870	40
Total	**679**

Casualties 1127; deaths 225

Data from Chance (1883).

Potential Problems for CBM Development

- Complex geologic structure; subsurface geology may not be as shown in cross –sections.
- Many surface and deep mines.
- Adequate seals, gas leakage?
- USBM Well, Minersville quadrangle, low porosity and permeability?
- Development of drilling units in areas of complex structure.
- Water disposal amounts and quality unknown.

Potential problems for CBM development.

Favorable factors for CBM Development

- Detailed Geologic studies.
- Many thick coal beds – great cumulative coal thickness, perhaps up to 100 feet locally.
- High GIP values.
- Good fractures, porosity, permeability?
- Thermally mature or post mature.
- Close to local markets.

Favorable factors for CBM development. GIP = Gas-in-Place.

Questions

- Does the coal have sufficient microporosity and permeability to store and release gas at economically sufficient rates to warrant development?
- Can we dewater the coal beds sufficiently to improve permeability and release methane to the well bore?

A major question for CBM development.

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