UGR 237

Proposal: 97141.003
RFP No.: DE-AC21 -78MC08089

ILLINOIS BASIN REPORT

Pennsylvania Geology and
Coal and Coalbed Methane
Resources of the Illinois Basin,
Illinois, Indiana, and Kentucky

DRAFT

by

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ACKNOWLEDGMENTS

TRW gratefully acknowledges the assistance of those organizations and persons who provided information, data, and advice during the preparation of this report. Among these, special thanks are due to John Popp (Illinois State Geological Survey), Donald Carr (Indiana State Geological Survey), Russell Brant (Kentucky Geological Survey), and Pat Diamond (U.S. Bureau of Mines) for their invaluable support.

In addition, the cooperation of the Illinois State Geological Survey, American Association of Petroleum Geologists, McGraw-Hill Publications, and W. R. Freeman and Company of San Francisco in permitting the reproduction of various figures and tables contained in the text is greatly appreciated.

1. SUMMARY

This geologic basin report provides a data base for determining the coal-bed methane resource and directing Methane Recovery from Coalbeds Project (MRCP) resource delineation efforts in the Illinois basin. An initial target area of approximately 9,100 square miles had been previously selected by the MRCP as having the highest probability of early commercialization. The information gathered in conjunction with this report and initial field testing provide the basis for redefining that area and for recommending project coring and testing efforts in the newly defined target areas.

The Illinois basin encompasses an area of approximately 53,000 square miles in east-central United States, covering a large portion of Illinois and extending into southwestern Indiana and western Kentucky. The central and northern parts of this region are characterized by low relief and gentle rolling topography. The southern portion of the basin is a dissected plateau. Because of its central location, and proximity to highly industrialized and populous areas such as Chicago, Indianapolis, and St. Louis, the Illinois basin is an attractive potential gas resource area.

The Illinois basin itself is a broad, spoon-shaped structural depression trending NNW to SSE. Except for large-scale faulting and folding in the southern and south-eastern portions, the basin is only gently disturbed. Deepest portions of the basin occur in a broad area centered around Wayne County, Illinois and in Union, Webster, and Hopkins Counties of Kentucky.

The Illinois basin contains extensive bituminous coal reserves in Pennsylvanian age rocks. The U.S. Geological Survey has estimated that the total coal resource of the Illinois basin might be 365 billion tons. More than 75 individual coal seams have been identified in this area, 20 of which are mined. The majority of the coals are not continuous and do not maintain constant thicknesses. Individual seams range from a few inches to 15 feet in thickness over large areas. The coals outcrop at the basin's periphery and dip gently towards its deeper portions in southeastern Illinois and western Kentucky. Lower and upper Pennsylvanian coals are thin and discontinous while the middle Pennsylvanian coals are thick, generally continuous, and provide the major reserves of the basin. Thin lower and upper Pennsylvanian coals have not been studied in as much detail and are not as well correlated as the thicker coalbeds of the middle Pennsylvanian. The greatest cumulative thickness of coal seams presumably occurs in the southeastern portion of the basin (near the tri-state boundary) where the thickest Pennsylvanian section occurs. All Illinois basin coal seams are covered by less than 3,000 feet of overburden, and the major coals are within 1,500 feet of the surface.

The Springfield-Harrisburg (No. 5) coals in Illinois and their correlatives, Springfield V in Indiana and No. 9 coals in Kentucky are the most extensive and uniformly thick coals in the Illinois basin; estimated coal reserves are over 67 billion short tons. The Herrin (No. 6) coal is also thick and extensive in Illinois and contains estimated coal reserves of over 77 billion short tons. Some deeper coals, the Colchester (No. 2) which is uniformly present over the entire basin, and the Davis (No. 6) and Mannington (No. 4) occurring primarily in Kentucky, contain combined reserves estimated at over 39 billion short tons.

Illinois basin coals have been mined by both underground and surface methods. The majority of the mining activities are near the perimeter of the basin where the coal is exposed or shallow, as in the southeastern portion of the basin, where vertical structural displacements have locally brought the coal to the surface.

The potential methane resource from selected coalbeds in the Illinois basin can be estimated from desorption data generated by the U.S. Bureau of Mines (USBM), the Illinois and Indiana State Surveys, and field tests performed under the MRCP. The Herrin (No. 6) and the Springfield-Harrisburg (No. 5) coals and their correlatives in Indiana have been sampled the most often. The estimated gas content of the Herrin (No. 6) ranges from 32 to 109 cubic feet per ton. A similar range of values, 32 to 147, has been calculated for the Springfield-Harrisburg (No. 5) coals. This variability cannot be directly related to sample depth, since some of the gassier coals were from relatively shallow horizons--the opposite of what might have been expected--, but is related to other geologic controls on the gas content, to analytical errors, or to the method used to determine the "remaining" gas.

MRCP data on the methane gas content of Illinois basin coals is presently limited to coring and well testing in Clay and Marion Counties of Illinois. In Clay County, the Danville (no. 7), Herrin (No. 6), Briar Hill (No. 5a), Harrisburg (No. 5) and Seelyville coals were cored between depths of 994 and 1,352 feet and samples were desorbed for approximately five months using the

USBM's direct method. Total gas contents ranged between 1.0 and 1.5 cc/g. In Marion County, the same coal seams, excluding the Seelyville, were cored and sampled at depths between 664 and 736 feet. Desorption tests are in progress.

Methane liberated from mines during operation also provides an indication of the potential methane resource in an area. The correlation between the amount of gas emitted from coal mines and that predicted to be there by desorption testing is not obvious, although experience in the Illinois basin has shown that typically 4 to 7 times more gas is liberated during mining than was predicted.

Investigations of data have shown that the gas content of the coals in the Illinois basin is generally low, ranging from less than 40 to 150 cubic feet per ton. Based on the limited data available, ranges for the maximum and minimum expected in-place gas resource have been made for the Danville, Herrin, Springfield-Harrisburg, and their equivalent coals. The Danville coals are anticipated to have a minimum of approximately 500 billion and maximum of nearly 1.7 trillion cubic feet of in-place gas. The Herrin, likewise, is estimated to contain 2.5 and 3.4 trillion cubic feet of gas. The Springfield-Harrisburg, 2.2 and 9.9 trillion cubic feet of gas. The minimum in-place gas resource for these three seams totals over 5 trillion cubic feet. It is reasonable to assume that the methane contained in major deeper coals (Colchester, Davis, etc.) may add significantly to this figure. It should be noted that although the specific gas content of coals in the Illinois basin is quite low, the simple magnitude of the coal resource produces large in-place gas resource estimates.

The gas content of coals in the Illinois basin is generally higher towards the southeastern portion of the basin and initial target area defined by the MRCP. On the basin of information gathered in this report, two target areas (totalling approximately 4,300 square miles) holding the greatest probability for early commercial gas production were recommended for additional testing. Target Area A, located in western Kentucky, contains a thick section of deep coals in a highly disturbed structural belt. Target Area B, in southeastern Illinois and southwestern Indian contains previously reported gassy coals, and thick coal sections at considerable depths.

It is recommended that a minimum of three Type I wells be planned in these target areas. Once these two target areas have been adequately tested an evaluation of the resource data should be made to determine the requirement for, or value of, additional testing in the Illinois basin. If sufficient gas is found, and pressures, porosities, and permeabilities suggest that production of methane gas from coalbeds in these areas is viable, then Type III wells should be planned for the purpose of gathering specific reservoir and production data from the coalbeds.

2. INTRODUCTION

This report examines the Illinois basin, or Eastern Interior Coal basin, in light of its potential coalbed methane resource. Various sections of this report present the basin's general geographic, cultural, and geologic setting, and give an overview of the basin's coal resource and methane potential. Prior to the writing of this report, a primary target area of approximately 9,100 square miles were selected out of the 53,000 square miles of the Illinois basin as having the highest probability of early commercialization. The information gathered in conjunction with this report provides the basis for redefining that area and for recommending project coring and testing efforts in the newly defined target areas.

The Illinois basin's geographic/physiographic, cultural, and geologic setting is presented in Sections 3.1 through 3.3. The section on the basin's geologic setting, Section 3-3, includes discussions of the regional geology, basin stratigraphy, and basin hydrology. Appropriate maps are included with these discussions.

The coal resources of the Illinois basin are reviewed in Section 4. The section begins with a generalized summary of the coal type, extent, stratigraphy, and chemical characteristics. Subsections discuss individual coal seams in more detail and provide correlations across state boundaries.

Section 5 deals with the potential methane resource of the basin and provides tables and figures summarizing pertinent data. This section includes a discussion of data from Methane Recovery from Coalbed Project wells in Clay and Marion Counties of Illinois. Conclusions and recommendations, made in Section 6, include a redefinition of the areas with highest probability of early cormiercialization, a suggested testing program, and an estimation of coalbed gas resource volume.

Cited references are presented in Section 7. Supporting maps, map indexes, and publication lists are provided in the appendices.

3. BASIN SETTING

3.1 GEOGRAPHY/PHYSIOGRAPHY

Situated in the east-central United States, the Illinois basin (Figure 3-1) covers a major portion of Illinois, and extends into south-western Indiana and western Kentucky. For the purposes of this report, the Illinois basin's area1 extent, as defined by the cross-hatched region in Figure 3-1, is that area underlain by Pennsylvanian age rocks. This encompasses an area of approximately 53,000 square miles.

Physiographically, a major portion of the Illinois basin lies in the Central Lowland province (Figure 3-2) and is characterized by low relief, gently rolling topography. Much of this lowland is a glacial till plain that is presently covered by loess, lacustrine, and alluvial deposits. Southernmost Illinois, south-central Indiana, and the Kentucky portion of the basin lie within the Interior Low Plateaus province (Figure 3-2). The plateaus province, contrasting with the lowland province, is typified by rolling uplands with moderate relief (400 to 500 feet above sea level) and is dissected by numerous entrenched meandering streams. Total relief in the Illinois basin is never over 1,000 feet and, except for the southern part of the basin, seldom over 200 feet. The entire basin area is drained by the Mississippi River and its major tributaries, the Ohio, Wabash, and Illinois Rivers.

The complete basin area has been topographically mapped in 15-minute quadrangle units, and much of it in 7.5-minute quadrangle units. Four 6^{o} topographic maps covering the Illinois Basin and indexes to other topographic and geologic maps of the area are included in Appendix A.

3.2 CULTURAL FEATURES

The Illinois basin is an attractive potential gas resource area owing to its central location and proximity to highly industrialized and populous areas. The region has rich agricultural lands, great mineral wealth, and thriving manufacturing and transportation industries. Access to the potential methane resource and delivery of gas within or from the basin to markets is facilitated by the maze of highways, railroads, and pipelines which crosscut the region. Transportation systems and population centers such as Chicago, St. Louis and Indianapolis can be seen on the topographic maps in Appendix A.

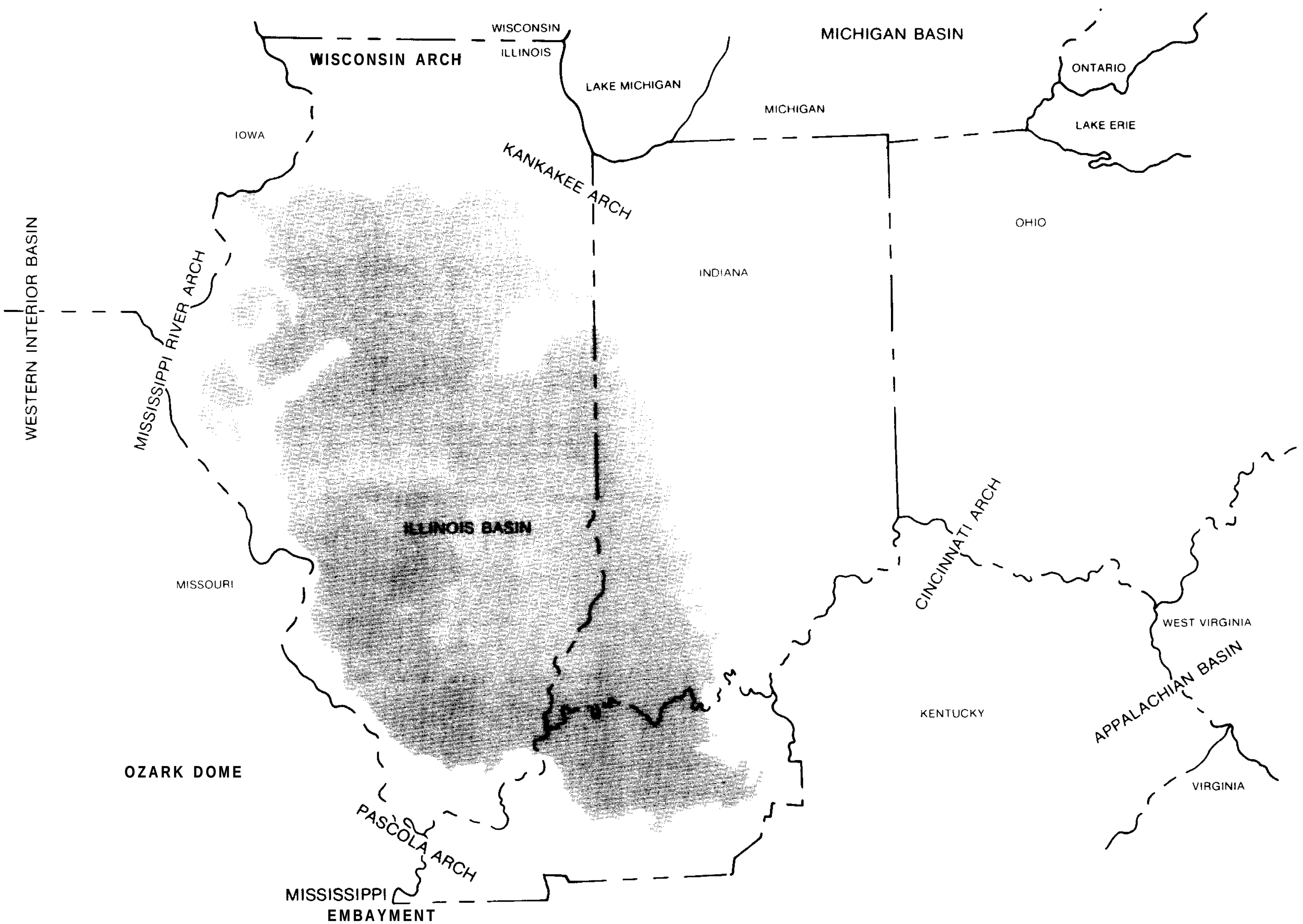


Figure 3-1 Regional setting of the Illinois basin

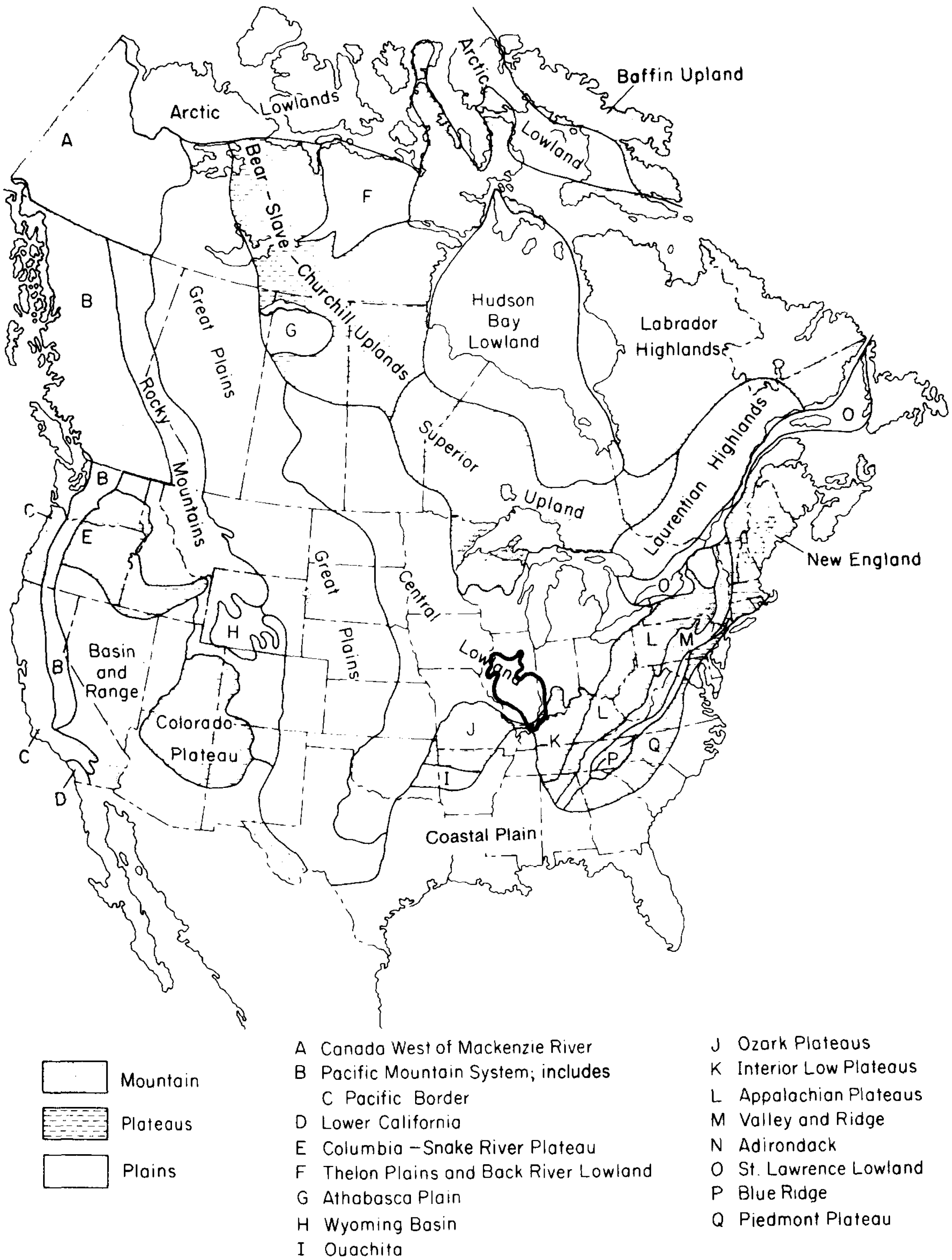


Figure 3-2 Physiographic regions of the United States and Canada and their dominant landforms (from Natural *Regions* of the *United* States *and Canada,* by C. B. Hunt, W. H. Freeman and Company, Copyright 1974 (courtesy of publisher, June 1979)

3.3 GEOLOGY

3.3.1 Basin Structure

As part of a central stable platform bordering the Canadian Shield, this region has seen little structural deformation since Precambrian time other than regional warping and differential sinking (Swann, 1968; Atherton, 1971). The Illinois basin itself is a broad, NNW-SSE trending, spoon-shaped synclinal feature, surrounded on all sides by positive structural arches and domes. The position of regional structural features relative to the basin is shown in Figure 3-l. Adjacent coal-bearing basins having similar characteristics and age, the Appalachian, Michigan, Forest City (Western Interior), and the Black Warrior basins, are isolated from the Illinois basin by the Cincinnati, Kankakee, Mississippi River and Pascola arches respectively. Other prominent surrounding features include the Wisconsin arch to the north, the Ozark dome to the southwest, and the Mississippi embayment area to the south.

The major structural features within the Illinois basin (Figure 3-3) are expressions of relief caused by high-angle faulting. These include: the La Salle anticlinal belt, a series of anticlines and westward dipping monoclines; the Du Quoin monocline, dipping east; and the Cottage Grove and Shawneetown-Rough Creek Fault systems trending east-west. Each of these uplift areas rises from a deep central interior basin, the Fairfield basin. South of the Shawneetown-Rough Creek fault zone is the Moorman syncline, structurally the deepest portion of the Illinois basin with Precambrian rocks at about 15,000 feet (Willman et al, 1975). It is also in this region that the thickest Pennsylvanian section is found.

