489

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Reserves of the Herrin (No. 6) Coal in the Fairfield Basin in Southeastern Illinois

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RESERVES OF THE HERRIN (NO. 6) COAL IN THE FAIRFIELD BASIN IN SOUTHEASTERN ILLINOIS

G. J. Allgaier and M. E. Hopkins

ABSTRACT

A thickness map of the Herrin (No. 6) Coal Member in the Fairfield Basin in southeastern Illinois was constructed using data from more than 4,100 electric logs. Areas in which the coal is either thin or absent, areas heavily drilled for oil and gas, areas in which coal has been mined out, and cutouts filled with sandstone have been excluded from calculations of classified reserves. After these exclusions, the classified reserves of the of the Herrin Coal greater than 3½ feet thick were estimated to be 14.6 billion tons.

In the area of study (5,809 square miles), only about 34 square miles of Herrin Coal have been mined. Mining of the Herrin Coal has been extensive south of the area of study, in shallower parts of the Fairfield Basin. From this study, deposits of relatively thick coal are inferred in some areas in the deeper part of the basin.

The normal roof lithologies of the Herrin Coal in the area consist of 2 to 3 feet of black "slate" (Anna Shale Member) and 2 to 4 feet of limestone (Brereton Limestone Member). In parts of Jefferson and Franklin Counties, the coal is directly overlain by a gray shale herein named the Energy Shale Member of the Carbondale Formation. Deposits of relatively low-sulfur Herrin (No. 6) Coal are found only in association with the Energy Shale.

INTRODUCTION

The Herrin (No. 6) Coal Member of the Carbondale Formation (Pennsylvanian) in Illinois is widespread, persistent in thickness, and readily identifiable in the subsurface through study of diamond-drill cores and geophysical logs. It is also the most important coal bed in Illinois, both in reserves and in production. Of the state's total mapped reserves, the Herrin Coal accounts for 65.8 billion tons, or 44 percent of the total (Hopkins and Simon, 1974); in 1973, 75 percent of the state's production was from this seam.

This report presents a thickness map of the Herrin Coal (pl. 1) and an estimate of its reserves for an area of southeastern Illinois where there has been little mining of the coal (fig. 1). This area contains the greater portion and deepest part of the Fairfield Basin; it includes all of Clay, Crawford, Edwards, Effingham, Hamilton, Jasper, Lawrence, Richland, Wabash, Wayne, and White Counties, and parts of Fayette (eastern quarter), Franklin (eastern half), Gallatin (Townships 7 South), Jefferson (eastern half), Marion (eastern half), and Saline (Townships 7 South) Counties.

Intensive prospecting and mining of coal have been confined mostly to parts of the Illinois Basin where coals are found at relatively shallow depths. For example, the Herrin Coal has been extensively mined in Williamson, Saline, and Gallatin Counties in slope, drift, and strip mines south of the area of this report. Mining in the area of this report has been limited to several shaft mines in southern Franklin County, one shaft mine at Norris City in White County, and one at Mt. Vernon in Jefferson County (see mined-out area on plate 1). The Herrin is also mined in several counties in western Kentucky, where it is called the Kentucky No. 11 Coal.

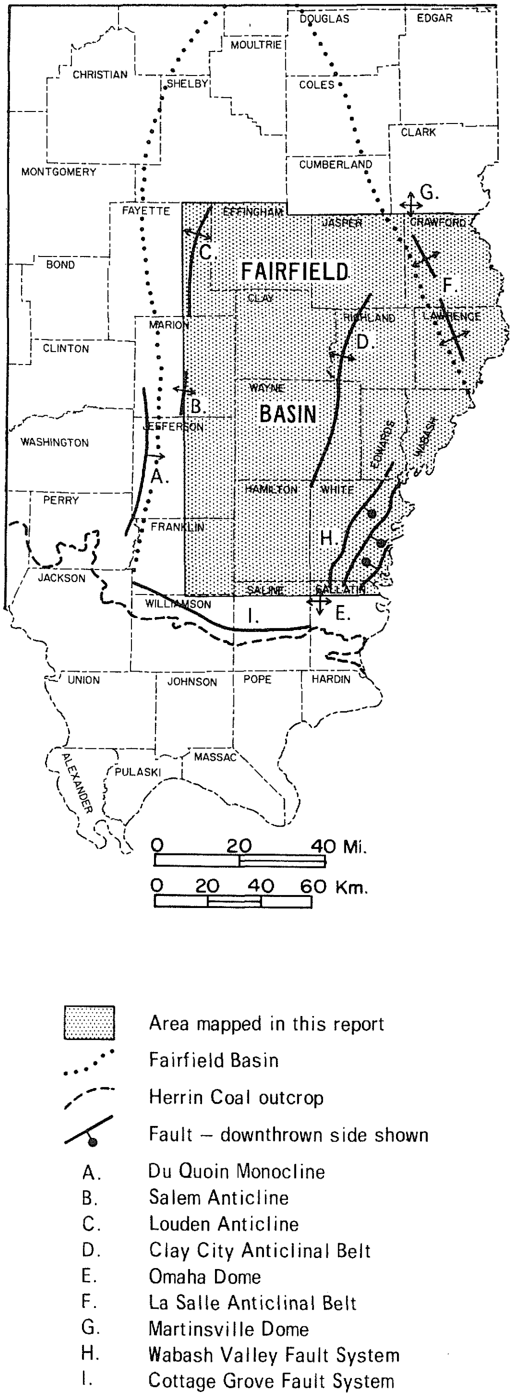


Fig. 1 - Index map showing report area and some structural features in southeastern Illinois.

This report (1) presents an isopach map of the Herrin Coal that shows variation of thickness, locates areas of potentially thick coal reserves, and provides a basis for estimating coal reserves for the study area; (2) locates areas where the coal has been cut out and replaced by sandstone channels; (3) notes lithologic variation of the roof strata; and (4) gives estimates of reserves of the Herrin Coal for the whole area and for individual counties.

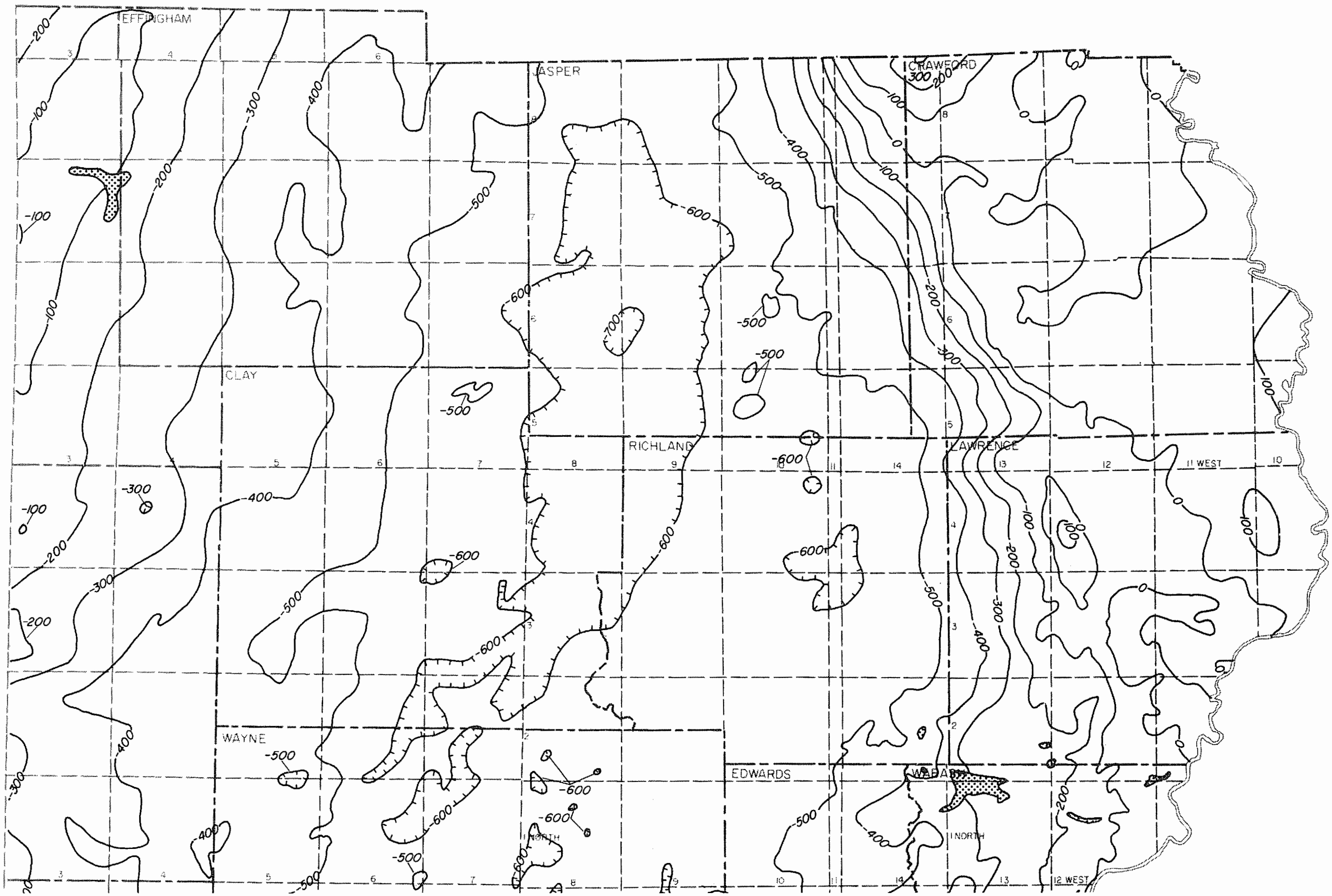
Although several diamond-drill cores were available from the southern and eastern parts of the study area, unfortunately there are no diamond-drill cores available for the Herrin Coal and associated rocks from the deeper part of the basin; therefore most of the estimates of coal thickness in this report were made from conventional electric logs of oil tests.