Although numerous folds, faults, and domes occur throughout the basin (Bushbach and Ryan, 1963; Bushbach and Heim, 1972; Willman et al, 1975), only those faults mentioned above have significant displacement or lateral extent. The Shawneetown-Rough Creek fault zone is composed of a complex pattern of high angle basement faults with more than 3,000 feet of vertical displacement in some areas (Davis, 1973). Major faults are sub-parallel in a east-west directionand frequently intersected by smaller cross faults. In a few places, limestone of late Mississippian age is brought to the surface and is in contact with late Pennsylvanian age rock. In areas where this intense faulting occurs (in the southeastern part of the Illinois basin) there are abrupt changes in

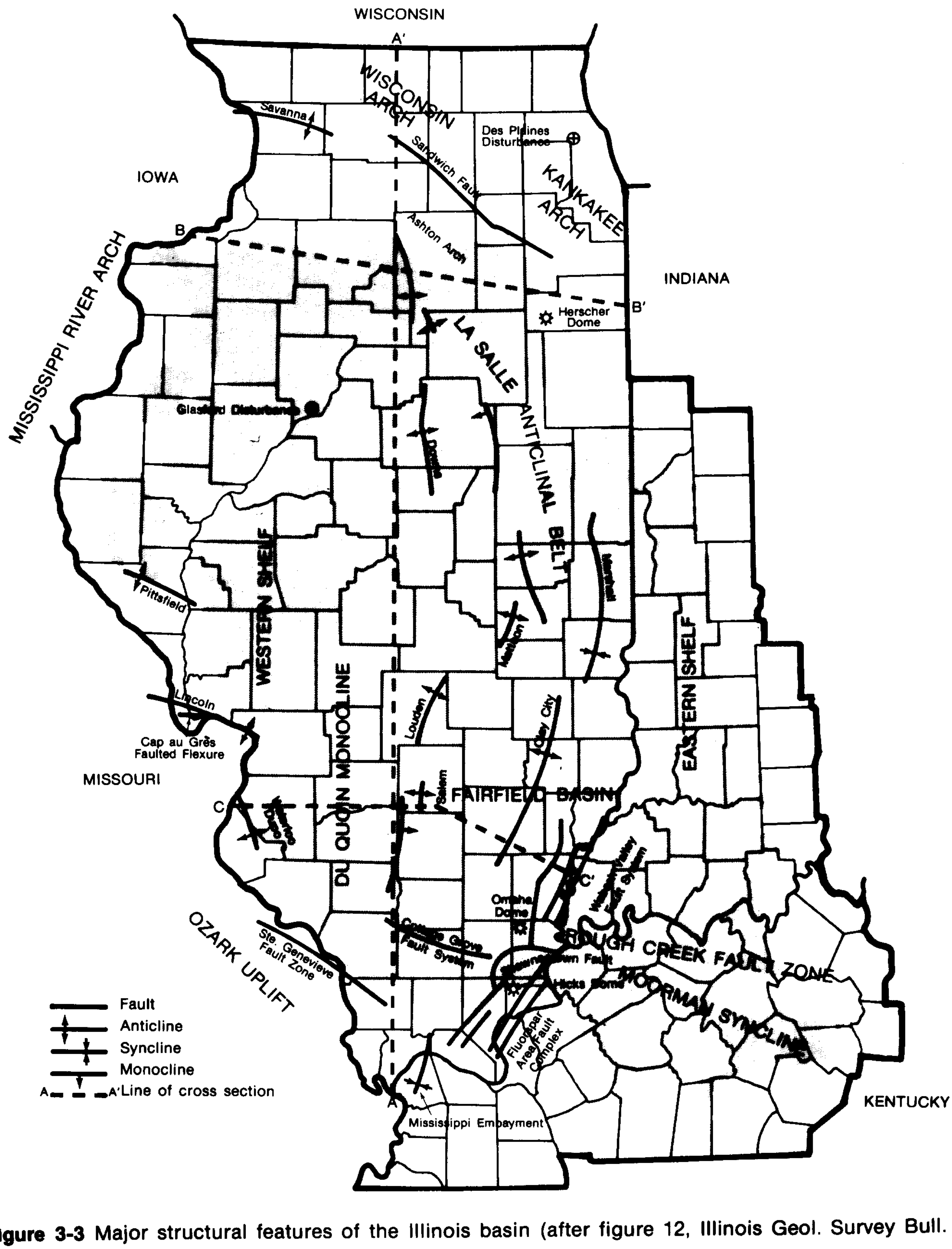


Figure 3-3 Major structural features of the Illinois basin (after figure 12, Illinois Geol. Survey Bull. 95)

rock units vertically and laterally; locally the bedrock dips steeply. The Fluorspar District, an extensively faulted, mineralized, and mined area, is located at the southern boundary of the basin.

Near-surface bedrock of the Illinois basin is of Pennsylvanian and upper Mississippian age. The generalized geologic map (Figure 3-4) shows their distribution. The rocks surrounding the Illinois basin generally are older, the exception being to the south, where Tertiary and Cretaceous sediments of the northern Mississippi embayment overlap Ordovician and Mississippian sediments. Paleozoic units dip gently from all edges toward the deeper parts of the basin, and as a result progressively younger rocks are exposed toward the basin's center. The sedimentary layering of the basin rocks has been likened to a nest of graduated measuring spoons (Swann, 1968). Exaggerated cross sections through the basin illustrate this configuration (Figure 3-5). As illustrated, the majority of the units thicken towards the basin's structural center in southeastern Illinois. Detailed geologic cross-sections of the Paleozoic section in the Illinois basin have been prepared by Swann (1968).

3.3.2 Basin Stratigraphy

A generalized stratigraphic column of the Illinois basin is shown in Figure 3-6. In the deeper portions of the basin, thickness of this column exceeds 14,000 feet. Paleozoic rocks are predominantly of marine origin and dominated by dolomite, limestone, shale, sandstone, chert, anhydrite, and coal, in that order (Swann, 1968). The entire basin was emergent numerous times during the Paleozoic; major regional unconformities occur beneath middle Ordovician, middle Devonian, and Pennsylvanian sediments (Swann, 1968; Buschbach, 1971). Since Paleozoic time, with the exception of periods of Pleistocene glaciation, the area has been one of non-deposition. Because very little bedrock is exposed, the stratigraphy of the Illinois basin has been largely compiled from subsurface data. All three state geologic surveys (Illinois, Indiana, and Kentucky) have extensive files containing well logs, cores, and cuttings.

Although a few thin coal horizons are present in upper Mississippian age rocks of Indiana, Pennsylvanian age rocks contain the primary coal-bearing seams of the Illinois basin. Pennsylvanian rocks were deposited unconformably

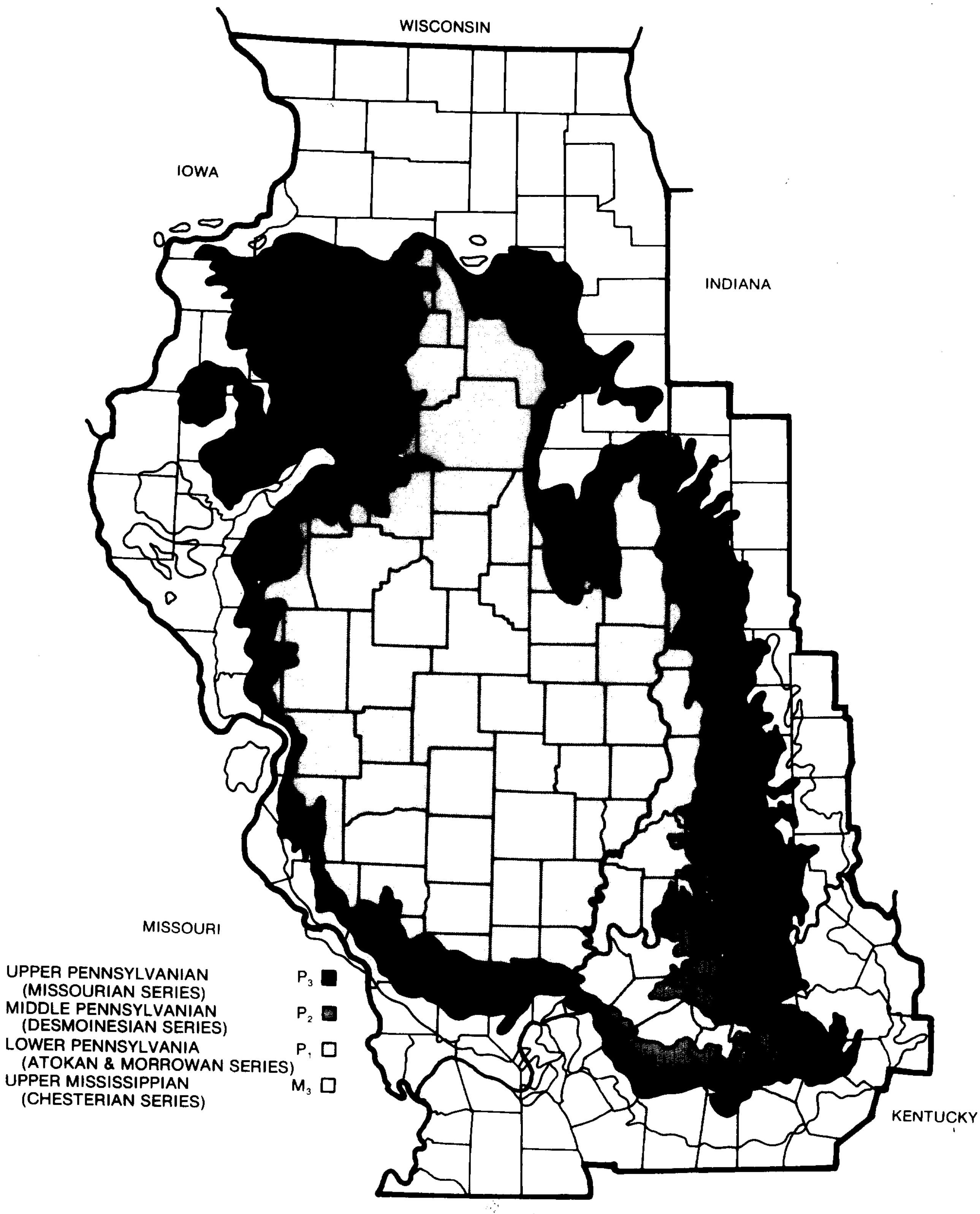


Figure 3-4 Generalized geologic map of the Illinois basin (after Geologic Map of the United States, 1:2,500,000, USGS 1974)

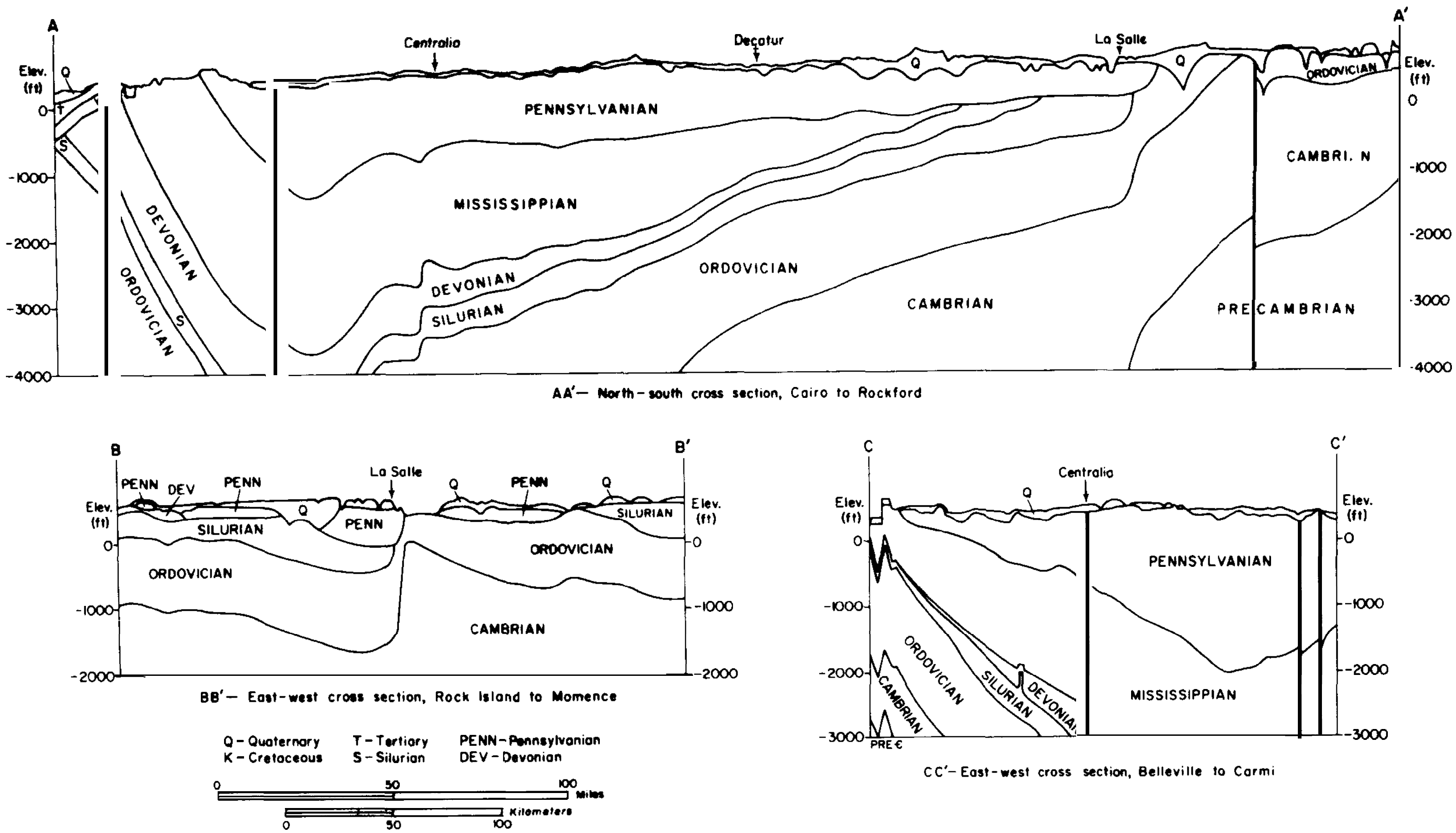


Figure 3-5 Geologiccross-sections along the lines shown in Figure 3-3 (figure 13, Illinois Geol. Survey Bull. 95)

ERA, ERATHEM	PERIOD, SYSTEM	ORIGIN AND CHARACTER	GREATEST THICKNESS (ft)	EPOCH, SERIES: ILLINOIS	EPOCH, SERIES: INDIANA	EPOCH, SERIES: KENTUCKY
CENOZOIC	QUATERNARY	Continental — glacial, river and stream, wind, lake, swamp, and colluvial deposits and soils	600	PLEISTOCENE	PLEISTOCENE	PLEISTOCENE
		Major unconformity				
	TERTIARY	Continental — river deposits, mostly gravel, some sand	50	PLIOCENE	PLIOCENE	PLIOCENE
		Major unconformity				
		Deltaic — mostly sand, some silt	300	EOCENE	EOCENE	EOCENE
		Marine — mostly clay, some sand	150	PALEOCENE	PALEOCENE	PALEOCENE
		Unconformity				
MESOZOIC	CRETACEOUS	Deltaic and nearshore marine — sand, some silt and clay, locally lignitic	500	GULFIAN	GULFIAN	GULFIAN
		Major unconformity				
PALEOZOIC	PENNSYLVANIAN	Marine, deltaic, continental — cyclical deposits, mostly shale, sandstone, and siltstone with some limestone, coal, clay, black sheety shale; sandstone dominant in lower part, shale above; coal most prominent in middle part, limestone in upper part	3000	VIRGILIAN MISSOURIAN DESMOINESIAN ATOKAN MORROWAN	CONEMAUGHIAN ALLEGHENIAN POTTSVILLIAN	UPPER MIDDLE LOWER
		Major unconformity				
	MISSISSIPPIAN	Marine, deltaic — cyclical deposits of limestone, sandstone, shale	1400	CHESTERIAN	CHESTERIAN VALMEYERAN KINDERHOOKIAN	CHESTERIAN MERAMECIAN OSAGIAN KINDERHOOKIAN
		Marine, deltaic — limestone, siltstone, shale chert, sandstone	2000	VALMEYERAN		
		Marine — shale, limestone, siltstone	150			
	DEVONIAN	Marine — shale, limestone	300	UPPER	SENECAN AND CHAUTAUQUAN ERIAN ULSTERIAN	UPPER MIDDLE LOWER
		Unconformity				
		Marine — largely limestone, some shale	450	MIDDLE		
		Major unconformity				
		Marine - cherty limestone chert	1300	LOWER		
	SILURIAN	Marine—shale, siltstone, limestone	100	CAYUGAN	CAYUGAN NIAGARAN ALEXANDRIAN	CAYUGAN NIAGARAN ALEXANDRIAN
		Marine — dolomite, limestone, shale, local reefs	1000	NIAGARAN		
		Marine — dolomite, limestone, shale	150	ALEXANDRIAN		
		Unconformity				
	ORDOVICIAN	Marine—shale, limestone, siltstone, dolomite	300	CINCINNATIAN	CINCINNATIAN CHAMPLAINIAN CANADIAN	CINCINNATIAN CHAMPLAINIAN CANADIAN
		Unconformity				
		Marine — limestone, dolomite, sandstone	1400	CHAMPLAINIAN		
		Major unconformity				
		Marine — dolomite, sandstone	1000	CANADIAN		
	CAMBRIAN	Marine—sandstone, dolomite, shale	4000	CROIXAN	ST CROIXAN	ST CROIXAN
		Major unconformity				
PRECAMBRIAN		Intrusive igneous rocks — mostly granite				

Figure 3-6 Generalized stratigraphic column of the Illinois basin (after figure 1, Illinois Geol. Survey Bull. 95)

on older Paleozoic rocks (Figure 3-7) following a major period of uplift and erosion at the end of the Mississippian. The region consisted of a south-westerly inclined coastal plain which received sediment from the Appalachian and Canadian Shield areas to the northeast. Subarea1 erosion of the coastal plain produced river valleys in a well developed linear drainage pattern. Alluvial sands and muds first filled these valleys, and as the seas gradually migrated northward clastic marine (deltaic) sedimentation infilled and covered the erosional surface (Pryor and Sable, 1974). Although the original area1 extent of Pennsylvanian rock is not known, they were deposited over a much larger area and subsequently eroded (Wanless, 1962). Oldest Pennsylvanian rocks were deposited only in the southern portions of the region, and in most places progressively younger Pennsylvanian rocks lie on older Paleozoic rocks in northern Illinois (Figures 3-7 and 3-8) (Willman et al, 1975). The majority of middle and upper Pennsylvanian deposition was in transitional and continental environments such as alluvial and delta plains, distributary channels, marshes, and swamps (Pryor and Sable, 1974). Several times the delta platform was covered by freshwater coal swamps, and then as sea level rose the swamps were flooded and black pyrite-bearing shales with beds of fossiliferous limestones were deposited. At least 51 repeated cycles of deposition (cyclothems; Wanless and Weller, 1932), have been identified in the Pennsylvanian sequence. Each cyclothem consists of distinct sandstone, shale, limestone, and coal units arranged in a regular sequence (Figure 3-9). The repeated initiation, growth, and abandonment of delta lobes, combined with their lateral migration, led to the complex vertical and horizontal arrangement of these cyclothems which is now observed in the stratigraphic column of Pennsylvanian rocks.

The present stratigraphic nomenclature of Pennsylvanian rocks in the Illinois basin area is shown in Figure 3-10. The sequence is divided into three major rock-stratigraphic units by the Illinois State Geological Survey: a basal McCormick Group; a middle Kewanee Group; and an upper McLeansboro Group. Within these groups, the Illinois State Geological Survey recognizes seven formations, the Indiana State Geologic Survey names 10 formations, and the Kentucky Geological Survey names five. More specifically, Pryor and Sable (1974) report that:

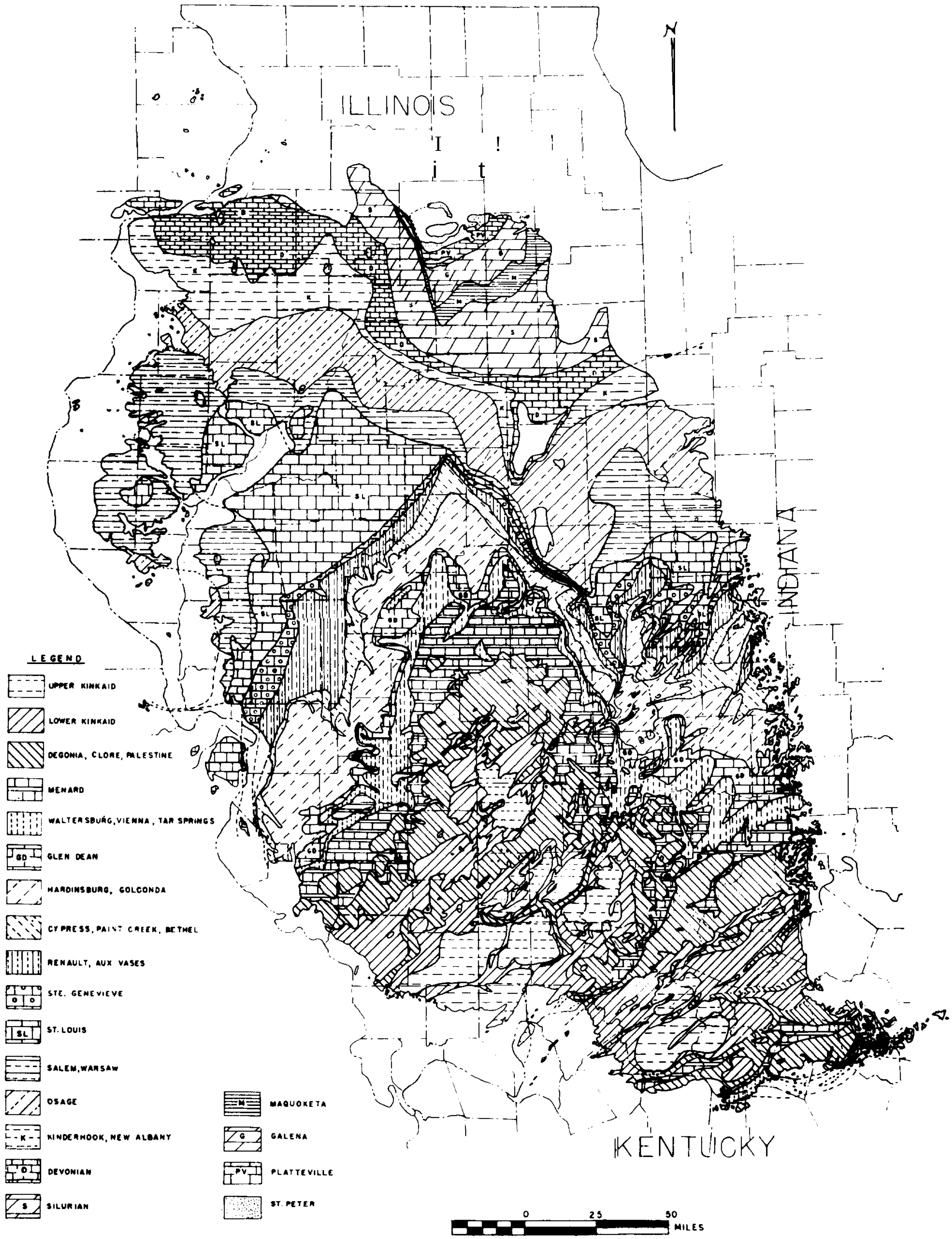


Figure 3-7 Pre-Pennsylvania paleogeologic map of Illinois basin (figure 2, Wanless, 1962) (courtesyAAPG, June 1979)

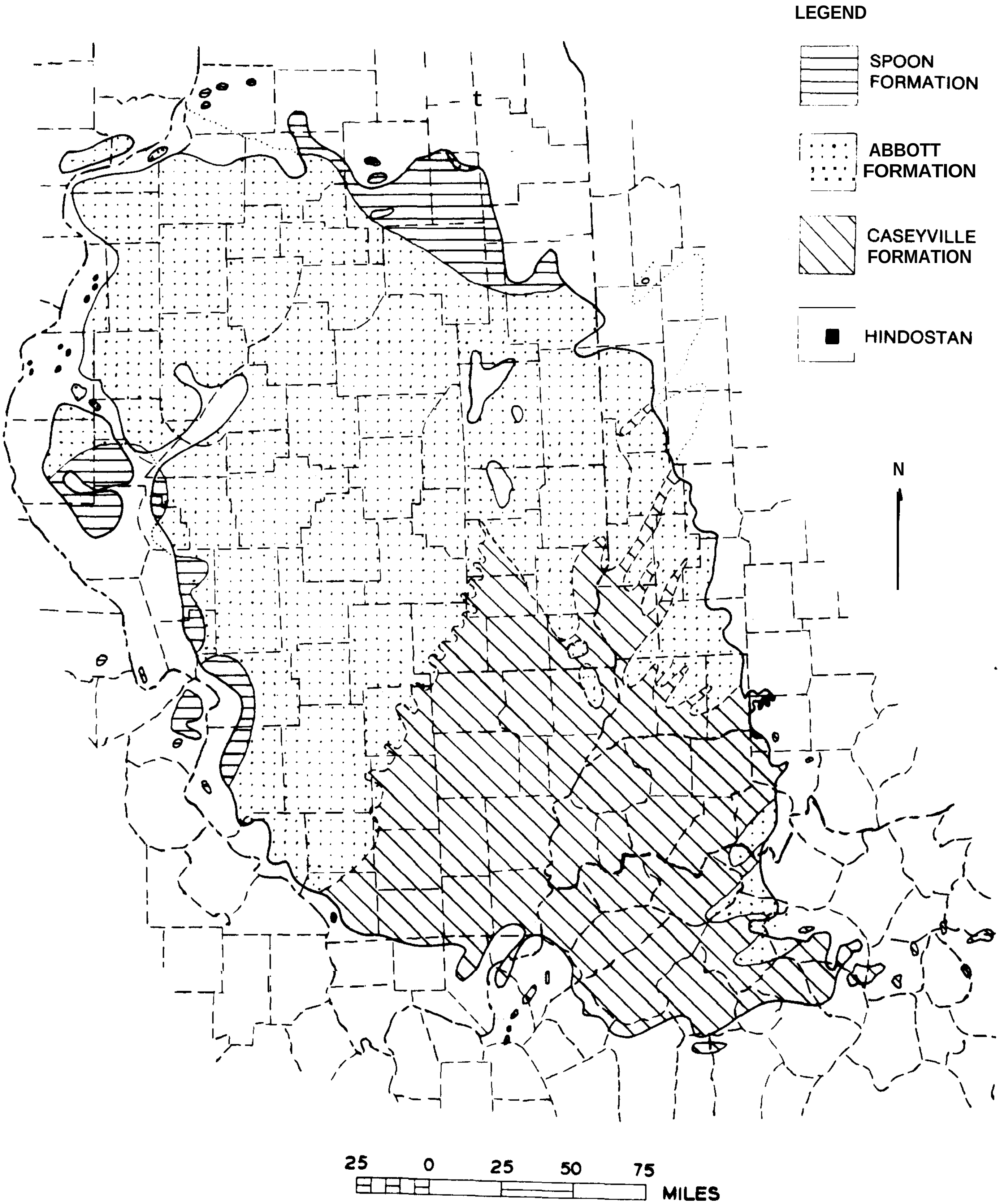


Figure 3-8 Worm's-eye-view map of earliest Pennsylvanian system after (figure 3, Wanless, 1962) (courtesy AAPG, June 1979)

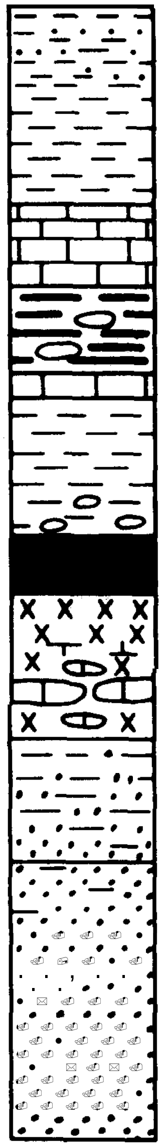


Figure 3-9 Sequence of lithologic units in a cyclothem (figure 3, Illinois Geol. Survey Bull. 95)

ILLINOIS		INDIANA		KENTUCKY	
GROUP	FORMATION	GROUP	FORMATION	GROUP	FORMATION
MCLEANSBORO	MATTOON	MCLEANSBORO	MATTOON	MCLEANSBORO	(HENSHAW)
	BOND		BOND		
	MODESTO		PATOKA		STURGIS
			SHELBURN		
KEWANEE	CARBONDALE	CARBONDALE	DUGGER		(LISMAN)
			PETERSBURG		CARBONDALE
			LINTON		
	SPOON	RACCOON CREEK	STAUNTON		TRADEWATER
			BRAZIL		
MCCORMICK	ABBOTT		MANSFIELD		
	CASEYVILLE				CASEYVILLE

Figure 3-10 Stratigraphic *nomemclature* of the Pennsylvanian system by state

- McCormick Group sediments and their equivalents are mostly fluviatile sandstones and mudstones, the coalbeds are thin and of limited extent, and limestones rare or absent.

- Kewanee Group sediments and their equivalents mark the beginning of well developed cyclic deposits with shales, limestones, and coals begin much more common.

- McLeansboro Group sediments and their equivalents are also cyclic, but more marine in character than earlier Pennsylvanian units, with thicker, more numerous limestones and thinner coals.

The thickest Pennsylvanian sections are found in the Fairfield basin (> 2400 feet) and Moorman syncline (> 3300 feet) areas of the Illinois basin (Figure 3-11). These areas also are generally believed to have the greatest cumulative thicknesses of coal.

3.3.3 Hydrology

Principal aquifers of the Illinois basin are classified into two groups, those in unconsolidated Pleistocene sands and gravels, and those in consolidated bedrock. Unconsolidated sands and gravels, primarily of glacial origin, are by far the best aquifers of the area and yield as much as 1,000 gallons per minute (gpm). Consolidated bedrock aquifers are primarily in sandstone and limestone units. These include coarse alluvial deposits which infilled the river valleys and covered the erosional plain of the late Mississippian, and sheet or channel sandstones in cyclothems of the Pennsylvanian sequence. The channel sandstones, often referred to as the basal sandstones of the cyclothems (Figure 3-9), generally are thicker than the sheet sandstones, and make better aquifers. Coalbeds also have been reported to produce small amounts of water.

An example of how hydrologic properties vary across a stratigraphic column in southwestern Indiana is shown in Figure 3-12. Generally, in moving from older to younger Pennsylvanian rocks, the relative number of sandstone units decreases, and shales and limestones increase. Coincident with these trends is a decrease in the number and the capacity of aquifers. Gray shales of cyclothems are thought to form effective hydrologic barriers and thereby restrict lateral and vertical movement (or recharge) in the section. A similar hydrologic situation exists in Illinois where the sandstone and limestone beds of Pennsylvanian age rarely yield over 25 gpm (Smith and Stall, 1975).

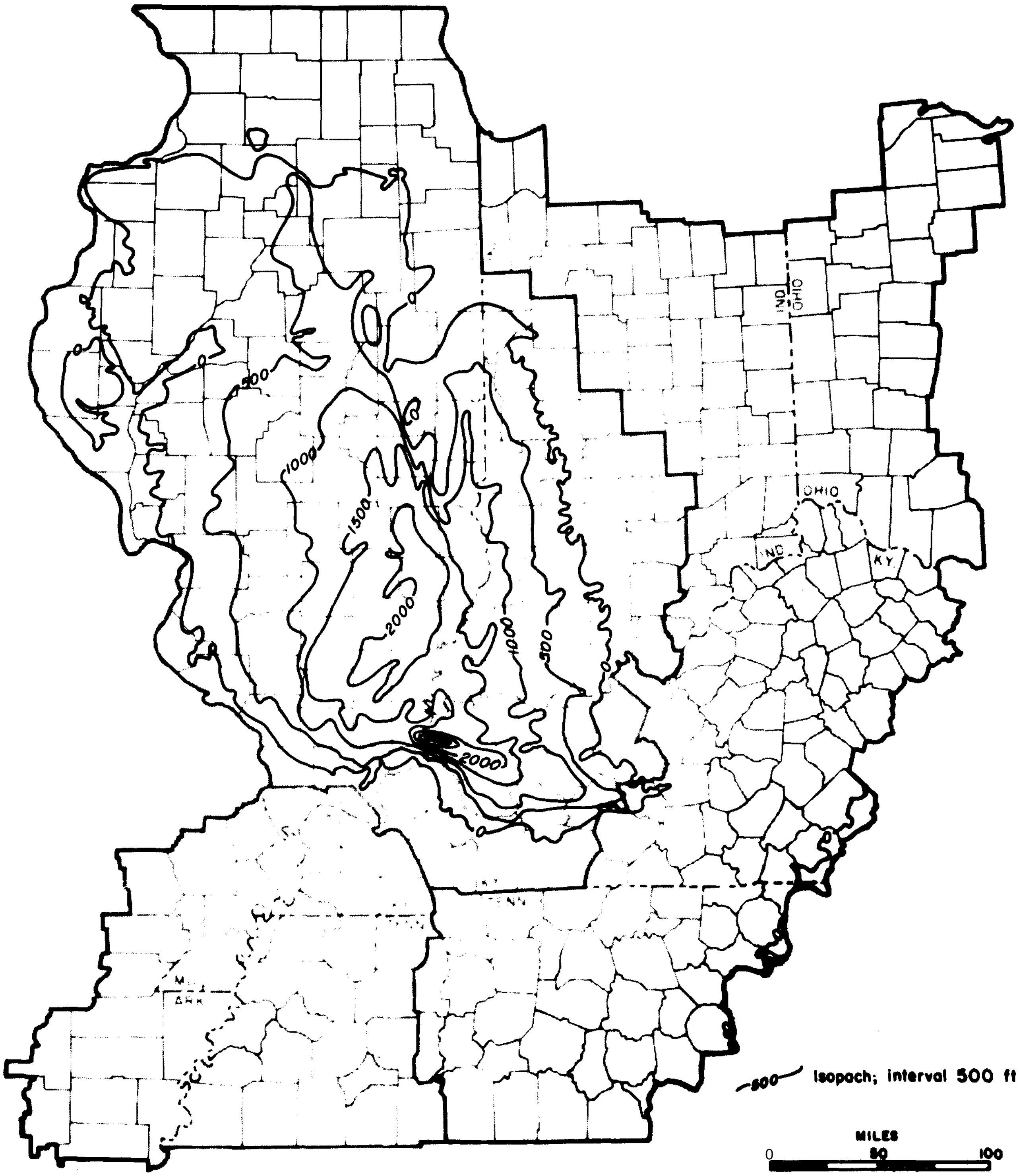


Figure 3-11 Thickness Map of the Pennsylvanian system (figure 3, Illinois Geol. Survey Pet. 96)

System	Series	Deposits or Formation	Important Aquifer(s)	Average yield of wells (gpm)	Estimated field coefficient of permeability	Estimated total amount of water in storage in millions of gallons	Estimated use (mgd)	Potential production considered adequate for:	Quality of Water
Quaternary	Recent	Alluvium	Sand and Gr avl: Unconfined	660	1,200	367,000	21.4	Large industrial and municipal supplies	Usually very hard and deficient in fluoride. Excessive iron common
	Pleistocene	Glacial	Sand and Gr avl: Confined	25	550	370	8	Moderately large industrial and municipal supplies	
Carboniferous: Pennsylvanian	Upper Pennsylvanian	Patoka (of local usage)**	None				1.8	Domestic, farm, small industrial and small municipal supplies	Shallow water usually similar to that in Quaternary rocks At depth, water usually soft, frequently high in fluoride, and has higher concentrations of bicarbonate, total dissolved solids and chloride. Excessive iron common at all depths
	Middle Pennsylvanian	Shelburn	Sandstone Unit 6	3.2	23	34			
		Dugger	sandstone Unit 5*	- - - - - -	- - - - - - - -	42			
		Petersburg	Sandstone Unit 4	5	4	52			
		Linton	Sandstone Unit 3	8	14	44			
		Staunton	None						
		Brazil	None						
		Mansfield	Sandsto ne: Unit 2	7.6	11	264			
	Lower Pennsylvanian		Sandsto ne: Unit 1	9.4	12	87			
Carboniferous: Mississipian	Chester (?)		None						Insufficient data

'No hydrologic data available.

'See Wier and Gray, 1961

Figure 3-12 Generalized stratigraphic column and hydrologic properties of Mississippian and younger rocks in Vigo and Clay Counties, Indiana (table 2, Indiana Dept. of Nat. Resources, Div. of Water, Bull. No. 34)

The chances of drilling a well in southern Illinois and producing more than 10 gpm from Pennsylvanian units are poor (Figure 24, Cooperative Resources Report 4, Illinois State Geological Survey). In the western Kentucky coal field region, bedrock sandstones of Pennsylvanian age change greatly in thickness and character over short distances (Maxwell and Devaul, 1962). Extensive faulting in this area limits the size (or extent) of sandstone aquifers, and mineralization along the fault zones has effectively restricted recharge (Davis et al, 1974). The Anvil sandstone of the upper Pennsylvanian and the Caseyville sandstone of the lower Pennsylvanian may produce 100 gpm, but other units will commonly produce less than 20 gpm.

Chemically, waters in aquifers of the Illinois basin typically are:

- Fresh near the basin edges,
- Calcium bicarbonate rich in shallow horizons,
- Sodium bicarbonate rich in deep horizons,
- Likely to increase in total dissolved solids content, particularly sodium, bicarbonate, and chloride, with increasing depth, and
- May contain undesirable amounts of sodium chloride and iron.

The hydrology of many areas in Indiana, Illinois, and Kentucky has been studied in detail. Indices to hydrologic reports in the Illinois basin area are included in Appendix B.

4. THE COAL RESOURCE

4.1 REGIONAL (BASIN) CHARACTER

Coal deposits of the Illinois basin are primarily confined to rocks of the Pennsylvanian system, although thin coalbeds of limited extent have been found in upper Mississippian rocks. The extent of the coal-bearing Pennsylvanian rocks is depicted by the Illinois basin outline in Figure l-l. These rocks underlie approximately 36,900 square miles (102 counties) of Illinois, 6,500 square miles (25 counties) of Indiana, and 6,400 square miles (14 counties) of Kentucky. Coals of the Illinois Basin are thought to have accumulated in freshwater swamp environments on broad delta plains (Willman, et al, 1975). Bright and dull banded coals, cannel coals, and paper coals have been found in the basin, These coals cover the full range of high volatile bituminous coals; a progressive increase in rank from high volatile C to high volatile A coals in a southeasterly direction across the basin (Figure 4-1) has been observed and documented by Damberger (1971). Analyses show that coals of the Illinois basin generally fall within the following range of values, although some compositions are known to be both higher and lower.

Moisture (%)	5 - 20
Ash (%)	6 - 14
Sulfur (%)	2 - 4
Btu/lb	11,000 - 14,000

The principal authigenic minerals found in these coals are kaolinite, calcite, marcasite, pyrite, and gypsum. The chemical composition of the authigenic minerals in the coal is commonly related to the mineralogy of the overlying strata.