It is not possible in a study of this type to evaluate many of the factors relating to the minability of the coal, but this report should serve as a guide to further investigations. Assessment of mining capabilities of the area will require investigation by more extensive subsurface exploration, including diamond-drill cores, to provide information on the quality and characteristics of roof material, coal, and floor.

There are several reasons for the lack of coal data in the deeper parts of the basin, but the principal reason is that thick better known coals are available in the shallower parts. However, because of the present shortage of oil and gas and because of air-pollution control standards that limit emissions of sulfur dioxide from coal-burning installations, research on processes which convert coal to gaseous or liquid fuels has become more extensive. Energy demands for the near future are such that large tracts of relatively thick reserves of coal will be required for coal conversion (Risser, 1968, 1973), and it is likely that exploration for coal for conversion plants, power plants, and other major needs will be conducted in the deeper parts of the basin within the next few years.

The usefulness, accuracy, and limitations of electric logs in estimating coal thickness and reserves have been discussed by Hopkins (1968) in a study of the Harrisburg (No. 5) Coal Member in southeastern Illinois. In previous studies in parts of this area, electric logs were used to locate and identify key coal beds. Structure contour maps of the Herrin Coal have been made for Clay County (Siever, 1950; Lowenstam, 1951), Crawford County (Potter, 1956), Edwards County (Smith and Cady, 1951), Effingham County (Siever, 1950; DuBois, 1951), Fayette County (Siever, 1950; DuBois, 1951), Franklin County (Cady and others, 1938), Gallatin County (Cady and others, 1939; Pullen, 1951), Hamilton County (Cady and others, 1939; Rolley, 1951), Jasper County (Williams and Rolley, 1955), Jefferson County (Cady and others, 1938; Siever, 1950), Lawrence County (Potter, 1956), Marion County (Siever, 1950), Richland County (Siever and Cady, 1951), Saline County (Cady and others, 1939), Wabash County (Cady et al., 1955), Wayne County (Siever, 1950; DuBois and Siever, 1955), and White County (Cady and others, 1939; Harrison, 1951).

A statewide study of coal resources (Cady and others, 1952) provided data on reserves for the counties covered in this report; however, electric logs of oil tests were not used in determining reserves in the 1952 study. A later summary of coal resources for each county and each coal bed was provided by Hopkins and Simon (1974). Strippable reserves of the Herrin Coal south of the present study area were delineated by Smith (1957).


EFFINGHAM
JASPER
CRAWFORD
CLAY
RICHLAND
LAWRENCE
WAYNE
EDWARDS
WABASH
11 WEST
12 WEST
1 NORTH

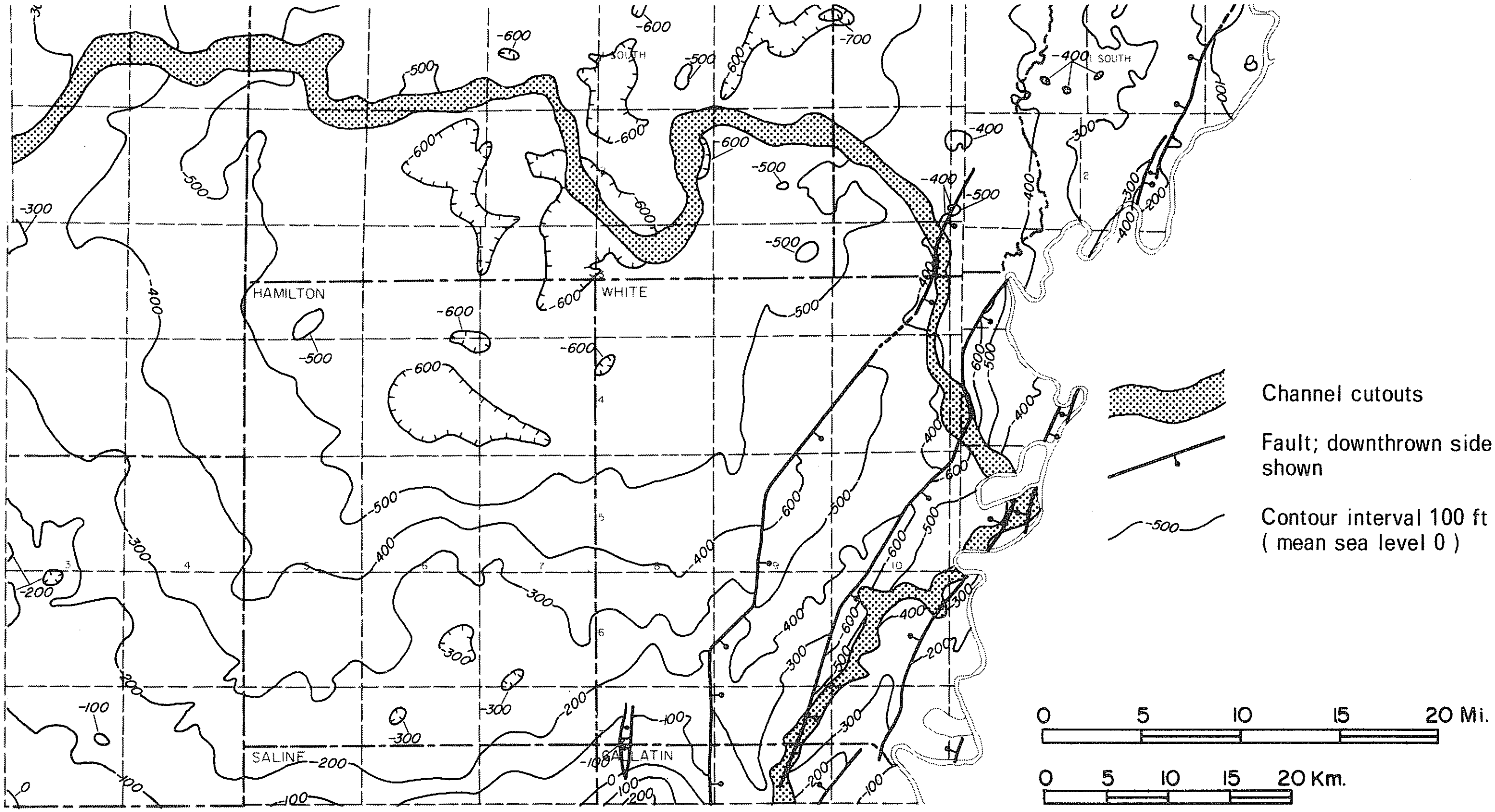


Fig. 2 - Structure map of the Herrin (No. 6) Coal Member in southeastern Illinois.

STRUCTURE

The Herrin (No. 6) Coal crops out south of the area covered in this report. The coal strikes in a general east-west direction along T. 9 S. in Williamson, Saline, and Gallatin Counties and dips generally northward. The coal also crops out to the south in the Eagle Valley Syncline in T. 10 S., Rs. 7 to 10 E., in eastern Saline and Gallatin Counties (Smith, 1957). Several high-angle faults, most of which are normal faults, occur in the eastern part of the area; these faults, which constitute the Wabash Valley Fault System, trend generally northeast and extend from Gallatin County northeastward into Wabash County.

The deep part of the Illinois Basin is called the Fairfield Basin. It is bounded on the west by the Du Quoin Monocline and an arbitrary northward extension of this structure and on the east by the La Salle Anticlinal Belt. The northern limit of the Fairfield Basin, as indicated on figure 1, was arbitrarily placed approximately along the subcrop of the Mattoon Formation. The Cottage Grove Fault System forms the southern boundary.

From Saline and Gallatin Counties, the Herrin Coal dips northward through Hamilton County into the Fairfield Basin at a rate of 20 to 25 feet per mile. Dips are approximately 15 to 20 feet per mile off the east flanks of the Salem and Louden Anticlines in the western part of this study area and approximately 20 to 50 feet per mile off the west flank of the La Salle Anticlinal Belt on the east side of the Fairfield Basin. The effect of the Clay City Anticline on the deposition and structure of the Herrin Coal is relatively minor (fig. 2).

The greatest depth of Herrin Coal noted in any drill hole record was 1,248 feet below the surface (at an elevation of 708 feet below mean sea level) in Jasper County, Sec. 19, T. 6 N., R. 9 E. However, the lowest elevation for the coal was found in Wayne County, Sec. 12, T. 1 S., R. 9 E., at 759 feet below mean sea level (at a depth of 1,150 feet below the surface). This relatively sharp structural low in Wayne County appears to have only local significance. Examination of electric logs in this vicinity (the only data available) does not at this time offer a definitive explanation for this feature. The highest elevation at which Herrin Coal was found was 309 feet above mean sea level (at a depth of 210 feet below the surface) in Sec. 2, T. 8 N., R. 14 W., on the portion of the Martinsville Dome (Clegg, 1970) that extends into the northwest corner of Crawford County.

STRATIGRAPHY

Herrin (No. 6) Coal Member

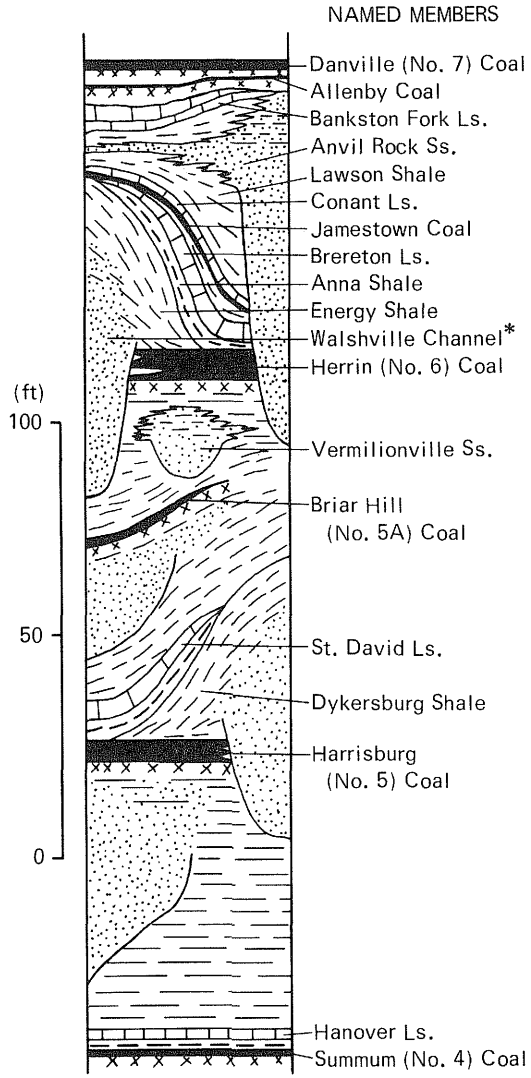
The Herrin (No. 6) Coal Member occurs in the upper part of the Carbondale Formation of the Kewanee Group, Desmoinesian Series, Pennsylvanian System (fig. 3). It is contained within the Brereton Cyclothem and is present throughout this area except in localities where channel cutouts occurred and over some structurally high areas where the coal is poorly developed and thin, or perhaps locally absent.

The Herrin Coal has been eroded and replaced in several areas in southern Illinois by channel sandstones of the Anvil Rock Sandstone Member

(Hopkins, 1958; Potter and Simon, 1961). In the area of this study the coal is cut out along a 1 to 2 mile wide strip which meanders in a more or less east-west direction across Jefferson and Wayne Counties, south-southeast through Edwards and White Counties, and southwest from the Wabash River through the remainder of White and into Gallatin County (fig. 2, pl. 1). The Herrin Coal is also known to be cut out in a few local areas in Richland, Wabash, Lawrence, and Marion Counties by Anvil Rock Sandstone (fig. 4A) and in a few localities in Fayette and Effingham Counties by the Trivoli Sandstone Member of the Modesto Formation (fig. 4B) (Andresen, 1961). In these cutouts, deposits of sandstone and siltstone are found in place of the normal-sequence deposits. As indicated on plate 1, the presence of the Anvil Rock channel deposits does not affect the thickness of the coal adjacent to them.

The Herrin Coal rises more than 600 feet in elevation from the deepest part of the basin in Jasper County on to the Louden Anticline in the west. Here the interval between the Harrisburg (No. 5) Coal and the Danville (No. 7) Coal Member decreases, and the Herrin Coal becomes thin or absent in western Effingham, eastern Fayette, and northern Marion Counties (fig. 5A). The Herrin Coal is also either thin or absent in most of eastern Crawford County (fig. 5B); in this vicinity its position is more than 800 feet higher in elevation than in the center of the basin.

Both the Brereton Limestone Member and the Herrin Coal were found to diminish in thickness when traced eastward over the steepest part of the west flank of the La Salle Anticlinal Belt into Lawrence and Crawford Counties. In a general way, in this area the Herrin Coal and the Brereton Limestone thin eastward whereas the overlying Jamestown Coal Member thickens (fig. 6).



* "Walshville Channel" is an informal name for the sandstone channel facies related to the Energy Shale.

Fig. 3 - Generalized columnar section of a portion of the Carbondale Formation in southeastern Illinois.

Energy Shale Member

In the "Quality Circle" mining area of Jefferson and Franklin Counties, where thick, low-sulfur Herrin Coal is being mined, a gray silty shale ranging in thickness from about 20 feet to about

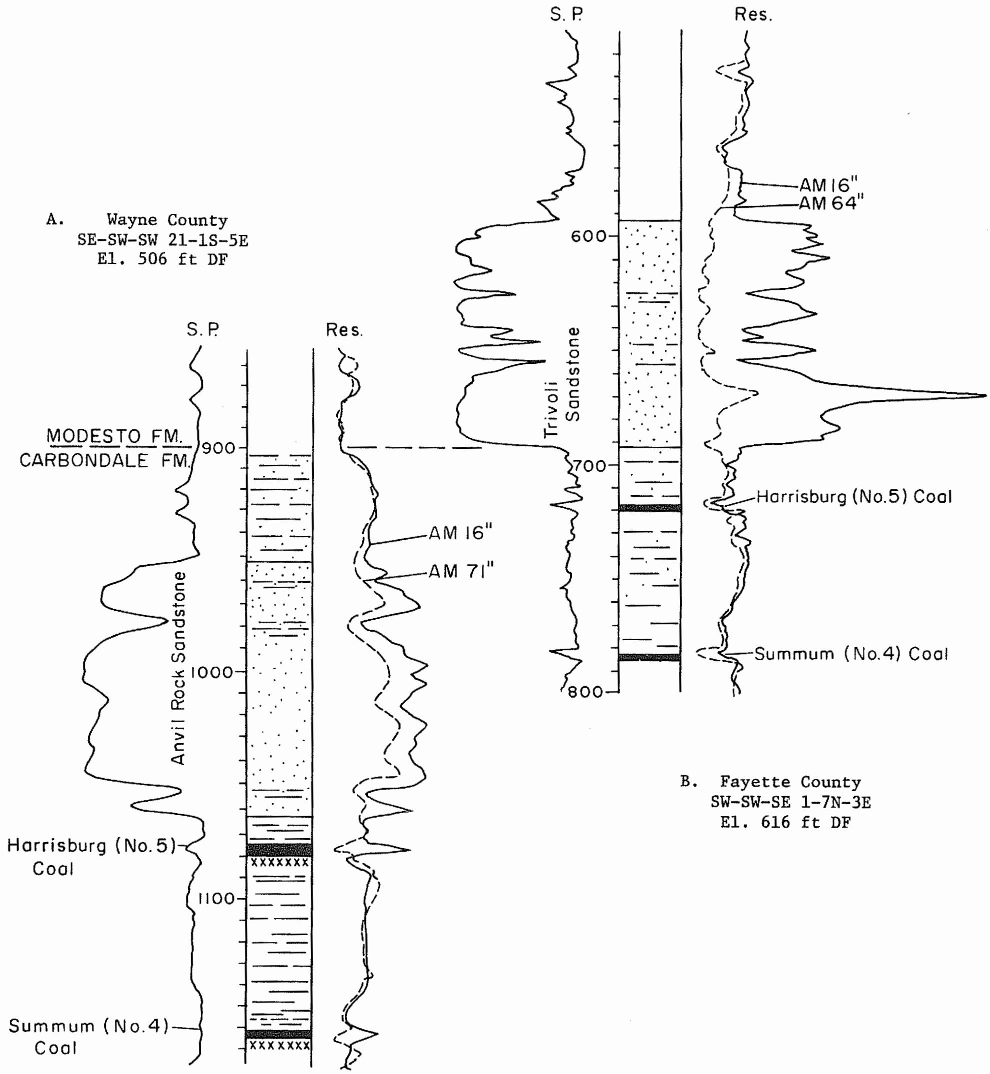


Fig. 4 - Electric logs showing the sandstone channel cutouts of the Herrin (No. 6) Coal observed in southeastern Illinois. A. Herrin Coal cut out by Anvil Rock Sandstone; B. Herrin Coal cut out by Trivoli Sandstone.

100 feet lies immediately above the Herrin Coal and below the Anna Shale and the Brereton Limestone (fig. 7A). In areas of maximum development of this gray shale, an associated sandstone, commonly 50 feet or more thick, occupies a belt up to about 2 miles in width and traceable for more than 100 miles.

The gray shale is here named the Energy Shale Member of the Carbondale Formation. The type locality is designated as SW$\frac{1}{4}$NE$\frac{1}{4}$NE$\frac{1}{4}$ Sec. 3, T. 9 S., R. 2 E., Williamson County, Illinois, on the Johnston City 7.5-minute Quadrangle.

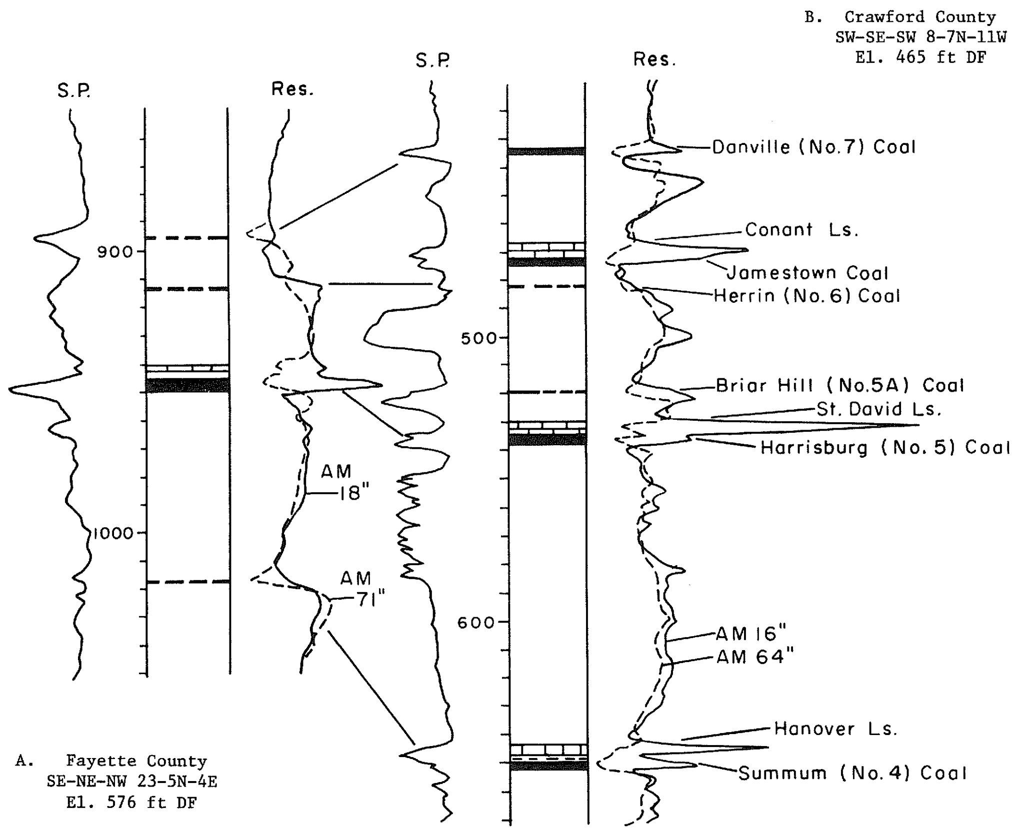


Fig. 5 - Electric logs showing thin development of the Herrin (No. 6) Coal on structural highs: A. - on Louden Anticline; B. - on west flank of La Salle Anticlinal Belt.