Detailed stratigraphic columns of the Pennsylvanian system in Illinois and Indiana are shown in Figures 4-2 and 4-3 respectively; none is available for western Kentucky. Although more than 75 individual coal seams have been identified, 20 of which are mined, the coals make up less than three percent of the total section. The majority of Illinois Basin Coals are not continuous and do not maintain constant thicknesses; some coals were deposited only

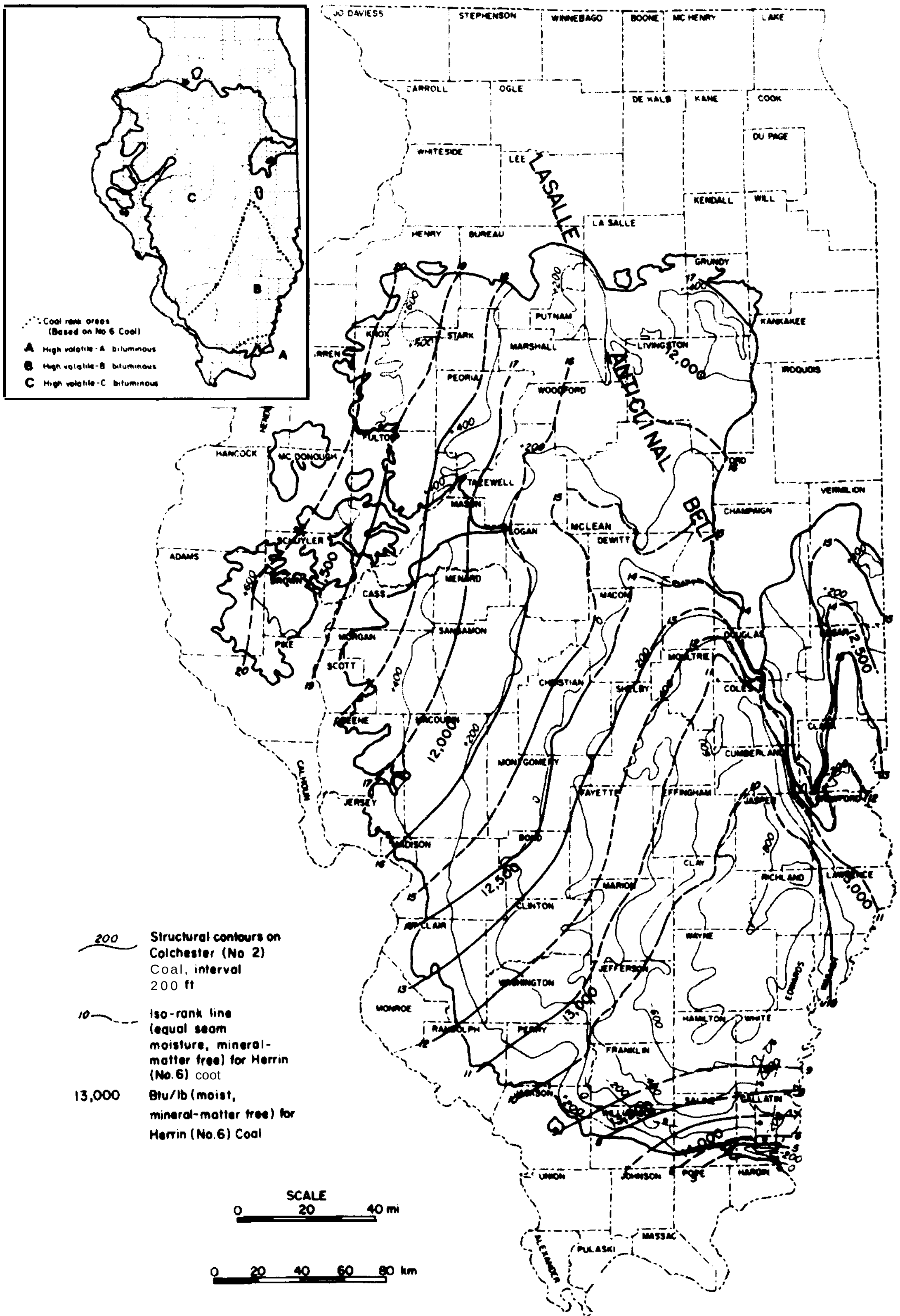


Figure 4-1 Coalification pattern in Illinois shows progressive increase in rank in the Herrin Coal southward (figure 11, Illinois Geol. Survey Coop. Resource Report 4)

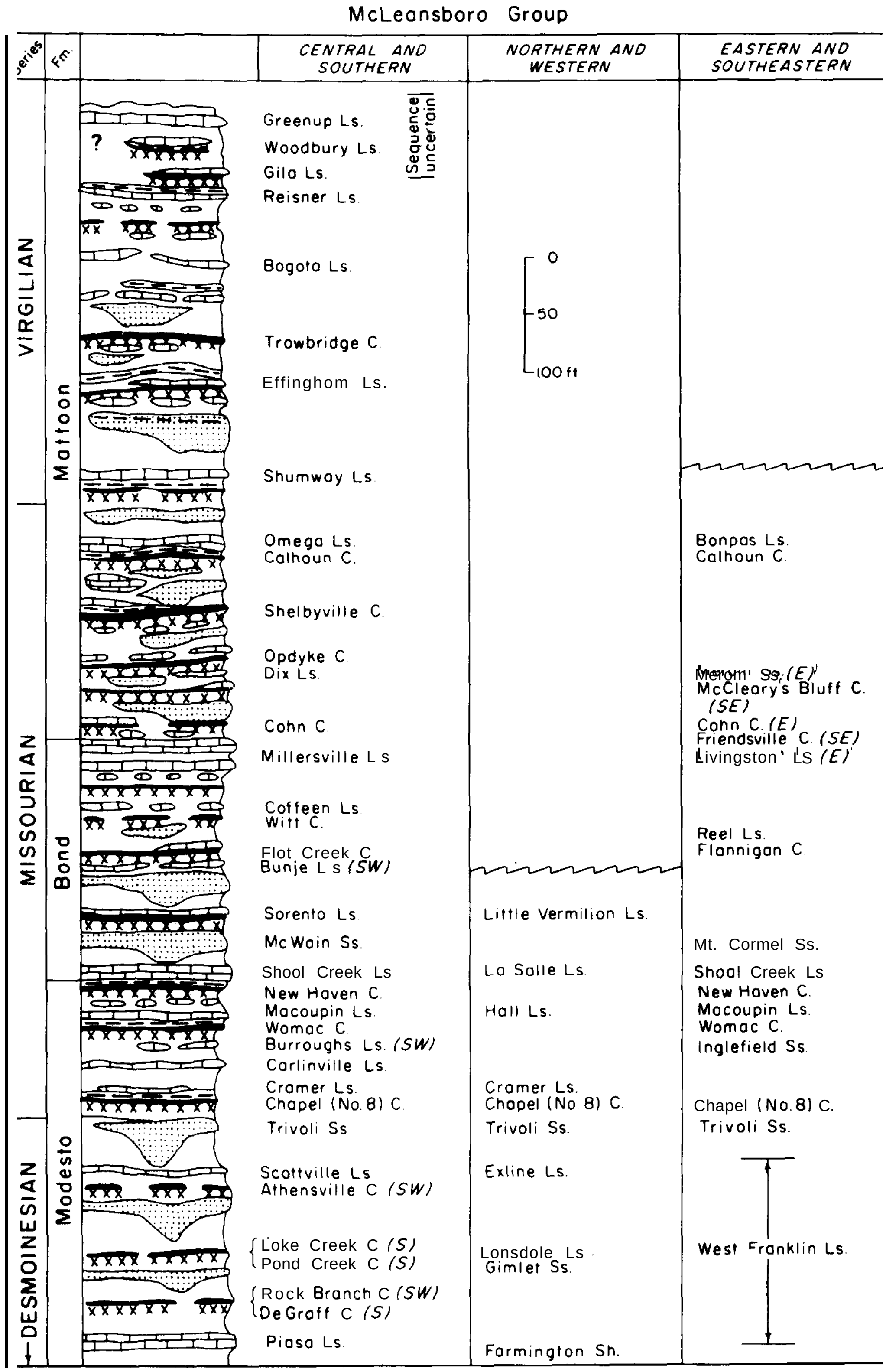
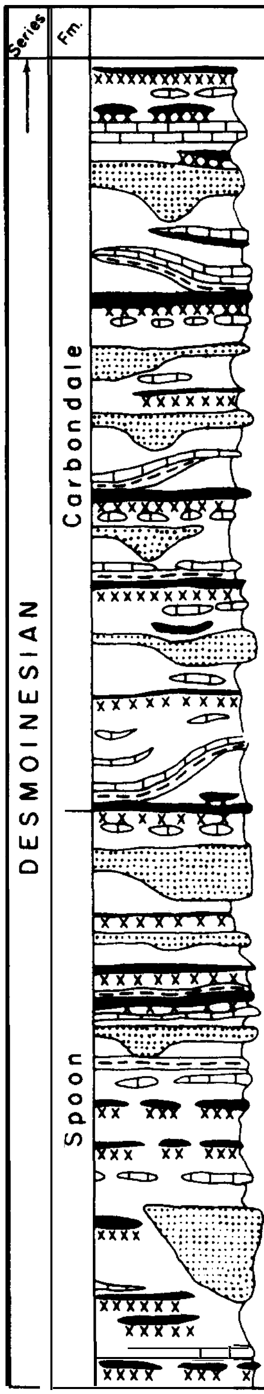


Figure 4-2 Generalized stratgraphic column of rock units in the Pennsylvanian system as named by the Illinois Geological Survey (figure P-2, Illinois Geol. Survey Bull. 95)

Figure 4-2 Continued

Kewonee Group



SOUTHWESTERN AND SOUTHEASTERN	NORTHERN AND WESTERN	EASTERN
Donville (No.71 C.	Donville (No.7) C.	Donville (No.71 C.
Galum Ls.		
Allenby C.		
Bankston Fork Ls.		Bonkston Fork Ls
Anvil Rock Ss	Copperos Creek Ss	
	Lawson Sh.	
Conont Ls.		Conont Ls.
Jomestown C.		Jomestown C.
Brereton Ls	Brereton Ls.	Brereton Ls.
Anna Sh.	Anna Sh.	Anna Sh.
Herrin(No6) C	Herrin(No.6) C.	Herrin(No.6) C.
	Spring Lake C.	
	Big Creek Sh	
	Vermilionville Ss	
Briar Hill (No 5A) C		Briar Hill (No. 5A) C.
Canton Sh.	Canton Sh.	Canton Sh.
St. David Ls.	St. Dovid Ls.	St. Dovid Ls
Dykersburg Sh.		
Horrisburg (No5) C	Springfield (No.5) C.	Harrisburg (No.5) C.
	Covel Cgl.	
Hanover Ls.	Honover Ls.	
Excello Sh.	Excel lo Sh.	Excello Sh.
Summum (No.4) C.	Summum (No.4) C	Summum (No.41 C.
	Breezy Hill Ls.	
Roodhouse C	Kerton Creek C.	
Pleosontview Ss	Pleosontview Ss.	Pleosontview Ss
	Purington Sh.	
Showneetown C.	Lowell C.	Showneetown C.
Oak Grove Ls	Ooh Grove Ls.	
Mecca Quarry Sh.	Mecca Quarry Sh.	Mecca Quarry Sh.
	Joke Creek Ss.	
	Francis Creek Sh.	
	Cardiff C.	
Colchester (No 2) C	Colchester (No.2) C.	Colchester (No.2) C.
	Browning Ss	
	Abingdon C.	
Palzo ss.	Isabel Ss.	
Seelyville C		Seelyvil le C.
De Koven C	Green bush C	
Davis C	Wiley C.	
Seohorne Ls	Seohorne Ls.	
Vergennes Ss		
Stonefort Ls		
Wise Ridge C		
Mt Roroh C	De Long C	
Creal Springs		
Murphysboro C		
Gronger Ss		
New Burnside C	Brush C	
Bidwell, O'Non C		
Curlew Ls	Hermon C.	
	Seville Ls.	
Litchfield, Assumption C.	Rock Islond (No.1) C.	

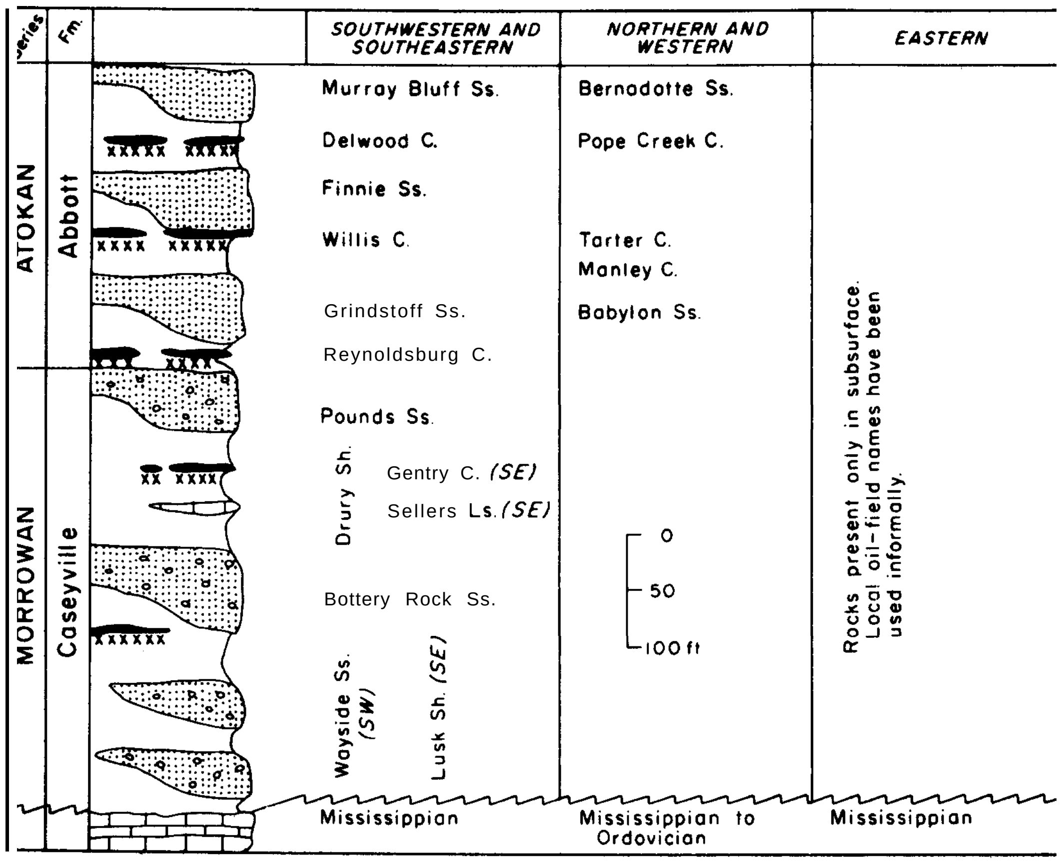
Che enham Clay

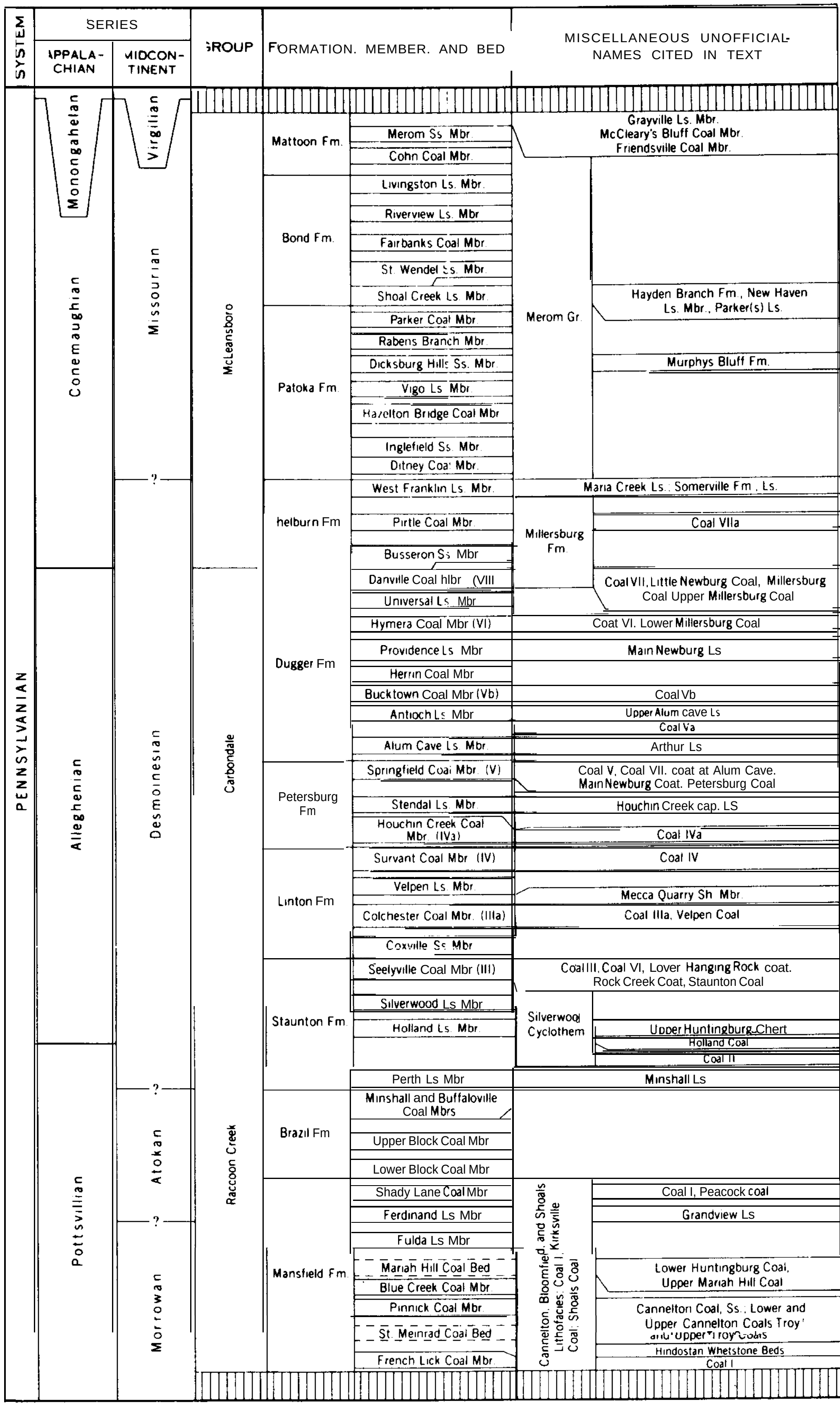
0 — 50 — 100 ft.

Rocks present only in subsurface. Local oil-field names have been used informally.

Figure 4-2 Continued

McCormick Group





PENNSYLVANIAN ROCK-UNIT NAMES USED IN INDIANA

Figure 4-3 Generalized stratigraphic column of rock units in the Pennsylvanian system as named by the Indiana Geological Survey (table 3, Indiana Geol. Survey Bull. 43)

in small isolated basins. Individual seams range from a few inches to 15 feet in thickness and some average four to six feet in thickness over large areas. Thicknesses often are controlled by the presence of prominent structural features (Figure 3-3) and proximity to major drainage systems in swamps (Smith and Stall, 1975). Little or no coal was deposited on topographic highs, and thick coal accumulated in the vicinity of principal channels. Lower and upper Pennsylvanian coals (McCormick, lower Kewanee, and McLeansboro Group coals) are thin and discontinuous while the middle Pennsylvanian coals (upper Kewanee Group coals) are thick, generally continuous, and provide the major reserves of the basin. Thin lower and upper Pennsylvanian coals have not been studied in as much detail and are not as well correlated as the thicker coalbeds of the middle Pennsylvanian. The greatest cumulative thickness of coal seams presumably occurs in the southeastern portion of the basin (near the tri-state boundary) where the thickest Pennsylvanian section occurs. Figure 4-4 shows the stratigraphic correlation of important coal seams in the Illinois basin.

Overburden thickness varies greatly throughout the basin and is dependent upon local topography and position within the basin itself. Coal seams outcrop on the basin's periphery and gently dip toward its center. In southwestern Indiana the coal seams dip at a rate of 25 to 30 feet per mile towards the deeper parts of the basin in Illinois and Kentucky. Approximate depths to individual coalbeds can be determined by studying isopach maps of the Pennsylvanian strata and Quaternary deposits overlying the coal seam of interest. All Illinois basin coal seams are covered by less than 3,000 feet of overburden, and the major coals are everywhere within 1,500 feet of the surface.

Illinois basin coals have been mined by both underground and surface methods. The majority of the mining activities are near the basin's perimeter (Figure 4-5) where the coal is exposed or shallow, as in the southeastern portion of the basin, where local vertical structural displacements have brought the coal to the surface. Estimated resources (those coals 28 or more inches thick and 1,000 feet or less in depth) on a county basis are shown in Figure 4-6. As shown, the southeastern and west-central basin portions have the greatest accumulation of remaining coal resources.

Illinois		Indiana		W. Kentucky	
Modest Fm.		Shelburn Fm.		Lisman Fm.	No. 14 No. 13 No. 12
Carbondale Fm.	Danville (No. 7)*	Dugger Fm.	Danville (VII)		
	Jamestown* Herrin (No. 6)*		Hymera (VI) Herrin		
	Briar Hill (No. 5A)* Springfield-Harrisburg (No. 5)'	Petersburg Fm.	Springfield (V)	Carbondale Fm.	No. 11 No. 10 No. 9
	Summum(No. 4)* Shawneetown Coal*	Linton Fm.	Houchin Creek (IVa) Survant (IV)		Upper Well (No. 8b) No. 8
	Colchester (No. 2)*		Colchester (IIIa)		Schultztown
Spoon Fm.	Seelyville* DeKoven* Davis' Murphysboro New Burnside Bidwell Rock Island (No. 1)*	Staunton Fm.	Seelyville (III) Buffaloville		DeKoven Davis (No. 6)
Abbott Fm.	Willis	Brazil Fm.	Minshall Upper Block Lower Block	Tradewater Fm.	Mining City (No. 4) Mannington
	Reynoldsburg	Mansfield Fm.	Mariah Hill Blue Creek St. Meinrad		Bell
Caseyville Fm.	Gentry		Pinnick French Lick	Caseyville Fm.	Main Nolin

'Modified from Kosanke et al., 1960.