The outcrop at the type locality is located 3.0 miles east of the village of Energy in the highwall on the west side of an abandoned strip pit of the Forsyth-Energy, Inc., Energy Mine. Within this pit the Energy Shale thickens southward from less than 1 foot to approximately 15 feet. The overlying Anna Shale is approximately 6 feet thick in the northern part of the pit and thins slightly as it rises over the thicker section of the Energy Shale. Blocks of Brereton Limestone (which overlies the Anna Shale) that cap the outcrop in the north are replaced by glacial drift in the south. The type section is located along the southern boundary of the "Quality Circle" area, where the Energy Shale is for the most part less than 20 feet thick.

Thicknesses of up to 80 feet of Energy Shale were observed in the study area. Where the thickness of this shale exceeds 20 to 30 feet, the Anna Shale and the Brereton Limestone are often absent and the Energy Shale is overlain by strata of the Jamestown or Bankston Cyclothems (fig. 7B). Where the Anna Shale and Brereton Limestone Members do occur over thick Energy Shale, they are usually poorly developed. Gray shale deposits more than 20 feet thick generally grade upwards from fine, well-laminated shale containing irregularly shaped sideritic nodules to a harder, silty shale or a medium- to coarse-grained siltstone. Carbonaceous plant fragments are found throughout the sequence; however, they are more abundant and better preserved near the coal. The siltstone and silty

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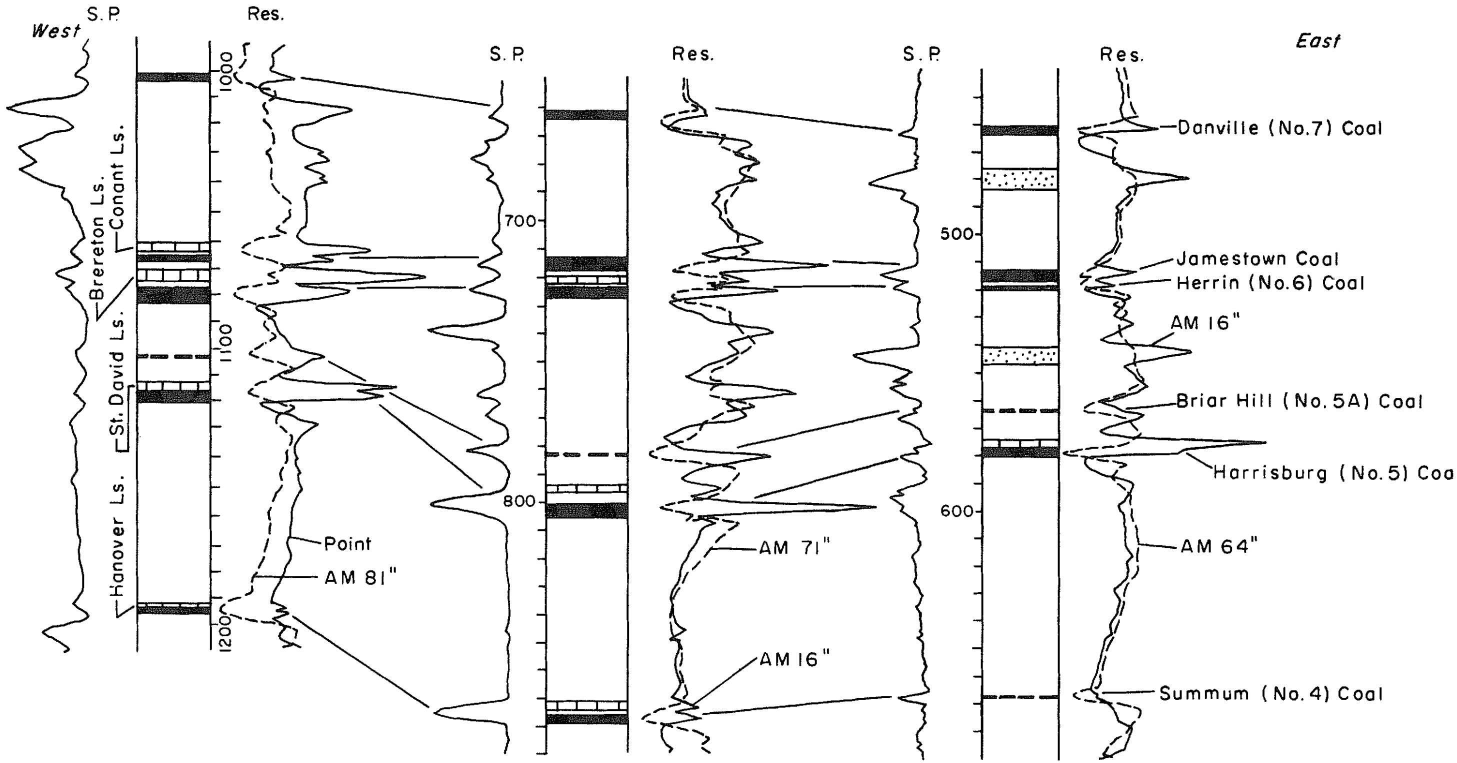


A. Richland County
SE-NW-SE 30-5N-11E
El. 508 ft DB

B. Lawrence County
NE-NE-SE 16-4N-13W
El. 470 ft L&S

C. Lawrence County
NE-NW-SE 10-4N-12W
El. 424 ft DF

Fig. 6 - Electric logs showing eastward thinning of the Herrin (No. 6) Coal and relative thickening of the Jamestown Coal across the west flank of the La Salle Anticlinal Belt. A. Herrin Coal thicker than Jamestown Coal in eastern Richland County. B. Herrin Coal and Jamestown Coal of equal thickness in western Lawrence County. C. Herrin Coal thinner than Jamestown Coal in central Lawrence County.