Figure 4-4 Stratigraphic correlation of coal seams in the Illinois basin (after table 3, Illinois Geol. Survey Min. Note 67)

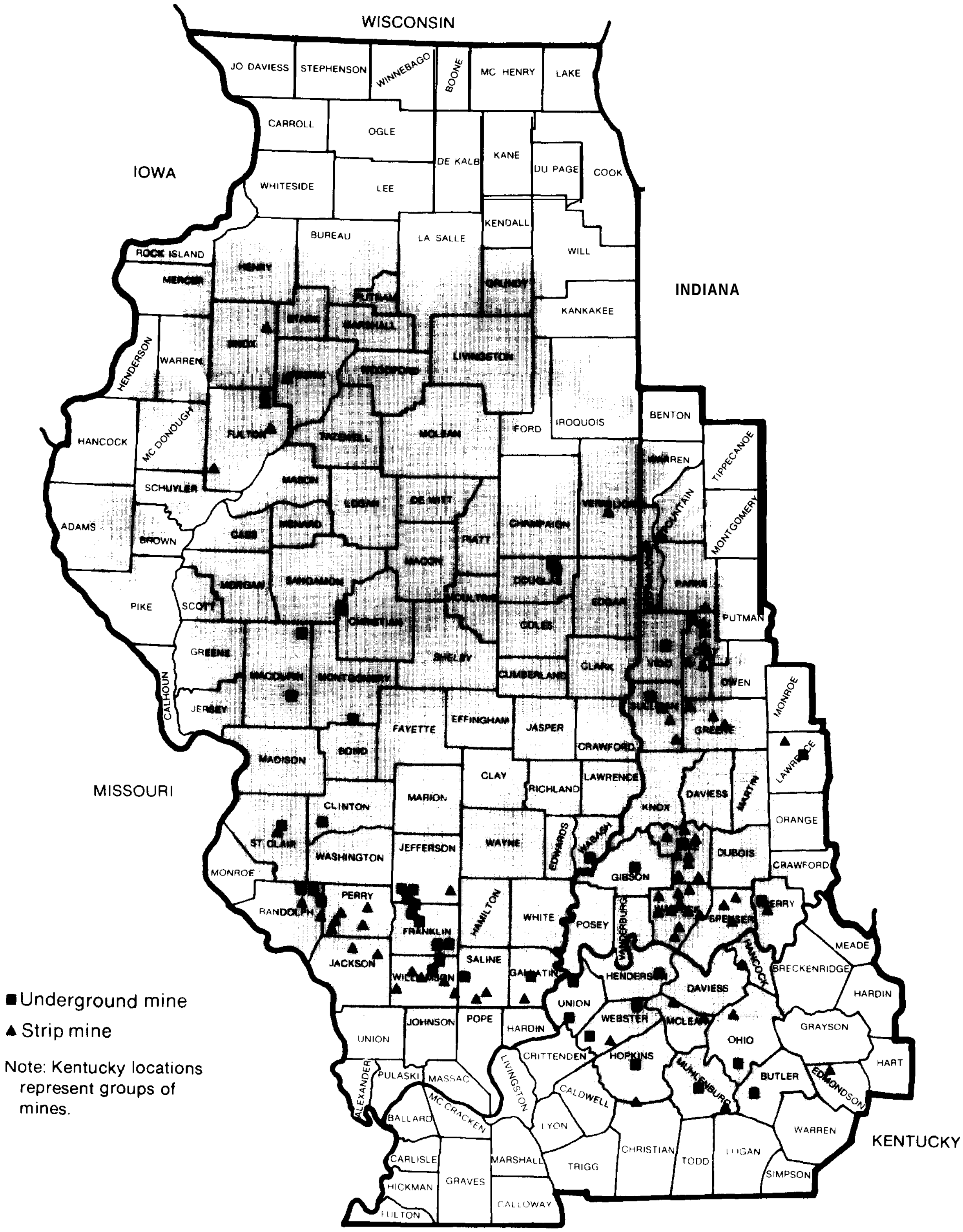


Figure 4-5 Operating coal mines of the Illinois basin

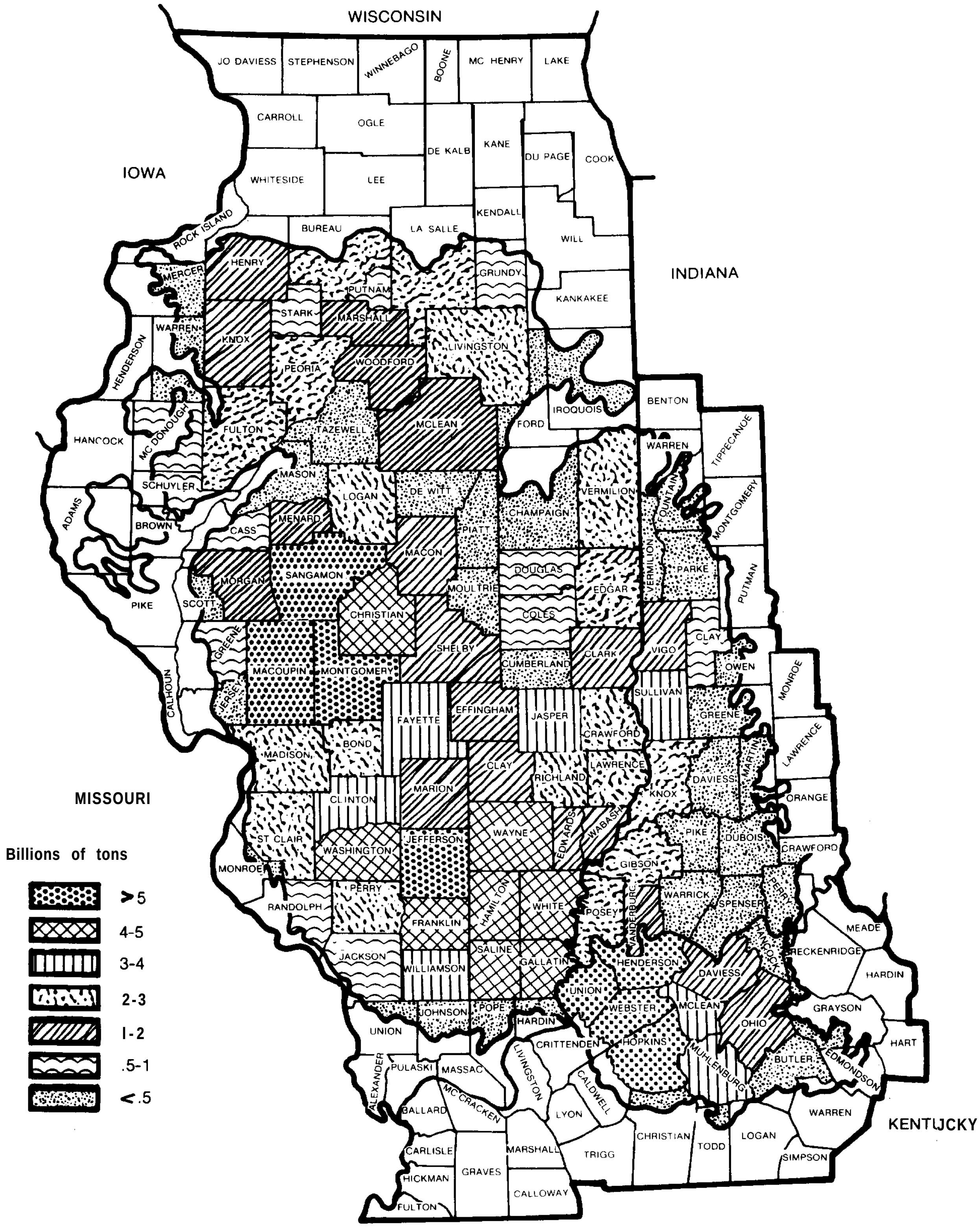


Figure 4-6 Remaining coal resources of the Illinois basin by county (Portions courtesy McGraw Hill Publications)

Certain portions of the basin (Fairfield Basin and Moorman Syncline) have Significant coal reserves at depths exceeding 1,000 feet.

The Herrin (No. 6), and the Springfield-Harrisburg (No.5) coals are commercially the most important coals in Illinois. The Springfield (V) coal is the most important commercial coal in Indiana. The No. 11, No. 9, and No. 6 coals are commercially most important in the western Kentucky coal field. Total coal resources by seam on a state basis are given in Table 4-l. The U.S. Geological Survey has estimated that the total in-the-ground resource (hypothetical and identified) is 365 billion tons (Averitt, 1975). An index to published reports discussing reserves and coal production in the Illinois basin is included in Appendix C.

4.2 STRATIGRAPHIC CHARACTER

Rocks of the Pennsylvania system have been classified in three groups (the McCormick, the Kewanee, and the McLeansboro) by the Illinois State Geological Survey (Figure 3-10). Available information concerning these groups varies significantly and is reflected in the discussions below. Section 4.2.1 discusses coals of the McCormick Group; Sections 4.2.2 and 4.2.3 discuss coals of the Spoon and Carbondale Formations of the Kewanee Group; Section 4.2.4 discusses coals of the McLeansboro Group. For simplicity and continuity, the names of coal members discussed in the following sections are those used by the Illinois State Geological Survey; stratigraphically equivalent coals in Indiana and Kentucky are discussed under the same names. Figures 3-10 and 4-4 serve as keys to these sections of the basin report. The coal seams discussed below are marked with an asterick(*) in Figure 4-4.

The information presented in these sections is derived primarily from personal communications with geologists from the Illinois, Indiana, and Kentucky Geological Surveys and from the following reports:

- Handbook of Illinois Stratigraphy; Illinois State Geological Survey Bulletin 95 (Willman et al, 1975).
- Coal Resources of Indiana; Indiana State Geological Survey Bulletin 42-I (Wier, 1973).

TABLE 4-1. COAL RESERVES BY SEAM

(Thousands of Short Tons)

ILLINOIS	INDIANA	KENTUCKY	TOTAL
Danville (No. 7) 7,791,547	Danville VII 5,539,698	No. 14 1,242,932	14,574,177
James town	Hymera VI 5,643,829	No. 12	5,643,829
Herrin (No. 6) 68,747,199	Herrin	No. 11 8,366,246*	77,113,445
Springfield-Harrisburg (No. 5) 50,620,791	Springfield V 7,432,426	No. 9 9,382,424	67,435,641
Shawneetown	Survant IV 2,986,880		2,986,880
Colchester (No. 2) 20,837,085	Colchester IIIa 4,270	Schultztown	20,841,355
Seelyville	Seelyville III 6,034,830		6,034,830
Davis 3,410,355		No. 6 (Davis) 7,474,404	10,884,759
Rock Island (No. 1) 1.575.194	Minshall 185,105	No. 4 (Mannington) 6,526,852	8,287,151
152,982,171	27,827,038	32,992,858	213,802,067

Illinois Data: Includes strippable, all coals indicated and hypothetical, 28" thick, less than 1000’
(11linois Geological Survey, oral communication)

Indiana Data: Total tons (January 1, 1965) measured, indicated and inferred, includes strippable
(Indiana Geological Survey, written communication, 1979)

Kentucky: Coal Resources of Western Kentucky, Kentucky G. S. Open File Report, includes strippable

*Includes Kentucky No. 12 resources

- Analyses of Tipple and Delivered Samples of Coal Collected During Fiscal Year 1977; DOE/ET-0045 (Janus, 1978); and
- 1978 Keystone Coal Industry Manual.

4.2.1 McCormick Group Coals

The McCormick Group coals are the lowest in the section and are comprised of coals in the Caseyville and Abbott Formations in Illinois, and their correlatives in the Mansfield and Brazil Formations in Indiana, and Caseyville and Tradewater Formations in Kentucky (Figure 4-4).

Numerous coal members have been identified in the McCormick Group sediments, the lowest members being characterized by:

- Lack of lateral persistence
- Greatly varying thickness within seams (few inches to 4 feet)
- Restricted occurrence to Indiana, Kentucky, and southeastern Illinois
- Mining on a local basis
- High moisture and ash, but low sulfur content

Higher in the McCormick section, the coals are more widespread and generally thicker. However, these coals, the Willis and the Lower and Upper Block members, are still quite restricted in their extent and require detailed mapping before mining or other commercial utilization can be attempted. The Lower and Upper Block coals are distinct in that a semi-splint variety of bituminous coal spits along two well-developed slip patterns at 90^{o} to each other, oriented at approximately N 20^{o} W and N 70^{o} E. These coals are dull banded, low in sulfur, and the Upper Block has a low ash content. Many of the McCormick Group coals outcrop in the extreme eastern portions of the basin and are locally strippable.

4.2.2 Spoon Formation Coals of the Kewanee Group

The Spoon Formation Coals of Illinois are part of the lower Kewanee Group sediments. The uppermost Brazil and all of the Staunton Formation in Indiana correlate with the Spoon Formation, as do the upper part of the Tradewater Formation and the lower part of the Carbondale Formation in western Kentucky. These formations contain the oldest widespread coalbeds in the basin; the coals are thicker and more extensive than coals of the McCormick Group and thinner than those of younger Pennsylvanian rocks of the Illinois basin.

Rock Island (No. 1) Coal Member

The Rock Island Coal is the basal member of the Spoon Formation and is the oldest coal in western 11 linois. It occupies a series of linear troughs up to four miles wide, treading east-west and northeast-southwest in western Illinois. The coal is typically four feet thick, but varies up to eight feet and down to a few inches at its margins. The roof rock of the coal is generally a fossiliferous limestone, the Seville. The floor rock is generally the Bernadotte Sandstone. Wanless et al (1969) report that the Rock Isl and was deposited in estuarine valleys prior to their drowning by a migrating sea. It is absent over large areas in Illinois but has been correlated with the Minshall coal of Indiana and the Mannington No. 4 coal of Kentucky. The Mannington, or Mining City No. 4 coal, is the most extensive of the major coals in western Kentucky. It is everywhere at least 14 inches thick, typically 42 to 56 inches thick in large areas of Hopkins and Muhlenburg counties, and up to 70 inches thick near Greenville, Kentucky. The No. 4 coal is generally 200 to 250 feet below the Kentucky No. 6 coal. The following is a summary of selected analyses of these coals:

	Rock Island No. 1 (Illinois)	Minshall[2]* (Indiana)	No. 4 [5] Kentucky)
Moisture (%)	14-18	11	10
Volatile Matter (%)	35-40	41	36
Fixed Carbon (%)	36-42	37-43	48
Ash (%)	7-10	11	5.8
Sulfur (%)	3-6	3-4	2.4
Btu/lb	10,400-11,200	11,100-11,400	12,300

*Superscript numbers refer to publications listed at the end of Section 4.

Davis Coal Member

The Davis Coal Member lies approximately 200 feet above the Rock Island Coal, averages 4 feet thick in southern Illinois and thins to the north and west. It is also called the No. 6 coal in Kentucky, where it thickens to 56 inches. It is present over nearly all of the western Kentucky coal field region and parts of southwestern Indiana. Much of the thicker coal (42 to 56 inches) is found in Union and Henderson Counties of Kentucky. The roof is typically a black marine shale overlain by limestone. The No. 6 coal varies from 265 feet to 230 feet below the Kentucky No. g coal, The Davis Coal is generally too deep for strip mining but has been mined locally by surface methods. Although relatively little is known about the chemical character of the No. 6 coal In Kentucky, it apparently has a low sulfur content. Selected analyses show the following:

	Davis (3) (Illinois)	No. 6 (6) (Kentucky)
Moisture (%)	5-7	5-12
Volatile Matter (%)	35-37	36-43
Fixed Carbon (%)	46-48	49-50
Ash (%)	8-10	8-13
Sulfur (%)	3-4	2-3
Btu/lb	12,500-12,800	11,100-12,800

De Koven Coal Member

The De Koven Coal Member is present in southernmost Illinois, and in Indiana, and Kentucky. It occurs from a few inches to 40 feet above the Davis and averaged 3 to 3 1/2 feet thick in Williamson, Saline, Gallatin Counties in Illinois. To the north and west, the coal is either absent or thin. Its furthest eastern extent is in Union and northwestern Henderson Counties of Kentucky. The roof rock is less commonly a marine fossiliferous shale than that of the Davis Coal. Analyses have shown the coal to have the following character:

	De Koven (Saline Co., Illinois) (3)
Moisture (%)	5-7
Volatile Matter (%)	35-37
Fixed Carbon (%)	46-48
Ash (%)	8-13
Sulfur (%)	3-5
Btu/lb	11,900-12,700

Seelyville Coal Member

The Seelyville Coal is among the uppermost coal members of the Spoon Formation and is an important minable coalbed in the eastern part of the Illinois basin. Its occurrence in Indiana is widespread, averaging six feet in thickness and increasing to as much as 10 feet. It also occurs up to six feet thick in Edgar, Clark, Crawford and Lawrence Counties of Illinois. The Seelyville is a highly banded coal which in some places has numerous shale partings that result in locally high ash contents. Analyses show the coal to have the following character:

	Seelyville (2) (Illinois)
Moisture (%)	11
Volatile Matter (%)	36-40
Fixed Carbon (%)	38-39
Ash (%)	11-15
Sulfur (%)	3-6
Btu/lb	10,500-11,100

4.2.3 Carbondale Formation Coals

The Carbondale Formation, from the basal Colchester (No. 2) Coal member through the Danville (No. 7) Coal member, includes the principal economic coals of the Illinois basin. The Carbondale Formation in Illinois correlates with the Linton, Petersburg, and Dugger Formations, or approximately the Carbondale Group in Indiana ; and with the upper portion of the Carbondale Formation and the lower part of the Sturgis (Lisman) Formation in Kentucky (see Figure 3-10). The coals of these formations are the thickest and most widespread of any coals in the Pennsylvanian section in the Illinois basin.

Colchester (No. 2) Coal Member

The Colchester Coal (No. 2) is the lowest coal member of the Carbondale Formation in Illinois. It is correlated with the Colchester (IIIa) coal in Indiana and the Schultztown coal in Kentucky. This coal is believed to be one of the most widespread coalbeds of the Illinois basin and the United States. It is absent in less than five percent of its outcrop area in the Illinois basin and has been correlated with coals in Iowa, Missouri, Oklahoma, and Pennsylvania. The Colchester (No. 2) is thickest (∿ 3.5 feet) in the northern and western parts of the basin. It uniformly thins to a few inches in thickness in southern Illinois, Indiana, and western Kentucky where its primary importance is that of a markerbed for correlation and mapping. The roof rock is a marine black shale except in parts of western and most of northern Illinois where the overlying strata are gray shales. The floor rock is a well developed underclay. The range of typical analyses in northern and western Illinois are:

	Colchester (No. 2) (3) (Illinois)
Moisture (%)	10-19
Volatile Matter (%)	31-45
Fixed Carbon (%)	35-48
Ash (%)	3-11
Sulfur (%)	1-5
Btu/lb	10,400-11,700

Shawneetown Coal Member

The Shawneetown Coal Member is a thin persistent coal occurring in southern and eastern Illinois. It is a relatively unimportant coal in Illinois, though it has been reported to occur locally as thick as eight feet. It is correlated with the Survant Coal (IV), as extensively mined coal in Indiana, and the No. 8 coal, a relatively unimportant unit in Kentucky. The Shawneetown is overlain by a dark shale and underlain by underclay. A shale parting divides the Survant Coal into two benches. The upper bench has a semi-blocky nature and the lower bench is more friable. The Survant coal averages four feet in thickness where mined, and when the shale parting is thin has a relatively low sulfur and ash content.

Summum (No. 4) Coal Member

The Summum coal is a laterally persistent coal member throughout Illinois. It is correlatable with the Houchin Creek (IVa) coal of Indiana and the No. 8b coal of western Kentucky. The coal is its thickest at one to two feet in the southern and eastern portions of the basin. It is overlain by a black shale and underlain by underclay. It normally lies within 25 feet of the overlying Springfield-Harrisburg (No. 5) and 50 feet of the underlying Shawneetown Coal. Analyses of this coal in northwestern Illinois show:

	Summum (No. 4) (3) (Illinois)
Moisture (%)	14-16
Volatile Matter (%)	37-39
Fixed Carbon (%)	38-40
Ash (%)	7-9
Sulfur (%)	3-4
Btu/lb	10,800-11,300

Springfield-Harrisburg (No. 5) Coal Members

The Springfield-Harrisburg Coal Members are the same unit, the name varying with location in Illinois. They are known as the Springfield (V) in Indiana, and the No. 9 in Kentucky. Together, they are commercially the most important coals in the Illinois basin. The Springfield-Harrisburg is present everywhere in the basin except in the extreme northern portions and in a few localities where it is known either to have been eroded or not deposited. Typical thicknesses of the coals are 4-8 feet in Illinois, 4-7 feet in Indiana, and 5 feet in Kentucky. It thins northward at a rate of one inch per mile in western Illinois, and is known to be as thick as 13 feet in Clay County, Indiana. Figure 4-7 illustrates the extent and thickness of the Springfield-Harrisburg coals in Illinois. The coals are underlain by underclay and usually overlain by a black fissile shale less than 3 feet thick, which in turn is overlain by marine limestone. Where the coal is thick enough, it may be distinguished by a positive resistivity response on electric logs bracketed between two negative peaks corresponding to the roof and floor rock. In some areas in southeastern Illinois the coal is thick, has a relatively low sulfur content, is commonly split by shale partings, and is over overlain by a gray silty shale. In addition, the coal in parts of western Illinois, and Sangamon, Logan and Menard counties, is frequently cut by claystone dikes.