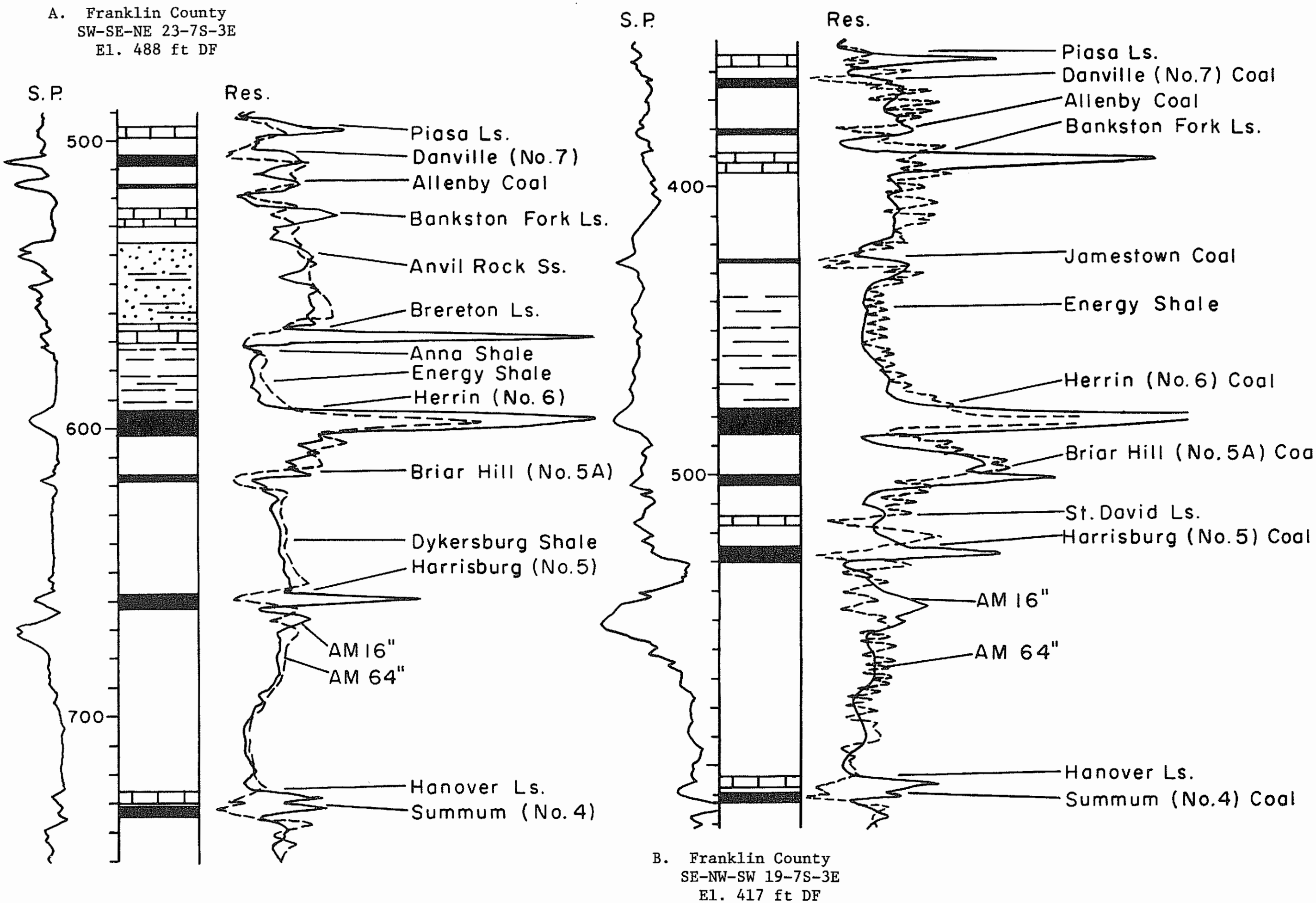
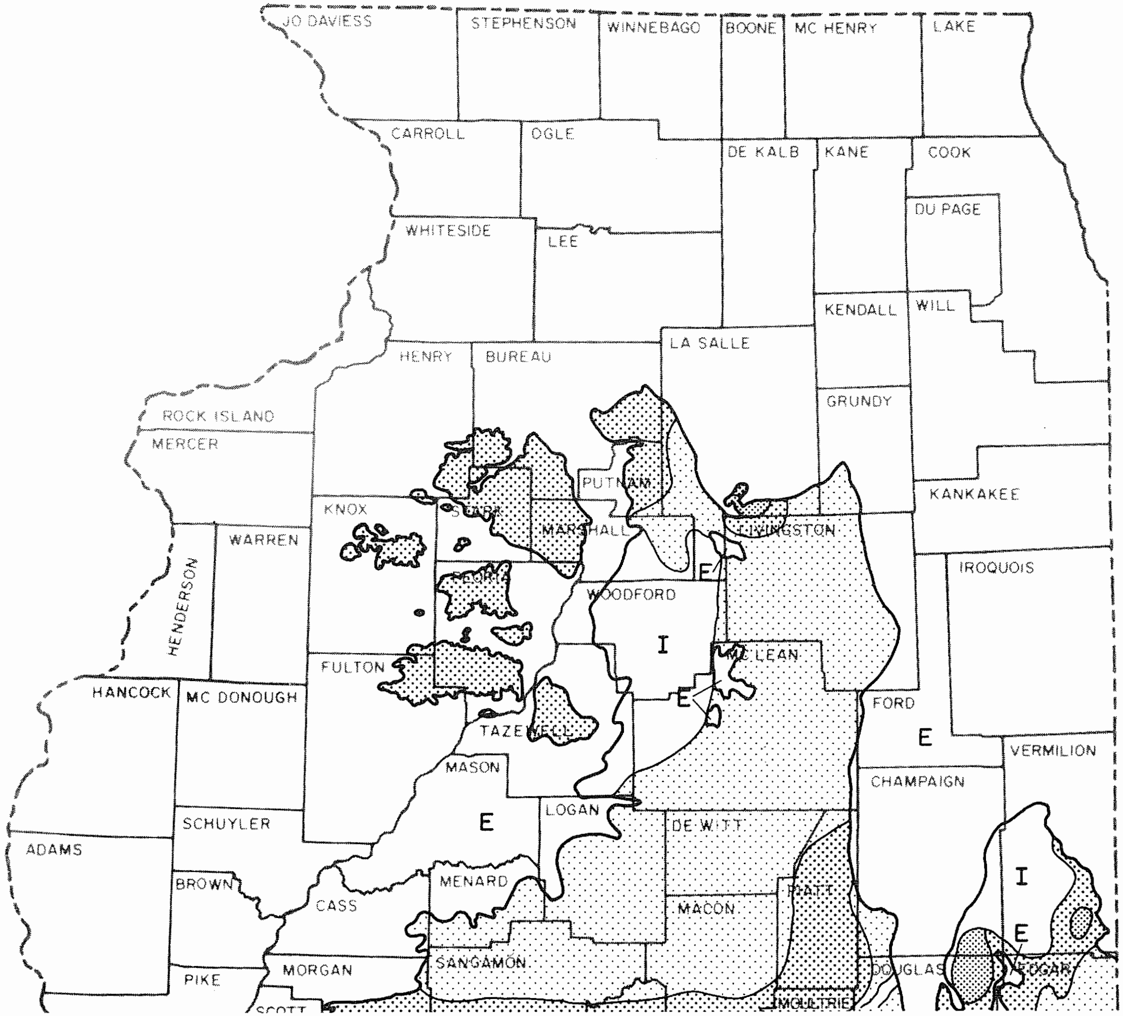


Fig. 7 - Electric logs showing Herrin (No. 6) Coal with gray shale roof (Energy Shale). A. Approximately 20 feet of Energy Shale overlain by Anna Shale and Brereton Limestone. B. Approximately 50 feet of Energy Shale overlain by the Jamestown Coal.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STEPHENSON
WINNEBAGO
BOONE
MC HENRY
LAKE
CARROLL
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DE KALB
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DU PAGE
WHITESIDE
LEE
KENDALL
WILL
HENRY
BUREAU
LA SALLE
GRUNDY
ROCK ISLAND
MERCER
PUTNAM
KANKAKEE
KNOX
STARK
MARSHALL
LIVINGSTON
WARREN
HENDERSON
PEORIA
WOODFORD
IROQUOIS
FULTON
MC LEAN
HANCOCK
MC DONOUGH
TAZEWELL
FORD
MASON
VERMILION
CHAMPAIGN
LOGAN
DE WITT
SCHUYLER
ADAMS
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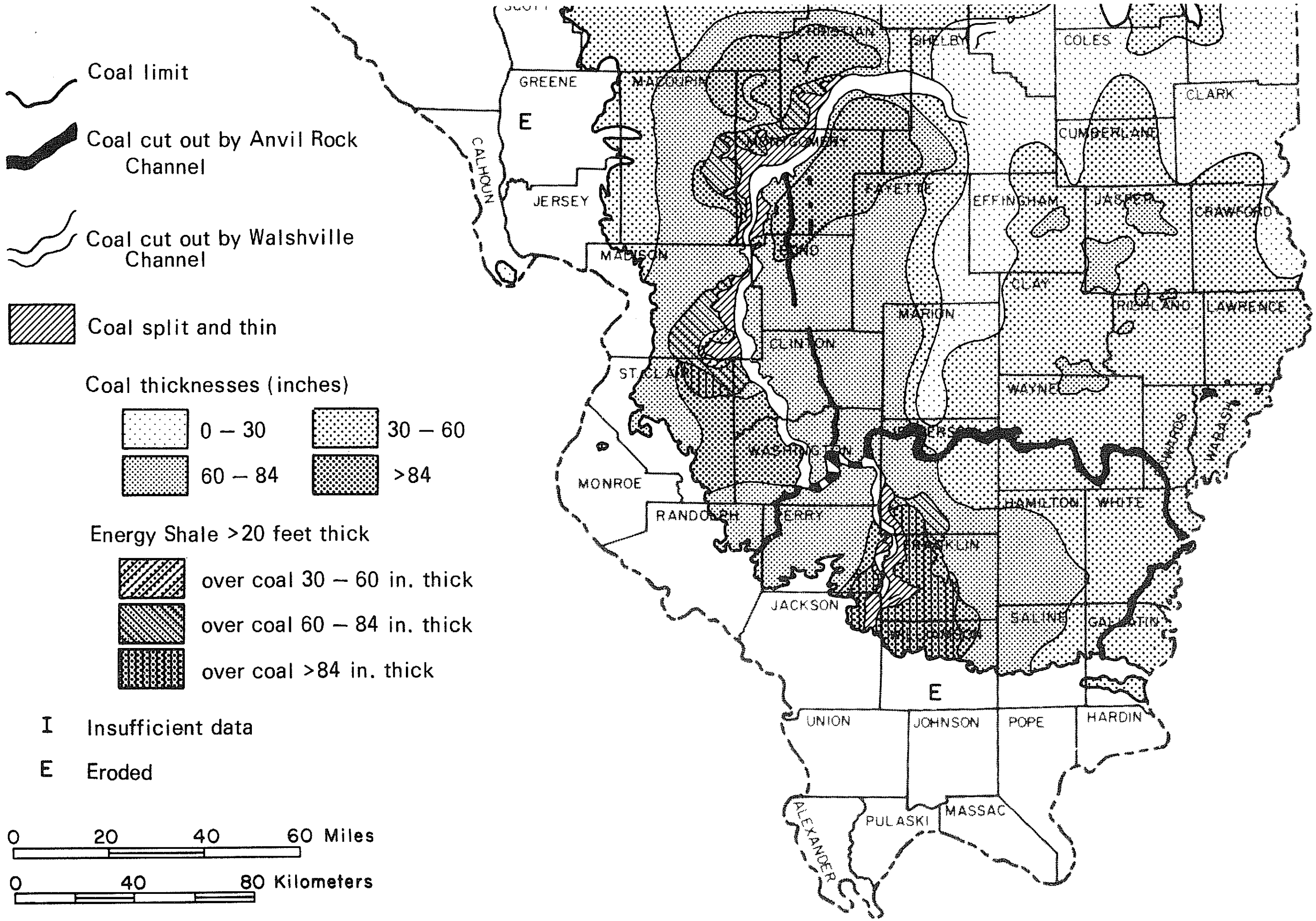

Fig. 8 - Generalized thickness map of the Herrin (No. 6) Coal.

shale in the upper part of the Energy Shale grade vertically and laterally into sandstone, which is part of a channel system found in southwestern Illinois. The name Walshville was proposed by Johnson (1972) for this channel, which existed during the formation of the Herrin Coal (peat) and the Energy Shale, to distinguish this channel from the channels of the Anvil Rock Sandstone, which were cut down to the Herrin Coal at a later time.

Facies distribution of the Herrin Coal, Energy Shale, and related sandstone in the Walshville Channel confirms the association of these deposits, in that sandstone channels and deposits of relatively thick coal, of coal split with clastic partings, and of thick gray shale are found in proximity to each other. The cutout of the Herrin Coal by the Walshville Channel in southwestern Illinois is shown on figure 8. This channel is a linear sandstone body that trends in a general southward direction from Christian County to Franklin County. The thick deposits of coal in the greater than 84 inches and the 60 to 84 inches categories of figure 8 surround the channel and appear to follow the direction of the channel. In contrast, the channel of the Anvil Rock Sandstone in southeastern Illinois does not appear to have any association with variations in Herrin Coal thickness. Although the Walshville Channel did not extend into the present study area, relatively thick Energy Shale deposits were noted in eastern Franklin and Jefferson Counties (fig. 9).