The following are typical analyses of the Springfield-Harrisburg coals across the basin. They show a systematic decrease in volatile matter and an increase in fixed carbon percent and Btu/lb in a southeasterly direction across the basin.

Harrisburg-Springfield (NO. 5) (3)
(Illinois)
Range of typical analyses, Harrisburg-Springfield (No. 5) Coal
(as *received basis)*

	Counties			
	Peoria Fulton Tazewell Schuyler	*McLean Logan Menard Sangamon*	*Macon Shelby*	*Edgar*
Moisture (%)	**14-18**	**13-17**	**12-16**	**10-12**
Volatile matter (%)	**33-38**	**34-39**	**34-39**	**36-40**
Fixed carbon (%)	**34-40**	**36-41**	**35-40**	**37-43**
Ash (%)	**9-12**	**9-12**	**8-12**	**8-10**
Sulfur (%)	**2-4**	**3-5**	**3-4**	**3-4**
Calorific value (Btu/lb)	10,100-10,800	**10,400-l 1,000**		

	Randolph Perry	*Jackson*	*Gallatin Saline Williamson*	*Gallatin Eagle Valley*
Moisture (%)	**8-13**	*8-9*	**5-7**	**4-5**
Volatile matter (%)	**35-38**	**35-36**	**33-38**	**34-37**
Fixed carbon (%)	**40-44**	**44-55**	**47-53**	**48-52**
Ash (%)	**9-12**	**11**	**8-12**	**10-11**
Sulfur (%)	**4-5**	**3-4**	**2-5**	**3-4**
Calorific value (Btu/lb)	11,00-11,400	**11,600-l 1,800**	11,900-12,500	12,400-12,700

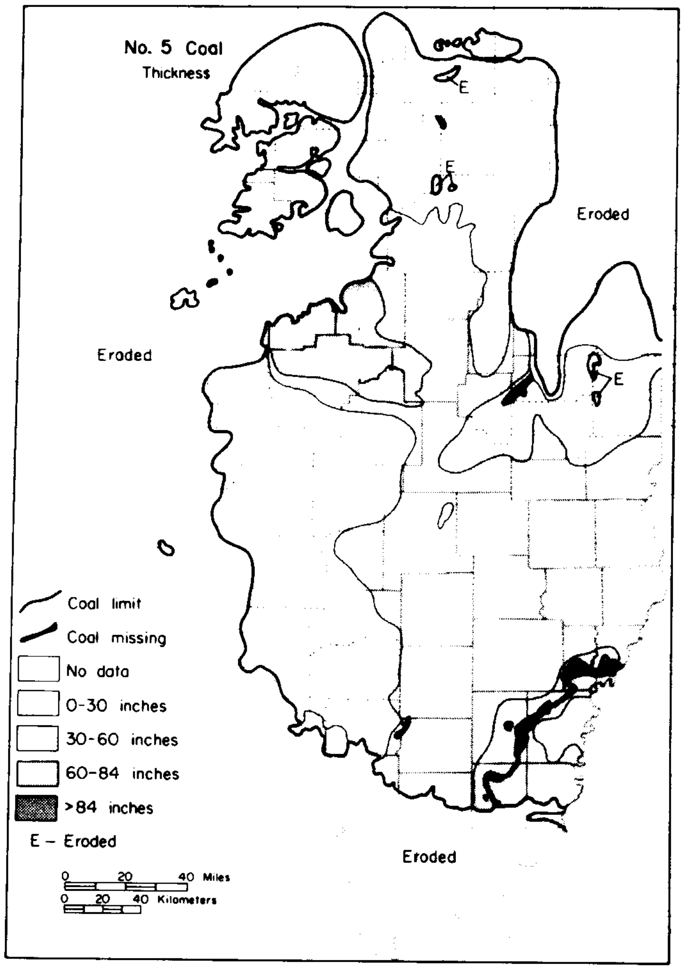


Figure 4-7 Generalized thickness of Harrisburg-Springfield Coal (figure P-12, Illinois Geol. Survey Bull. 95)

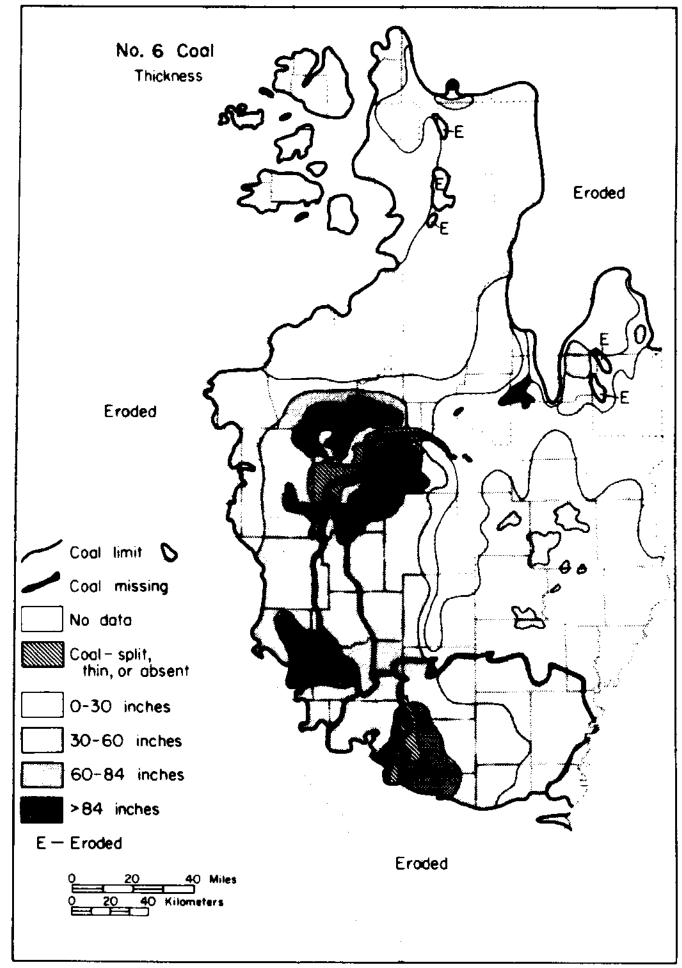


Figure 4-8 Generalized thickness of Herrin Coal (figure P-13, Illinois Geol. Survey Bull. 95)

	Springfield (V) (2) (Indiana)	No. 9 (5) (Kentucky)
Moisture (%)	8-10	5
Volatile Matter (%)	41	40
Fixed Carbon (%)	39-41	50
Ash (%)	9-11	11
Sulfur (%)	3-6	3
Btu/lb	11,600-1 1,700	12,900

Herrin (No. 6) Coal Member

The Herrin Coal Member is the most extensively mined coal in Illinois. It is correlated with the Herrin Coal Member in Indiana and the No. 11 coal in Kentucky. The Herrin is present throughout much of the Illinois basin, is typically more than 6 feet, and up to 15 feet thick (it averages approximately 1 foot thicker than the Springfield-Harrisburg (No. 5) across the entire basin). It is thin in parts of central and southeastern Illinois, and is probably not greater than 5 feet thick in Indiana. The extent and thickness of the Herrin (No. 6) in Illinois is shown in Figure 4-8. The Herrin (No. 6) coal is separated from the Springfield-Harrisburg (No. 5) coal by as few as 30 feet in the northern part of the basin and more than 130 feet in the southeastern portion of the basin (see Figure 4-9). The Herrin is characterized by a persistent claystone (shale) parting of l-3 inches in the lower part of the bed. The roof rock varies between black fissile shale, limestone, or gray shale. Where thick gray shales are the roof, coals are variable in thickness, contain gray shale lenses, and have relatively low sulfur contents. In addition, a channel sandstone, the Anvil sandstone, is associated with the thick gray shales and locally cuts out the coalbed. The area of highest quality Herrin Coal (Franklin, Williamson, and Jefferson Counties of Illinois) has been extensively mined. The Fairfield basin area of southeastern Illinois probably has the largest reserves of the Herrin (No. 6) coal; a detailed report, including thickness and structure maps of the Herrin in this region was compiled by Allgaier and Hopkins (1975). The Herrin coal is similar to the Springfield-Harrisburg coals in that there is a general systematic decrease in volatile matter, and increase in fixed carbon and Btu/lb from north to south across the basin (see Figure 4-l). Analyses across Illinois show the following character:

Range *of typical analyses, **Herrin** (No. 6) Coal by Counties* (3)
(as received **basis)**

(Illinois)

	LaSalle Grundy	*Bureau Stark Henry Knox*	*Peoria Fulton*	*Sangamon Macouple*
Moisture (%)	**36-41**	**16-20**	**15-19**	**12-16**
Volatile matter (%)	**13-16**	**31-35**	**32-35**	**35-40**
Fixed carbon (%)	35-40	**37-40**	**37-43**	**37-41**
Ash (%)	**7-11**	**6-13**	**6-13**	**9-11**
Sulfur (%)	**3-5**	**3-5**	**2-4**	**3-5**
Calorific value (Btu/lb)	**10,500-11,400**	9,700-10,300		**10.400-10.900**

	Christian Montgomery Bond Madison	*Douglas Vermilion*	*Clinton St. Clair*	*Marion Washington Randolph Perry*
Moisture (%)	**12-14**	**14-16**	**10-13**	**6-12**
Volatile matter (%)	**35-40**	**32-36**	**35-40**	**35-39**
Fixed carbon (%)	38-41	**36-41**	**37-42**	**38-44**
Ash (%)	**9-11**	**8-12**	**9-12**	**9-13**
Sulfur (%)	**3-5**	**1-3**	**1-4**	**1-4**
Calorific value (Btu/lb)	10,500-11,000	**10,400-11,100**	10,700-11,100	**10,600-11,300**

	Jefferson Franklin Jackson	*White Saline Williamson*	***Gallatin** (Eagle Valley)*
	7-10	*4-9*	**3-5**
	32-37	**30-36**	**32-35**
	45-50	**46-52**	**46-50**
	7-10	**7-10**	**10-13**
	1-3	**1-3**	**3-4**
	11,600-12,000	11,700-12,300	12,400-13,700

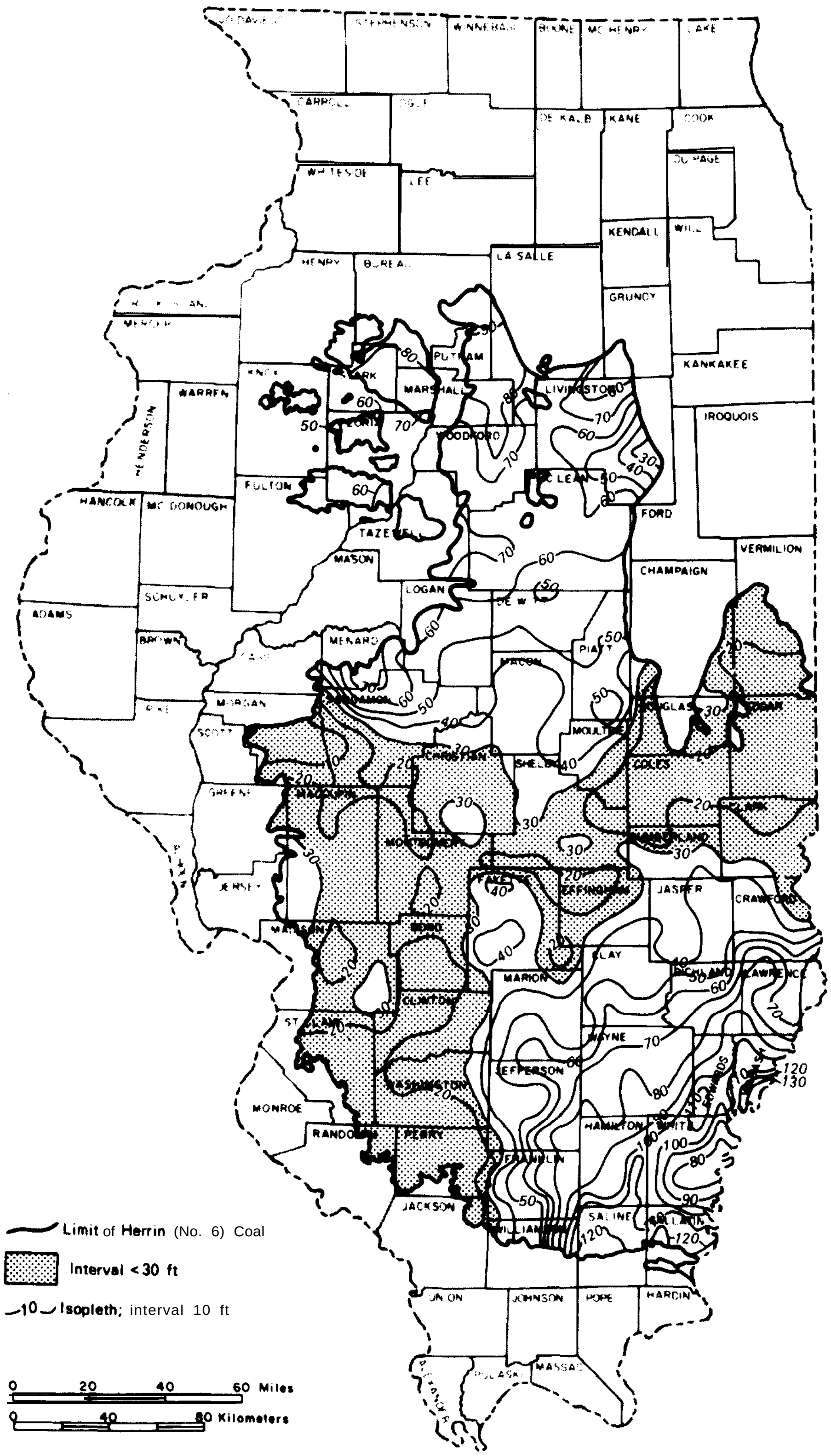


Figure 4-9 Generalized thickness of the interval between the Herrin and Harrisburg-Springfield Coals (figure 20, Illinois Geol. Survey, Coop. Resource Report 4)

Jamestown Coal Member

The Jamestown Coal Member is a widespread, thin, and relatively unimportant coalbed occurring in southern Illinois. However, it correlates with the commercially important Hymera (VI) and No. 12 coals of Indiana and Kentucky respectively. It averages 5 feet and runs up to 8 feet thick in underground Indiana mines. The coal is persistent in Kentucky but greatly varies in thickness over the entire western Kentucky coal field. It is generally thin (< 14 inches) near the Illinois boundary, in Union and Henderson counties, but thickens through central Hopkins, Webster, and northern Muhlenburg counties where it is greater than 70 inches thick in numerous local basins.

In Indiana, the coal is stratigraphically close to the overlying Danville and is mined in conjunction with it. In Kentucky, the No. 12 coal is often mined in conjunction with the underlying No. 11 coal. One or more clay partings are known to exist in the Hymera coal in the northern coal fields of Indiana. Analyses show the Hymera coals to have ash content similar to the underlying Springfield coals, but to be considerably lower in sulfur content. Typical range of analyses in Indiana are:

	Hymera VI (2) (Indiana)
Moisture (%)	6-13
Volatile Matter (%)	32-36
Fixed Carbon (%)	41
Ash (%)	10-18
Sulfur (%)	3-4
Btu/lb	10,400-11,100

Danville (No. 7) Coal Member

The Danville Coal Member is the uppermost member of the Carbondale Formation and is the highest commercial coalbed of the Illinois basin. It is extensive but generally only of minable thickness in the northern portion of the basin and east of the LaSalle anticline. The Danville (No. 7) is known as the Danville (VII) in Indiana, and as the No. 14 coal in western Kentucky. The coals are 2.5 to 6 feet thick where mined and generally a few inches to 3 feet thick in other areas.

The overlying stratum is usually a gray shale and the underlying stratum is a thick (50-100) feet uniform underclay. Because of these units, the coal horizons are quite easily picked from geophysical logs and thus serve as excellent marker beds. In contrast with the underlying Hymera Coal, the Danville has relatively few partings and is usually lower in ash content.

Typical analyses showing the character of the Danville Coals are shown below:

	Danville (No. 7) (3) (Illnois)	Danville (VII) (2) (Indiana)
Moisture (%)	13-19	11-13
Volatile Matter (%)	33-39	35
Fixed Carbon (%)	34-40	40-42
Ash (%)	9-l 5	11-12
Sulfur (%)	3-4	2
Btu/lb	9,600-l 1,300	10,300-10,900

4.2.4 McLeansboro Group Coals

The McLeansboro Group of the upper Pennsylvanian sequence contains at least 15 coal horizons within the Illinois basin. These coalbeds are generally quite thin, less than 1 foot, of extremely variable quality, and of limited or unknown lateral extent. Only rarely has a coalbed occurred in minable thickness. An example is the Fairbanks Coal in western Sullivan County, Indiana. Here the coal has been mined along its outcrop. Coals of the McLeansboro Group are reported to have an average ash content of 28% and sulfur content of 2%.

4.3 STRUCTURAL CHARACTER

The structural character of coals of the Illinois basin, such as fracture or cleat density and orientation, has not been systematically investigated on a basin-wide scale. Comparison of local or county-wide studies is difficult as there is no consensus by authors on what should be defined as cleat and what as fracture, and what tectonic forces or conditions are responsible for producing each. What can be said, however, is that:

- Major cleat orientation is often not apparent when investigations are made on a small scale (outcrop, small section of mine, etc.).

- No areas in the basin have been reported to have a higher density of cleats or fractures relative to other areas.

- However, the southeastern portion of the basin is intensively faulted and folded in comparison with the remainder of the basin, suggesting the presence of at least local areas with high fracture density.

- Fractures in the coal generally have been mineralized, and thus have low permeabilities.

Structure contour maps on top of individual coalbeds often are available on a county basis. Appendix D provides an index to these and other coal structure maps in the basin. A few coal seams have been mapped over the entire or larger portions of the basin and these maps are included in this report. Where structure contour maps on the coal are unavailable, it is possible to use structure maps on other marker beds when a good idea of the section between the marker bed and the coal of interest is known. Contour maps on numerous sandstones and limestones in the Pennsylvanian and Mississippian are available in the literature for heavily drilled oil and gas areas of the basin.