The pattern of the Energy Shale in figure 9 is somewhat digitiform and lobate. Similarity is observed between it and the pattern of the Energy Shale mapped by Johnson (1972) and that of the Dykersburg Shale Member mapped by Hopkins (1968). The characteristic pattern of these shales and their association with coal and channels suggest a depositional model whereby floods causing breaks in levees along the banks of channels, which ran through the coal swamp, resulted in crevasse splays of gray shale wedges over coal (peat) deposits; in some cases the shale "split" the coal when the accumulation of plant material was interrupted by these floods. The relation of these shale deposits to the sulfur content of the Herrin Coal is discussed in the section "Sulfur Content."

Anna Shale Member

In most places the Herrin Coal is overlain by 1 to 4 feet (usually less than 2 feet) of hard, black, fissile shale named the Anna Shale Member for the type locality in Bourbon County, Kansas (Jewett, 1941). In Kansas, the Anna Shale is included as a member of the Pawnee Limestone Formation and underlies the Myrick Station Limestone Member, which is equivalent to the Brereton Limestone Member of Illinois (Weller et al., 1942). The name Anna Shale was geographically extended into Missouri by Green and Searight (1949), and extended into the Illinois Basin by Tubb (1961, plate 12 [also in Wanless et al., 1963, p. 481]; see also Givens, 1965). It contains marine fossils dominated by nectonic forms (fish parts, pectenoid pelecypods, and conodonts).

Brereton Limestone Member

The Brereton Limestone Member overlies the Anna Shale. Alternating zones of darker gray, impure limestone and less argillaceous, lighter gray,

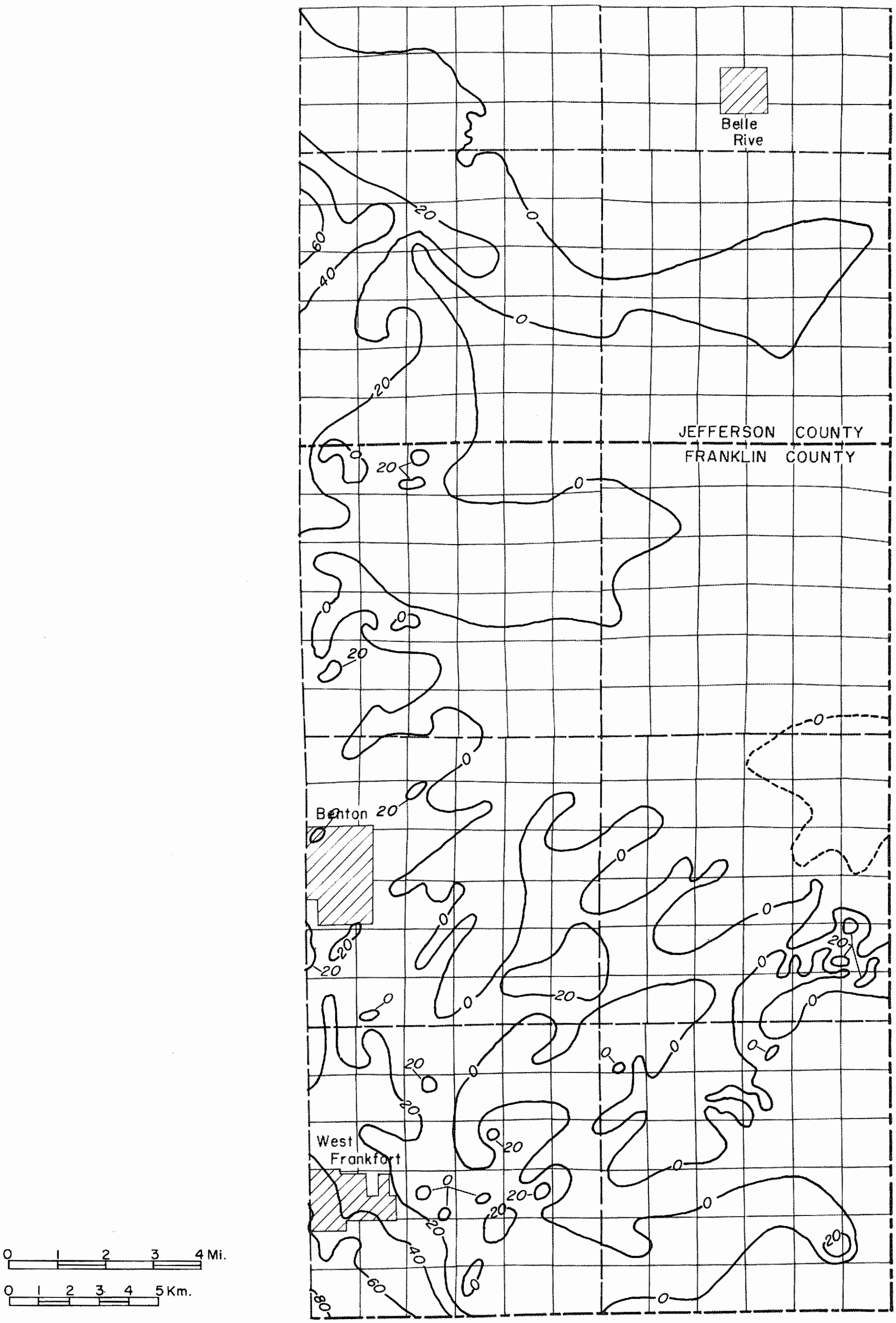

Fig. 9 - Thickness map of the Energy Shale in eastern Jefferson and Franklin Counties. Contour interval 20 feet.

fine-grained, dense limestone are characteristic of the Brereton in the study area; an open-marine fossil assemblage consisting predominantly of small brachiopods, crinoid columnals, fusulinids (*Fusulina gyrtii* common), and small tubular foraminifera is also characteristic of the Brereton. The Brereton Limestone is usually 3 to 4 feet thick; however, its thickness ranges from an inch or less to about 10 feet. Like the Herrin Coal, the Brereton Limestone thins over the Louden Anticline and on the west flank of the La Salle Anticlinal Belt.

It is not uncommon to find less than 1 foot of black Anna Shale separating the Herrin Coal from the Brereton Limestone, or to find the limestone lying directly over the coal (fig. 10). In these places it is difficult to estimate coal or limestone thicknesses from electric logs, because resistivity peaks of the Herrin and of the Brereton are similar in intensity and tend to coalesce.

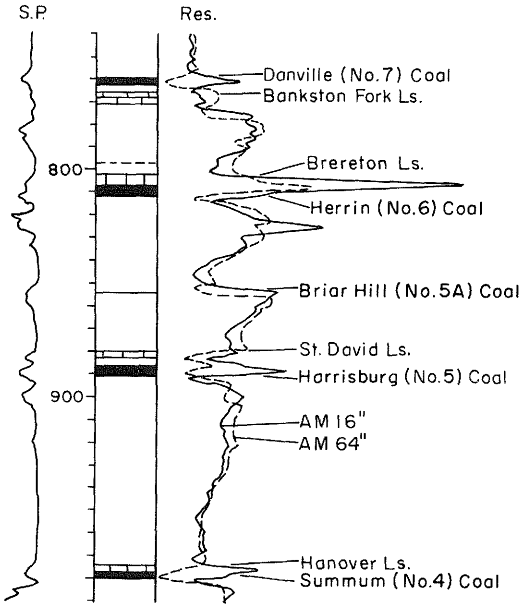

Fig. 10 - Electric log showing coalescing of resistivity peaks of Herrin Coal with those of Brereton Limestone where Anna Shale is either very thin or absent.

RANK OF COAL

The variation in rank of the Herrin Coal has been mapped by Cady (1935) and Damberger (1971). According to Damberger (1971, p. 490), the Herrin Coal is classified as a high-volatile B bituminous coal in the greater part of the study area. It varies from about 8 percent moisture and 13,500 Btu per pound on the moist, mineral-free basis in the southern part of the area to 10 to 11 percent moisture and 13,300 to 13,000 Btu per pound on the north to about 12 percent moisture and 12,750 Btu per pound on the northeast in Crawford and Lawrence Counties, where the coal is classified as a high-volatile C bituminous coal. These limits, shown by Damberger, are based primarily on projections made from coal analyses outside the study area.

SULFUR CONTENT

It has been noted that all known relatively low-sulfur coal deposits in the Illinois Basin occur where the coal lies immediately beneath a thick gray shale member (Cady and others, 1952, p. 35; Gluskoter and Simon, 1968; Hopkins, 1968; Gluskoter and Hopkins, 1970). Examples of this association in Illinois include the Murphysboro Coal Member in parts of Jackson County; the Colchester (No. 2) Coal Member in parts of Kankakee, Will, and Grundy Counties, where it is overlain by the thick Francis Creek Shale Member; and

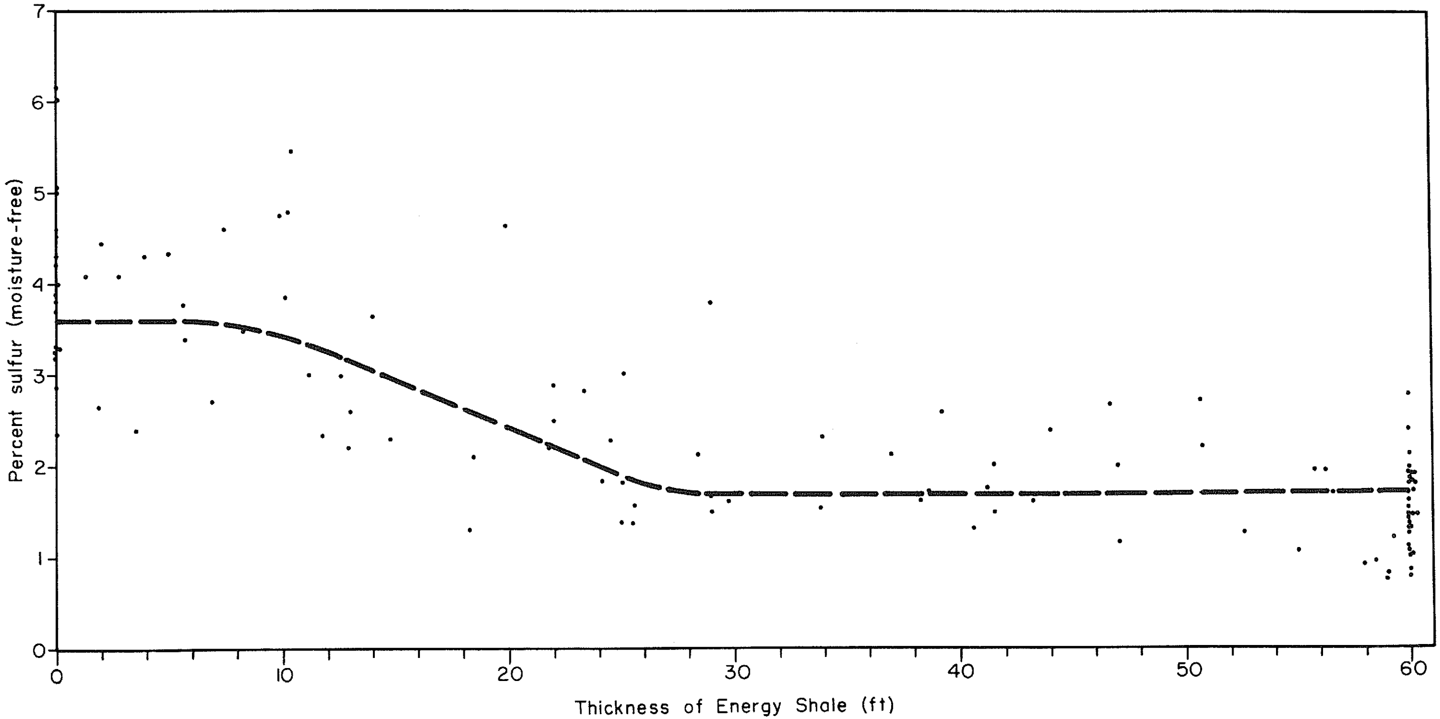

Fig. 11 - Relation of total sulfur content from 116 core samples of the Herrin (No. 6) Coal to thickness of the overlying Energy Shale.

the Harrisburg (No. 5) Coal in areas of southeastern Illinois, where it is overlain by the Dykersburg Shale (Hopkins, 1968). Comparatively low-sulfur Herrin Coal is found in the "Troy" area of St. Clair and Madison Counties and in the "Quality Circle" in parts of Franklin, Jefferson, and Williamson Counties, where thick deposits of low-sulfur coal have been extensively mined. The major portion of the "Quality Circle" area lies west of the present study area. A third area (the "Hornsby" area) containing Herrin Coal that is probably relatively low in sulfur is located in the eastern part of Macoupin County (Gluskoter and Hopkins, 1970). The Herrin Coal in these three areas is overlain by at least 20 feet of Energy Shale, and shale thicknesses of 80 feet are common.

Values of total-sulfur content (moisture-free basis) of the Herrin Coal versus thickness of the overlying Energy Shale are plotted in figure 11 for 116 diamond-drill core samples from the "Troy" area and from "Quality Circle," of which only a part of Franklin and Jefferson Counties is covered in this report. Sulfur content of coal samples from coals overlain by 25 feet or more of gray shale averaged 1.5 percent (with a standard deviation of 0.55) whereas the sulfur content for those samples with less than 25 feet of gray shale overburden averaged 3.6 percent and varied greatly (standard deviation of 1.10). Where the coal is overlain directly by either the Anna Shale or the Brereton Limestone Members, both deposited in a marine environment, the sulfur content averaged 4.1 percent and was as high as 6.1 percent.

There are various mechanisms which may explain this relationship. It is assumed that marine water is a likely source of sulfate ions, which would have been introduced into coal (peat) during marine transgression. However, if gray shale of sufficient thickness was laid down rapidly over the peat in fresh to only slightly brackish water prior to the deposition of the normal marine transgressive sequence of black shale and overlying limestone, the migration of sulfate ions from sea water to peat would have been prevented, thereby allowing the subsequent development of relatively low-sulfur coal. Once a deposit of gray shale of sufficient thickness to protect the coal has covered the coal, there is no reason to assume that further increase in thickness of gray shale necessarily would bring about a further decrease in the sulfur content of the coal.

Anomalous high-sulfur values are sometimes obtained locally from coals overlain by thick gray shale in an area of generally low-sulfur coal. These occurrences are probably due to post-depositional addition or segregation of pyrite that was localized because of some change in the geochemical environment. There are also areas in Illinois where the roof material is gray shale and the coal is high in sulfur. In these places, however, the shale contains open-marine invertebrates, the presence of which indicates deposition in normal marine water. These shales lie immediately above the coal because of the absence of the normal black shale and limestone roof strata, which commonly can be seen immediately above the coal and under the gray shale when the strata are traced laterally.

COAL RESERVES

The U.S. Bureau of Mines and the U.S. Geological Survey define a <u>resource</u> as a concentration of naturally occurring solid, liquid, or gaseous materials in or on the earth's crust in such a form that economic extraction of a commodity is currently or potentially feasible (U.S. Department of the Interior, 1974). The classification system for resources adopted by these agencies is based on the degree of certainty about the existence of the materials and the economic feasibility of recovering them (McKelvey, 1973, p. 11). Specific bodies of mineral-bearing material whose location, quality, and quantity are known from geologic evidence are considered identified resources as opposed to hypothetical or speculative undiscovered resources. That portion of the identified resource from which a usable mineral and energy commodity can be economically and legally extracted at the time of determination is classified as reserves. Although it is believed that the reserves calculated in this study are (or could be) recoverable, it was not possible to evaluate the various aspects of technology, economics, and legalities that would be involved. In this respect the term reserves as used in this report follows the definition of identified resources adopted by the U.S. Bureau of Mines and the U.S. Geological Survey. Estimates of quality and size of the identified coal deposits in most of the area covered in this report where no coal exploration has taken place are inferred from the available geologic evidence and reasonable projections.

More than 4,100 electric logs were used in the construction of the coal thickness map (pl. 1). A sample density of one drill hole per section, where possible, was selected for this mapping. More than one log per section was used in areas such as the vicinity of cutouts, where more detail was needed.

The scale of the majority of electric logs of oil tests is 50 feet to 1 inch. We felt that, for practical purposes, estimates of coal thicknesses from logs at this scale should be made to the whole foot, unless additional information was available. Isopach lines were drawn at 3½, 5½, and 7½ feet, between datum points with whole-foot values. Coal reserves were calculated on a per township basis using the average thickness found within 3½ to 5½ feet, 5½ to 7½ feet, and greater than 7½ feet categories. Areas within these three categories were measured by a dot-count method in which comparison was made to dot density on a grid of known area (Knudsen, 1954). This method was satisfactory for measuring areas within contours based on the density of data points used in this study.

Coal less than 3½ feet thick was not included in estimates of reserves because thicknesses of less than 3 feet could not be reliably differentiated on the electric logs. Areas on plate 1 where coal is thin or absent are areas where no coal was interpreted on electric logs. Mined-out areas and channel cutouts were also excluded from the estimates. Following the practice of Cady and others (1952), coal occurring in oil and gas fields where drill holes are closely spaced (as closely as one well per 10 acres) was also excluded.

The exclusion of oil fields warrants further explanation. The plugging of abandoned oil and gas wells is required by state law in order to protect coals 30 inches or more thick and lying less than 1,000 feet deep from invasion by water, gas, or oil. Mining law also requires that a certain-size pillar be left around these wells. However, for the purposes of this study, heavily drilled areas were excluded because it was felt that protective measures taken in the past were probably inadequate except in active mining areas or where future mining was planned. In addition, much of the coal was not protected, inasmuch as it lies below 1,000 feet in depth. The possibility of mining in areas that contain properly plugged drill holes is currently being studied by the U.S. Bureau of Mines.

More than half of the total area in this study was excluded for reasons mentioned above (see table 1). Following U.S. Geological Survey procedures, tonnages were calculated using a conversion factor of 1,800 tons per acre-foot

TABLE 1 - AREAS OF COAL RESERVES AND EXCLUDED AREAS

County	Total area of county (sq mi)	Area in each thickness interval			Total area of classified reserves (sq mi)	Total area excluded (sq mi)
		3½ to 5½ ft (sq mi)	5½ to 7½ ft (sq mi)	>7½ ft (sq mi)		
Clay	464	185	23		208	256
Crawford	442	24			24	418
Edwards	225	101	4		105	120
Effingham	483	155	29		184	299
Fayette	198*	11			11	187
Franklin	216*	88	73	13	174	42
Gallatin	46*	9	1		10	36
Hamilton	435	243	96	19	358	77
Jasper	495	261	118		379	116
Jefferson	288*	149	65	3	217	71
Lawrence	374	53			53	321
Marion	288*	28	1		29	259
Richland	364	238	15		253	111
Saline	54*	34	7		41	13
Wabash	221	45	<1		45	176
Wayne	715	265	20	<1	285	430
White	501	215	25	2	242	259
TOTAL	5,809	2,104	477+	37+	2,618	3,191

*Figure accounts only for the part of the county included in this study.

of coal (1.152 million tons per square mile foot of coal). This equals a density of 1.32 g/cm^3. County totals are listed in table 2.

The total reserves of the Herrin (No. 6) Coal calculated for this area are 14.6 billion tons, 3.7 billion less than the 18.3 billion tons given by Cady and others (1952) for the same area. This difference occurs because: (1) the present study does not include coal less than 42 inches thick, whereas Cady and others used a minimum thickness value of 28 inches; (2) more and larger oil pool areas and areas where the coal is cut out by sandstone were excluded in this study; and (3) many more electric log data have been utilized in the present study, and thus the pattern of thickness has been altered.