As noted in Section 3.3, the deepest portions of the. Illinois basin are in the Fairfield basin, which includes a large area in southeastern Illinois; and the Moorman syncline, just south of the Rough Creek fault system in Kentucky. The Fairfield basin covers a much larger area and is uniformly deeper than the Moorman syncline. For example, the Herrin (No. 6) and Springfield-Harrisburg (Mo. 5) coals are at depths of greater than 1,000 feet over large areas of Cumberland, Effington, Jasper, Clay, Richland, Wayne, Edwards, Hamilton, and White Counties,' Illinois, as shown in Figures 4-10 and 4-11. The Moorman syncline, however, is much smaller but contains numerous graben type features which bring major coals in some locations to depths exceeding 2,000 feet, Although these deepest areas are not shown, Figure 4-12 illustrates the large areas in Union, Webster, and Hopkins Counties, where the Davis (No. 6) coal is at depths below 1,200 feet (note that there is typically 400-500 feet of positive relief in this region). The structure contours on the Colchester No. 2 coal (Figure 4-13), as mapped by Wanless

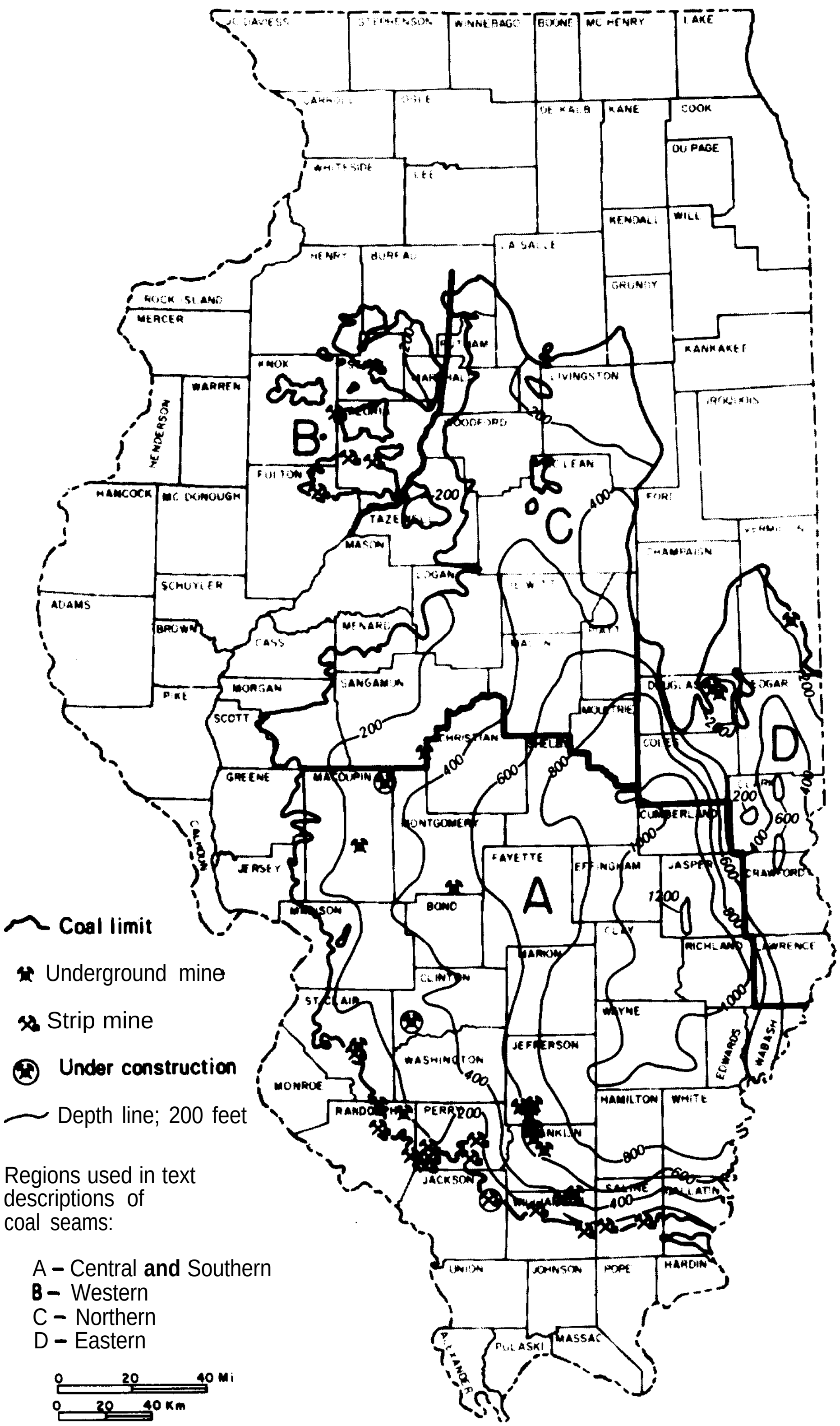


Figure 4-10 Generalized depth of the Herrin Coal. Mines active in the Herrin seam on January 1, 1975 are indicated (figure 15, Illinois Geol. Survey, Coop. Resource Report 4)

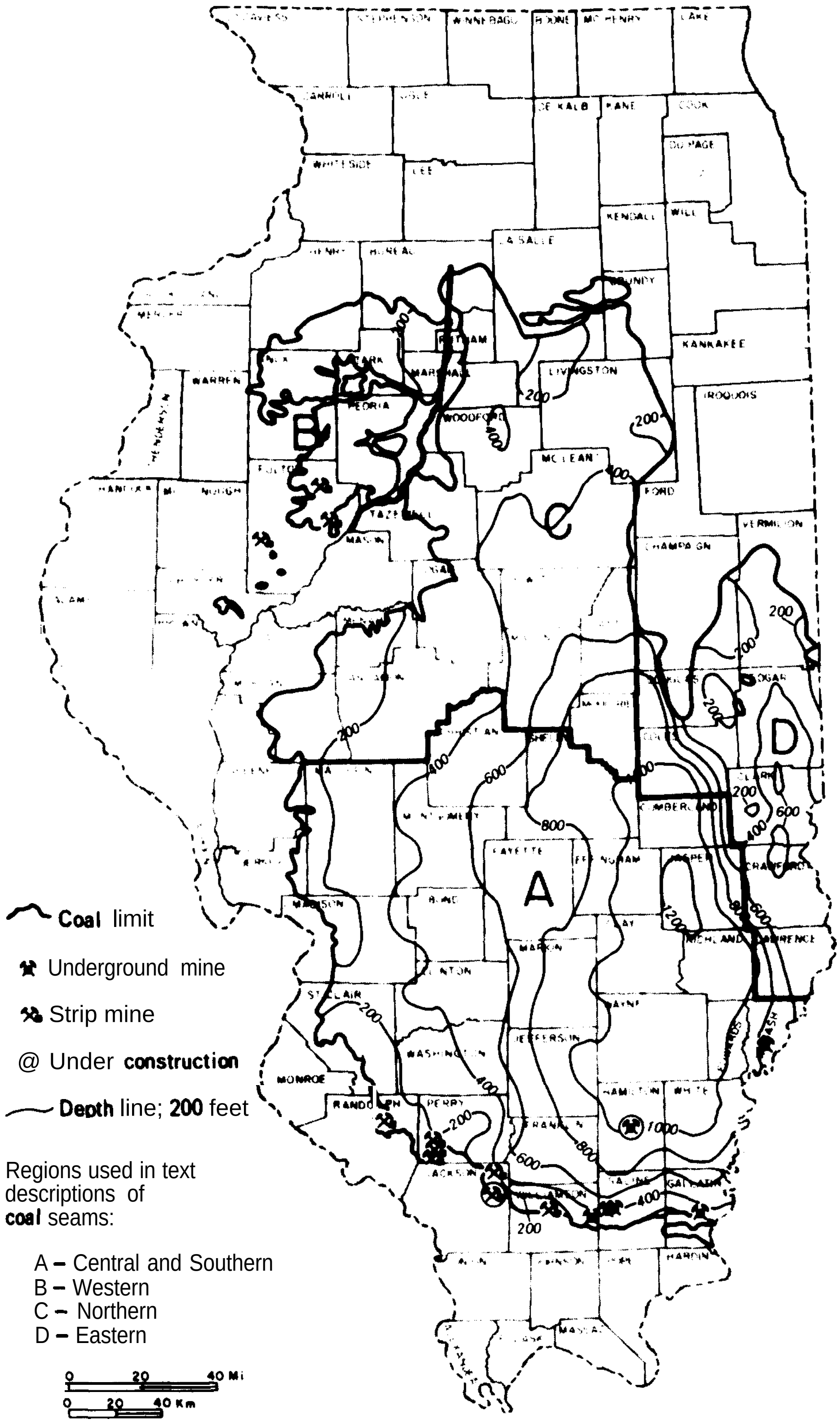


Figure 4-11 Generalized depth of the Harrisburg-Springfield **Coal** Mines active in the **Harrisburg-Springfield seam on January 1, 1975 are located (figure 17, Illinois Geol. Survey, Coop. Resource Report 4)**

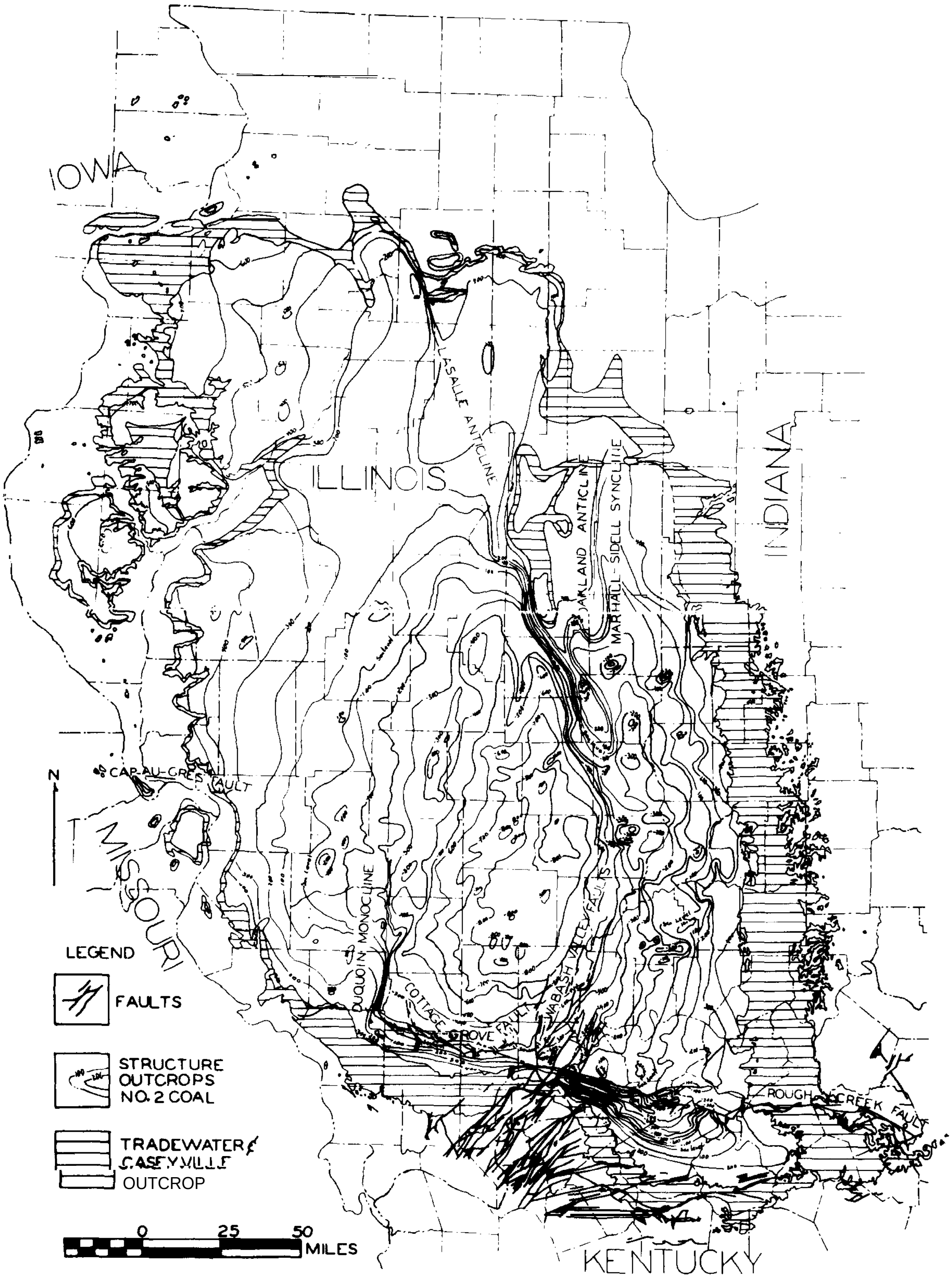


Figure 4-13 Structure-contour map of Illinois basin on Illinois coal No. 2 (figure 8, Wanless, 1962) (courtesy AAPG, June 1979)

(1962), further demonstrate that the Fairfield basin and Moorman syncline areas are the deepest portions of the Illinois basin.

Regional cross sections through southeastern Illinois, illustrating the position of the No. 7 to the No. 2 coals, are provided in Figure 4-14 (Plate 2, Illinois State Geological Survey Circular 489). Regional cross sections through the western Kentucky coal field region (Figures 4-15 and 4-16) likewise show the depths and positions of numerous coals in this area (note that the No. 7 coal as marked on these cross sections is actually the Davis No. 6 coal).

References for tabular data in Section 4:

1. Willman, H.G., Atherton, E., Buschbach, T.C., Colliman, C., Frye, J.C., Hopkins, M.E., Lineback, J.A., and Simon, J.A., 1975, Handbook of Illinois Stratigraphy: Illinois State Geol. Survey Bull. 95, 261 p.

2. Wier, C.E., 1973, Coal Resources of Indiana; Indiana State Geol. Sur. Bull. 42-1, 40 p.

3. McGraw-Hill Mining Informational Services, 1978, Keystone Coal Industry Manual, McGraw-Hill, p. 478-489.

4. McGraw-Hill Mining Informational Services, 1978, Keystone Coal Industry Manual, McGraw-Hill, p. 490-493.

5. McGraw-Hill Mining Informational Services, 1978, Keystone Coal Industry Manual, McGraw-Hill, p. 501-506.

6. Janus, J.B., 1978, Analyses of Tipple and Delivered Samples of Coal Collected during fiscal year 1977: U.S. DOE/ET-0045, 15 p.

5. POTENTIAL METHANE RESOURCE

5.1 PREVIOUS STUDIES/ANALYSES

Previous studies involving the desorption of methane gas from coal in the Illinois basin are limited to a few tests made by the Illinois and Indiana State Geologic Surveys and the United States Bureau of Mines (USBM). Location of this data by county is shown on the map in Figure 5-l. The Herrin (No. 6) and the Springfield-Harrisburg (No. 5) coals and their correlatives in Indiana have been sampled most often. Very little data exist on the methane content of major coal seams such as the Colchester No. 2 of Illinois and the Davis No. 6 and Mannington No. 4 of Kentucky.

The estimated gas content of the Herrin (No. 6) ranges from 32 to 109 cubic feet per ton. A similar range of values, 32 to 147, has been estimated for the Springfield-Harrisburg (No. 5) coals. This variability cannot be directly related to sample depth alone, since the gasier coals were from the shallower horizons--contrary to what might be expected--but is related to other geologic controls, analytical errors , or to the method used in determining the "remaining" gas. The graphical method of determining the "remaining" gas in coal samples (McCulloch, et al, 1975) has been found by the USBM to be invalid. Aside from the problem of ascertaining whether a particular coal sample should be classified as blocky or friable, the graph used for estimating "remaining" (residual) gas was constructed using data obtained by mechanically crushing samples in a "crushing box." Data which was generated through use of the crushing box is now disputed due to confirmed leakage of gas from the box. Thus, the data in Table 5-l generated by use of the graphical method, denoted by (G), should be considered questionable and used with care.

The only predrainage or degasification test to date in the Illinois basin was performed by the USBM in Jefferson Co., Illinois. Five vertical boreholes were drilled and stimulated at an average depth of 733 feet in the Herrin (No. 6) coalbed. Although a drop in methane concentration was observed when the borehole was passed during mining, the holes produced little gas. According to USBM Report of Investigations 8260 (Elder, 1977), which gives a complete discussion of the predrainage tests, the gas flow increased from an initial 10 to 4,300 cubic feet per day. This flow rate thus raises a large question as to the producibility of the methane resource in this relatively less tectonically disturbed portion of the basin.

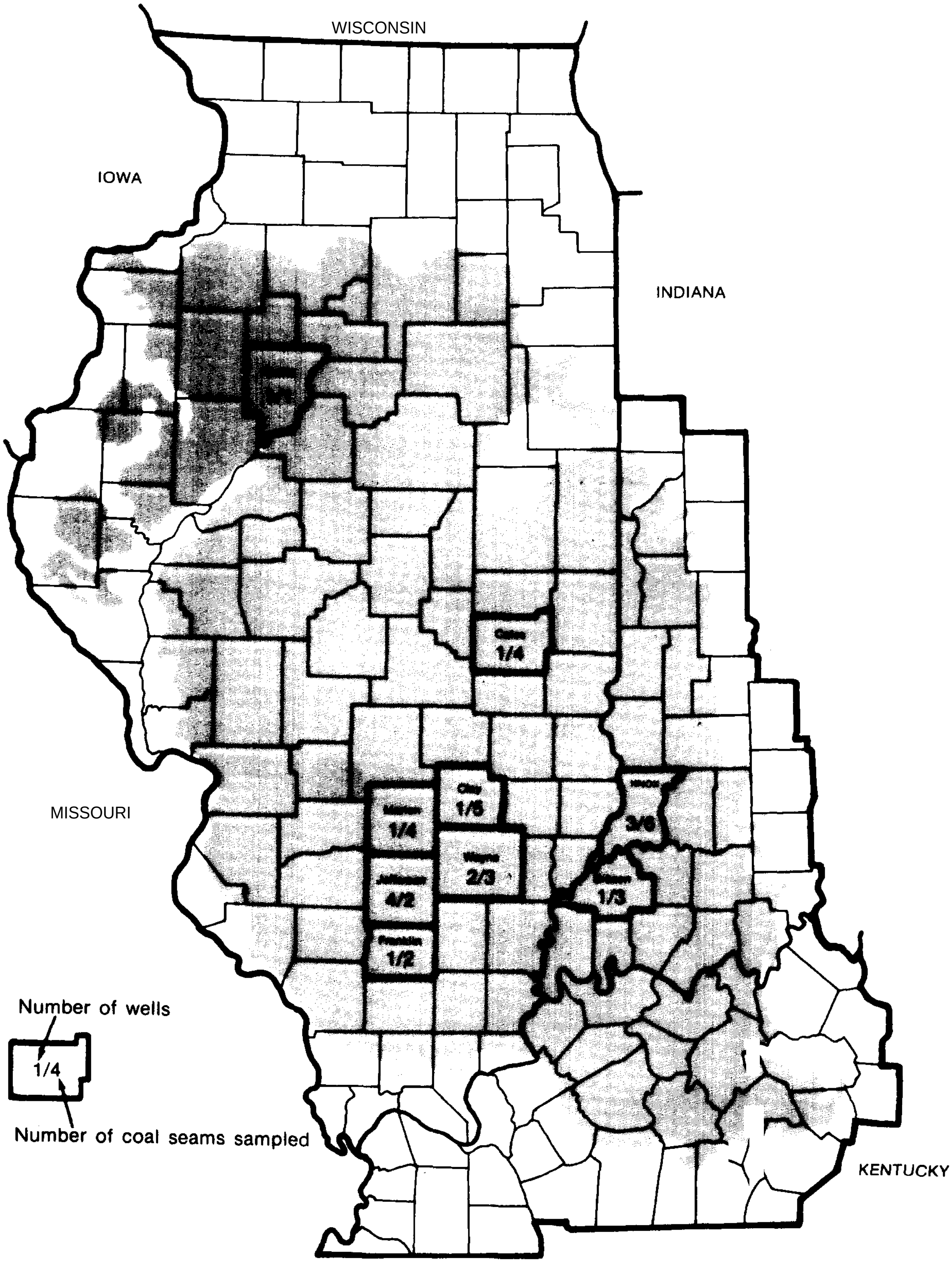


Figure 5-1 Illinois basin map locating counties in which methane desorption data are available

TABLE 5-1
METHANE DESORPTION DATA FROM THE ILLINOIS BASIN

Coalbed	State	County	Depth (Feet)	Desorbed Gas (cc/g)	Remaining Gas* (cc/g)	Total Gas Content (cc/g)	(cu ft/ton)
Danville (No. 7)[a]	Illinois	Clay	994	0.9	0.4 (BM)	1.3	40**
Herrin (No. 6)a	do	do	1035	0.6	0.4 (BM)	1.0	32**
Briar Hill (No. 5a)	do	do	1075	0.5	0.5 (BM)	1.0	32**
Harrisburg (No. 5)	do	do	1090	0.9	0.3 (BM)	1.2	38**
Seelyville	do	do	1352	1.1	0.4 (BM)	1.5	48**
Shelbyville (?)	do	Coles			Analysis in Progress		
Danville (No. 7)	do	do			Analysis in Progress		
Herrin (No. 6)	do	do			Analysis in Progress		
Harrisburg (No. 5)	do	do			Analysis in Progress		
Herrin (No. 6)	do	Franklin	~650	1.7	Not Determined		53
do	do	do	~650	2.3	Not Determined		72
do	do	do	~650	2.2	Not Determined		69
Harrisburg (No. 5)	do	do	~700	1.2	Not Determined		38
do	do	do	~700	2.2	Not Determined		70
do	do	do	~700	1.9	Not Determined		62
Herrin (No. 6)	do	Jefferson	733	1:B	0.1 (CB)	1.9	61
Harrisburg (No. 5)	do	do	793	0.8	0.2 (CB)	1.0	32
Danville (No. 7)	do	Marion	664				**
Herrin (No. 6)	do	do	698				**
Briar Hill (No. 5A	do	do	727				**
Harrisburg (No. 5)[a]	do	do	732				**
Colchester (No. 2)	do	Peoria	133	0.6	0.5 (G)	1.1	35
Herrin (No. 6)	do	Wayne	900	1.2	0.7 (G)	1.9	61
do	do	do	969	1.6	1.8 (G)	3.4	109
Harrisburg (No. 5)	do	do	1010	2.4	1.3 (G)	3.7	118
do	do	do	1066	1.4	1.3 (G)	2.7	86
Seelyville	do	do	1287	1.3	0.7 (G)	2.0	64
do	do	do	1290	1.5	1.6 (G)	3.1	99
Herrin	Indiana	Gibson	580	1:B	1.1 (G)	2.9	93
Springfield (V)	do	do	665	-	- (G)	4.5	144
Seelyville (III)	do	do	994	1.3	0.9 (G)	2.2	70
Danville (VII)	do	Knox	339		- (G)	2.8	91
do	do	do	413	2.2	1.4 (G)	3.6	116
Hymera (VI)	do	do	361	-	- (G)	1.7	55
Hymera (VI)	do	do	422	2.2	1.4 (G)	3.6	116
Coal Vb	do	do	522	1.9	1.2 (G)	3.1	100
Springfield (V)	do	do	420	2.7	1.9 (G)	4.6	147
do	do	do	536	2.5	1.7 (G)	4.2	134
Survant (IV)	do	do	695	2.8	1.9 (G)	4.7	149

a - Data is average of two or more samples.

* - Method of determination is indicated: (BM) - Gas released by crushing sample in ball mill.
(G) - Graphical method as in USBM RI 8043.
(CB) - Gas released in crushing box.

** - MRCP data.

TABLE 5-2
GAS EMISSION DATA FROM COAL MINES IN THE ILLINOIS BASIN

Name of Mine	County	Coalbed	Average Depth Of Shaft Or Slope (Ft.)	Age Of Mine (Yr.)	Coal Production (Tons/Day)	Cubic Ft. Of Gas Ton Of Coal Mined (Cf/Ton)	Year Data Collected
Orient #3	Jefferson, Il.	Herrin (No. 6)	800	27	9,670	186	1973
Orient #6	do	do	530	4	8,950	113	1971
Inland	do	do	735	10	9,500	126	1975
Old Ben #21	Franklin, Il.	do	666	16	6,200	258	1975
Old Ben #24	do	do	660	11	8,000	237	1975
Old Ben #26	do	do	658	8	8,600	208	1975
Peabody #10	Saline, Il.	do	325	24	16,800	89	1975
Crown	Montgomery, Il.	do	500	25	8,400	124	1971
Fies	Hopkins, Ky.	No. 11	200	24	4,200	286	1973
Wabash	Wabash, Il.	Harrisburg (No. 5)	768	3	6,800	206	1975

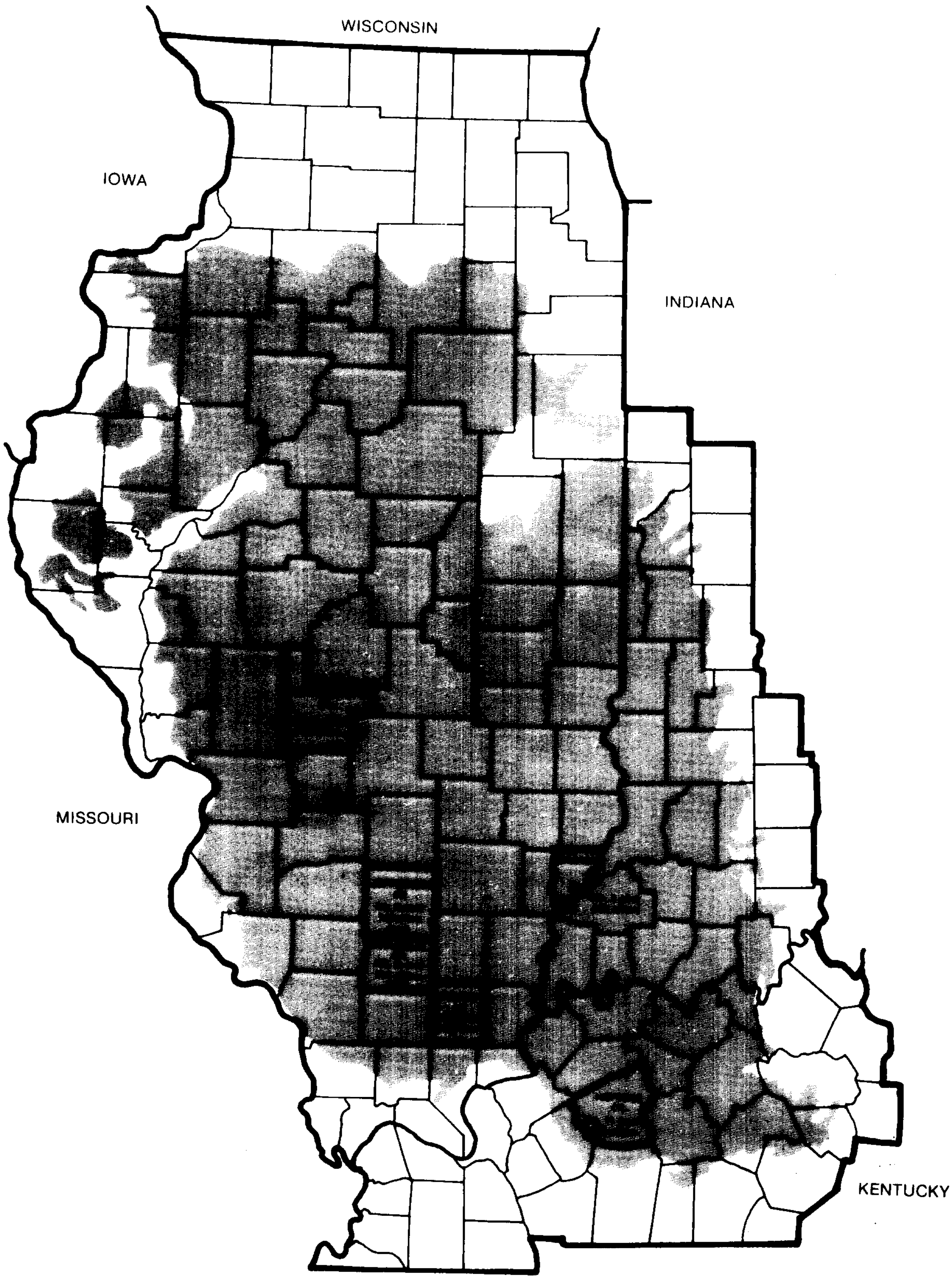


Figure 5-2 Illinois basin map locating coal mines, by county, and the amount of gas emitted per ton of coal mined

The only other reports giving an indication of the methane gas associated with particular coalbeds are from mine methane emission surveys. These are available from the United States Department of Labor Mine Safety and Health Administration (MSHA) but cannot be used directly to estimate the gas content of a coalbed because once mining has occurred a significant portion of the methane emitted into a mine may come from adjacent strata. However, correlation between the amount of gas emitted from coal mines and the gas content predicted from the "direct method" of coal core desorption for large deep mines that have been producing for a few years up to levels of at least a few thousand tons a day (see USBM RI 7767 and 8043). Available published data are given in Table 5-2 and shown in Figure 5-2 on a county basis. In the Illinois basin area, total gas emitted during mine operations is typically on the order of 4 to 7 times the gas indicated to be present in the coal from USBM "direct method" determinations.

5.2 METHANE RECOVERY FROM COALBEDS PROJECT DATA

Methane Recovery from Coalbeds Project data on the methane gas content of Illinois basin coals are presently limited to coring and well testing in Clay and Marion Counties of Illinois. In Clay County, five coal seams were cored between depths of 994 and 1,352 feet (see TRW, Preliminary Well Test Report, Illinois Basin Site AA) and samples were desorbed for approximately five months using the USBM's direct method. Desorption data and total gas content for the coalbeds are presented below (Table 5-3). These numbers should be considered minimal values as some leakage of methane gas is suspected to have occurred between desorption measurements.

Table 5-3. Methane Data from Coals Sampled in the Hagen Oil, Henderson #2 Well, Clay County, Illinois

Coalbed	Depth (feet)	Desorbed gas (cc/g)	Remaining gas (cc/g)	Total gas content (cc/g)	Total gas content (ft^3/ton)
				1.3	
Danville (No. 7)	994	0.8	0.5	1.2	42
do	995	0.9	0.3	...	38
do (No. 6)	1035	0.6	0.3	0.9	29
Briar Hill (No. 5A)	1036 1078	0.6 0.5	0.5 0.5	1.1 1.0	32 35
Harrisburg (No. 5)	1091	0.9	0.3	1.2	38
Seelyville	1352	1.1	0.4	1.5	48

In Marion County, the same coal seams, excluding the Seelyville, were cored at depths between 664 and 736 feet and sampled for desorption testing (see TRW, Preliminary Well Test Report, Illinois Basin Site AB). Tests are still in progress.

5.3 COMMERCIAL GAS PRODUCTION FROM COALBEDS

Virgin coal has never been a target in the Illinois basin to which an operation has drilled for the purpose of commercial gas production. To date, coalbed gas production has been limited to mined-out (gob) areas in Saline County, Illinois. Two parties, Petro-Search Associates of Harrisburg, Illinois and WOERA of Eldorado, Illinois are presently producing a combined 400 Mcf/d from 3 wells. Gas production is at low pressures. The methane content has been between 90 and 92%. After compression to about 25 psi, the gas is sold to United Cities Gas Corporation for direct use in its system. It was these operators' opinion that many additional "gob" gas wells could be economically viable at this time. It should be noted that the present wells were placed into old and completely sealed off mines and that the gas user was local. Both parties are expanding their lease and marketing agreements and intent to produce gas from additional mined-out areas in the near future.

Petro-Search Associates is also investigating the feasibility of fracturing virgin coal and attempting to produce the gas. If they decide to pursue this option, they will fracture the Illinois No. 5 coal at a depth of about 450 ft. This experiment would be performed in Saline County on property where Petro-Search Associates owns both the coal and gas rights.

5.4 ESTIMATED RESOURCE VOLUME

The limited data available on the methane content of coals in the Illinois basin makes it difficult to make an accurate resource estimate at this time. A detailed resource estimate requires precise knowledge of each coal's physical and chemical character (including rank, depth to coal, porosity, etc.) and how these properties affect the methane content of the coal.

Based on the limited data in Tables 4-l and 5-1, it is possible, however, to present reasonable ranges for the maximum and minimum expected <u>in-place</u> gas resource of coals in the Illinois basin. These estimates have been made for the Danville, Herrin, Springfield-Harrisburg, and their equivalent coals (Table 5-4). Estimated total coal reserves for the Danville (No. 7) coal seam, and its equivalents, are over 14.5 billion short tons. Given a range of gas contents from 40 to 116 cubic feet per ton, minimum and maximum gas resource estimates are 0.5 and 1.7 trillion cubic feet. The total Herrin (No. 6) and equivalent coal reserves are estimated at over 77.1 billion tons. Given a range of gas contents from 32 to 109 cubic feet per ton, minimum gas resource estimates are 2.5 and 8.4 trillion cubic feet. Likewise, the Springfield-Harrisburg (No. 5) and equivalent coals with total reserves of over 67.4 billion tons, and gas contents of 32 to 147 have gas resource estimates of 2.2 and 9.9 trillion cubic feet,

The minimum in-place gas resource for these three seams totals over 5 trillion cubic feet. It is reasonable to assure that the methane resource contained in major deeper coals (Colchester, Davis, etc.) may add significantly to this figure. It should be noted again that even though the specific gas content of coals in the Illinois basin is quite low, the simple magnitude of the coal resource of the Illinois basin produced large in-place gas resource estimates.

TABLE 5-4. ESTIMATED IN-PLACE COALBED GAS RESOURCE

(1 JUNE 1979)

Coal Seam	Gas content cubic ft./ton	Gas Resource cubic ft. minimum	Gas Resource cubic ft. maximum
Danville (and equivalents)	40 - 116	5.83×10^{11}	1.69×10^{12}
Herrin (and equivalents)	32 - 109	2.47×10^{12}	8.41×10^{12}
Springfield-Harrisburg (and equivalents)	32 - 147	2.16×10^{12}	9.91×10^{12}

6. CONCLUSIONS AND RECOMMENDATIONS

Although the data are derived from a relatively small data base, it appears that the gas content of coals in the Illinois basin is low--30-150 cubic feet per ton. Additionally, there seems to be a general increase in gas content towards the southeastern portion of the basin as a whole and initial target area defined by the MRCP.

On the basis of information gathered in this report, it is possible to redefine those areas of the basin which hold the greatest probability for early commercial coalbed methane gas production. The criteria used to select areas with the greatest potential methane resource are:

- Areas reporting exceptionally gassy coals
- Areas having the thickest cumulative section of coal
- Areas having the highest coal rank
- Areas whose major coal units are at the greatest depths
- Areas where some structural deformation has potentially enhanced coal porosity and permeability.

Two target areas which meet these criteria and thus have the highest potential for early commercialization of coalbed gas in the Illinois basin are outlined in Figure 6-l.

For the "Fast Track" commercialization effort of the MRCP, it is recommended that a minimum of three Type I wells be planned in these target areas and directed toward the acquisition of data in specific reservoirs and locations which have not been adequately sampled to permit precise methane resource estimates. If gas content and reservoir analyses justify, an additional Type III test in this area may be necessary.

Area A, located in western Kentucky in the Moorman syncline region, has relatively high-rank coals, many of which are located below 1,000 feet of overburden. This area should receive top priority in testing because of its favorable geologic setting (meeting the above criteria) and because no data on the methane content of coals in this area presently exists. It is recommended that core samples be obtained from two wells within this region; both should penetrate the Davis (No. 6) and, if possible, the Mannington (No. 4) coal. Drill stem tests and porosity/permeability determinations should be made to ascertain potential gas producibility.

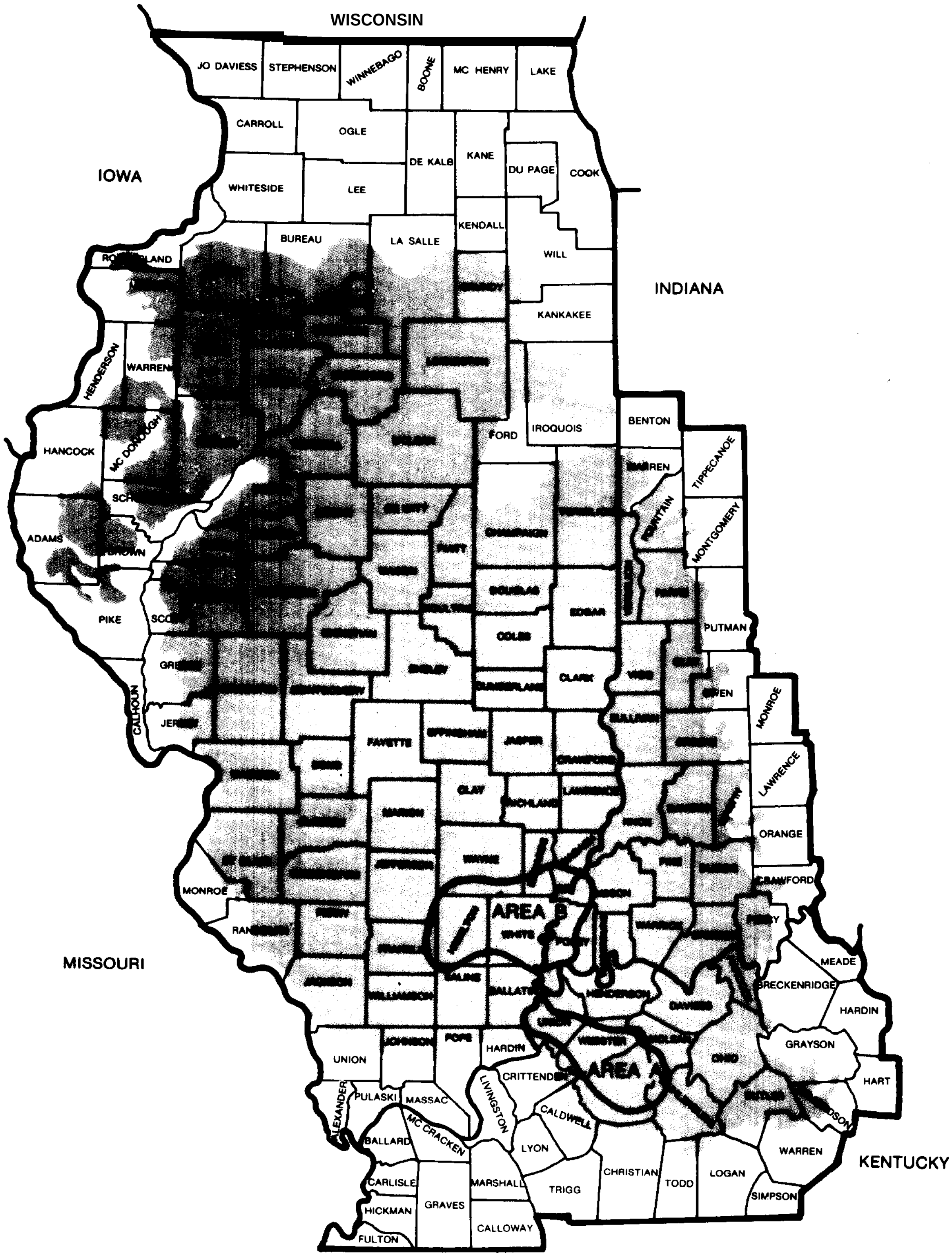


Figure 6-I Redefined Illinois Basin Coalbed Methane Target Areas

Target Area A covers approximately 1,100 square miles. The total estimated coal resource in the area is near 15.5 billion short tons. Although no coals have been sampled for desorption testing in this area, a conservative estimate of the gas content based on the depth, rank, and reported gassy nature of the coals, is 90 cf/ton. The resulting estimated in-place resource is 1.4 trillion cubic feet of gas or 2,000 mcf/acre. The cumulative thickness of major seams in this area is typically 15 feet; under these conditions the specific in-place gas resource is on the order of 133 mcf/acre-ft.

Area B, located in the southern part of the Fairfield basin is targeted because it has a favorable combination of geologic features (meeting the above criteria) and has not been adequately sampled. One or two wells should be drilled in this area; each should penetrate the Colchester and Seelyville coals. These wells will serve the dual purpose of verifying previously acquired data, and will provide data from deeper, less frequently sampled coal seams. The position of the wells in this target area should be <u>carefully</u> planned (not randomly selected) due to local variability of thickness and structure. In this way, the total coal section may be maximally cored and wells may be located in particular areas which provide structural enhancement of coal porosity and permeability. Drill stem tests and in situ porosity/permeability determinations also should be a part of these well test programs.

Target Area B includes approximately 3,200 square miles. The total estimated coal resource of this area is over 18.6 billion short tons. Of this, the Herrin (No. 6) and Springfield-Harrisburg (No. 5) coals contain 5.5 and 7.6 billion tons, respectively. Based on desorption data presently available, a modest estimate of 70 cubic feet of gas per ton of coal can be used to provide in-place gas resource estimates. The total in-place gas resource is approximately 1.3 trillion cubic feet, which converts to 635 mcf/acre. The Herrin (No. 6) coal is estimated to contain 400 billion cubic feet of gas, or 195 mcf/acre. The Springfield-Harrisburg (No. 5)) is estimated to contain 500 billion cubic feet of gas, or 244 mcf/acre. The cumulative coal thickness in this area is typically 10 feet; under these conditions the specific in-place gas resources are estimated to be near 64 mcf/acre-ft. for the total coal section.

Once these two target areas have been adequately tested, an evaluation of the resource data should be made to determine the requirement for, or value of, additional testing in the Illinois basin. If sufficient gas is found, and reservior evaluation suggest that production of methane gas from coalbeds in these areas in viable, then additional Type III wells should be planned for the purpose of gathering specific reservoir and production data from the coalbeds.

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APPENDIX A

MAPS AND MAP INDEXES OF ILLINOIS BASIN

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SELECTED PUBLICATIONS DEALING WITH COAL RESERVES AND PRODUCTION IN THE ILLINOIS BASIN AREA

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ILLINOIS STATE GEOLOGICAL SURVEY

B 78 Minable Coal Reserves of Illinois. 1952.

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