COAL RESERVES BY COUNTY

Clay County

The thickness of the Herrin Coal in Clay County ranges from less than 3 feet to approximately 4 to 5 feet, with a few small areas of 6 feet or more. The coal dips in a general east-southeast direction, with elevations that range from less than 350 feet below mean sea level in the west to more than 650

TABLE 2 - RESERVES OF HERRIN (NO. 6) COAL IN SOUTHEASTERN ILLINOIS
(millions of tons)

County	Thickness**			Total
	(3½ to 5½ ft)	(5½ to 7½ ft)	(>7½ ft)	
Clay	933	154		1,087
Crawford	130			130
Edwards	508	32		540
Effingham	782	198		980
Fayette*	61			61
Franklin*	516	536	138	1,190
Gallatin*	43	6		49
Hamilton	1,279	730	178	2,187
Jasper	1,322	817		2,139
Jefferson*	780	452	29	1,261
Lawrence	263			263
Marion*	132	6		138
Richland	1,336	107		1,443
Saline*	183	46		229
Wabash	214	3		217
Wayne	1,296	141	3	1,440
White	1,057	173	16	1,246
TOTAL	10,835	3,401	364	14,600

*Study area includes only parts of these counties.
**Thicknesses averaged per township for each thickness group. Thicknesses of less than 3½ ft not included.

feet below mean sea level in the east. Likewise, coal depths range from approximately 820 feet below the surface in the west to 1,120 feet in the east.

Large tracts of the thicker coal are inferred to be more prevalent in the central and eastern portions of the county. Herrin Coal reserves estimated to be between 5½ and 7½ feet thick total 154 million tons. These are included in an area of approximately 23 square miles. Approximately 185 square miles contains 933 million tons of coal that is estimated to be 3½ to 5½ feet thick. More than half the area of Clay County was excluded from calculations of reserves, mainly because much of the coal was estimated to be less than 3½ feet thick. Areas heavily drilled for oil that contain coal more than 3½ feet thick are relatively small.

The immediate roof rock consists of Anna Shale and/or Brereton Limestone. The Brereton Limestone is poorly developed in many localities in western Clay County, whereas it appears well developed (up to 4 feet thick) and forms the principal roof material in northern and eastern parts of the county.

Crawford County

Most of the Herrin Coal in Crawford County is estimated to be less than 3½ feet thick. In addition, much of the county has been heavily drilled for oil; therefore large portions of the few areas containing thicker coal are excluded from estimates of reserves. The total reserves of Herrin Coal consist of 130 million tons of coal 3½ to 5½ feet thick. The Herrin Coal becomes thin or absent toward the Wabash River, whereas the Jamestown Coal becomes more prominent (pl. 2, cross-section A-A'; nos. 10-13). The shaly interval between these two coals is less than 10 feet.

The depth of the Herrin Coal ranges from approximately 980 feet below the surface in the southwest to approximately 200 feet in the northwest corner of the county. Coal elevations range from more than 500 feet below mean sea level to more than 300 feet above mean sea level.

Edwards County

In Edwards County, reserves of coal from 3½ to 5½ feet thick are estimated to total 508 million tons, and reserves from 5½ to 7½ feet thick are estimated at 32 million tons. The area of reserves includes 105 square miles.

The normal roof lithologies encountered were 2 feet of Anna Shale and 3 to 4 feet of Brereton Limestone; however, many electric logs observed in various locations throughout the county had an irregular resistivity peak for the Herrin Coal, which was interpreted as showing a situation where the Brereton Limestone lies either on or very close to the coal (pl. 2, cross-section B-B'; no. 9). The Anvil Rock Sandstone Channel runs diagonally southeast-northwest across Tps. 3 and 4 N., R. 70 E., where it cuts out the coal.

The Herrin Coal dips in a general west-northwest direction. Coal elevations range from less than 400 feet below mean sea level to approximately 700 feet below mean sea level. Depths increase westward and range from approximately 770 feet below the surface to about 1,200 feet below the surface.

Effingham County

The Herrin Coal is either thin or absent in most of western Effingham County, which lies on the eastern flank of the Louden Anticline. Relatively large tracts of coal interpreted as more than 5½ feet thick are located towards the east and north. The coal thickness estimated from a gamma-gamma density log taken of an oil test hole in Sec. 21, T. 9 N., R. 7 E., Cumberland County (fig. 12B) is 7 feet. This location is only about 2 miles north of the 5½-foot isopach line in northeastern Effingham County on plate 1. This log is significant because it confirms that black shale occurs above the peak interpreted as coal. Since this is the normal situation in this area, it is likely that the interpretation of the peak on the electric log (fig. 12A) as coal is correct. The area of coal reserves is approximately 184 square miles, with estimated coal reserves of 980 million tons. Herrin Coal estimated to be between 5½ and 7½ feet thick makes up 198 million tons within an area of 29 square miles.

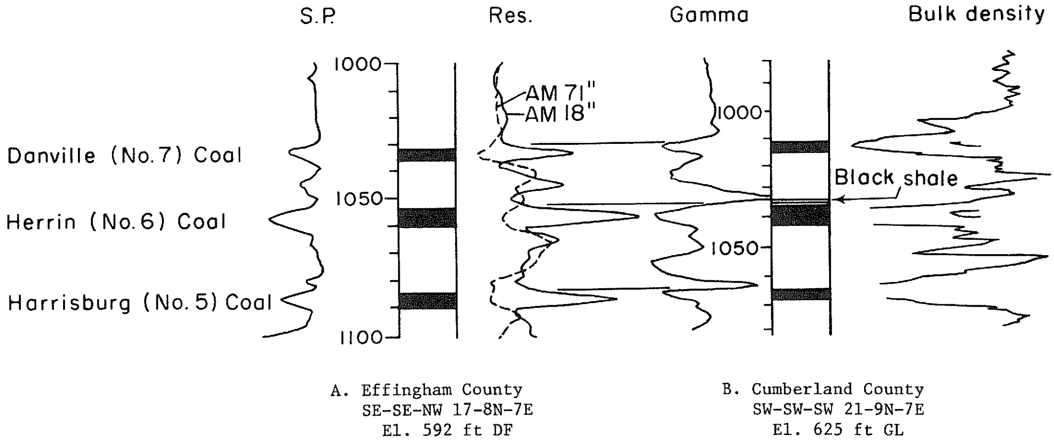

Fig. 12 - Comparison of lithologic and coal thickness interpretations from gamma-ray log (B) with those from electric log (A).

The depth of the coal increases from approximately 700 feet beneath the surface in the northwest to 1,150 feet near the southeast border with Jasper County. There is a general basinward dip, with elevations below mean sea level ranging from less than 100 to more than 600 feet. Both the Herrin Coal and the Brereton Limestone become well developed towards the eastern part of the county (pl. 2, cross-section A-A', nos. 2-5).

Fayette County (eastern part)

The axis of the Louden Anticline is located in the eastern quarter of Fayette County, and only this portion of the county was included in this study. The Herrin Coal is either very thin or absent (pl. 2, cross-section A-A', no. 1), except for an estimated 61 million tons of coal 3½ to 5½ feet thick on the northwest flank of the Louden Anticline in T. 9 N., R. 3 E. The coal thickens rapidly west of the Louden Anticline, beyond the study area. In certain parts of Tps. 5 through 9 N., R. 2 E., the coal has been estimated to be at least 7 feet thick.

The depth of the Herrin Coal increases to the southeast from approximately 670 feet below the surface to 930 feet. The Trivoli Sandstone is found at the horizon of the Herrin Coal in the northeastern part of T. 7 N., R. 3 E. (fig. 4B).

Franklin County (eastern half)

In the eastern half of Franklin County the Herrin Coal dips in a generally basinward direction to the northeast. Coal elevations range from less than 100 feet below mean sea level to more than 400 feet below mean sea level. The depths of coal range from approximately 425 feet beneath the surface in southwest T. 7 S., R. 3 E., to 920 feet in the northeast part of the county.

Large areas of relatively thick, relatively low-sulfur coal occur in Franklin County. However, the Herrin Coal has been extensively mined only in Tps. 6

and 7 S., R. 3 E., in the part of the county included in this study. These mined-out areas (approximately 32.4 square miles) account for essentially all of the area excluded in the calculation of reserves for Franklin County. The reserves total 1,190 million tons, of which there are 138 million tons of coal estimated to be more than 7½ feet thick and 536 million tons estimated to be between 5½ and 7½ feet thick. The coal tends to become thinner to the northeast. This area is one of the few areas in this study area where data obtained from electric logs could be supplemented by diamond-drill cores (pl. 2, cross-section C-C', nos. 1 and 2).

The Energy Shale constitutes the immediate roof rock for much of the western part of this area and attains thicknesses in excess of 80 feet in the southwest corner of T. 7 S., R. 3 E. (fig. 9). The Brereton Limestone thickens eastward as the Energy Shale thins. Where the Energy Shale is absent, approximately 2 feet of Anna Shale lies between the Brereton Limestone and the Herrin Coal (pl. 2, cross-section B-B', nos. 1 and 2).

Gallatin County

For Gallatin County, only the tier of townships in 7 N. has been included in this study. This is a 46 square mile area, of which 36 square miles were excluded from calculations of reserves because most of the Herrin Coal was estimated to be less than 3½ feet thick and a few heavily drilled areas extend into areas of thicker coal. In addition, the coal was cut out by the Anvil Rock Sandstone Channel, which runs through a relatively large tract of thick coal in T. 7 S., R. 9 E. (pl. 2, cross-section C-C', no. 8). Herrin Coal reserves were estimated to total 49 million tons.

The roof generally consists of 0 to 2 feet of Anna Shale and 2 to 3 feet of Brereton Limestone except in the vicinity of the Anvil Rock Channel, where sandstone or silty shale may lie on or very near the coal (pl. 2, cross-section C-C', no. 7). The depth of the coal may vary several hundreds of feet because of shallow depths found on the Omaha Dome in the northwestern part of the county and the greater depths found around several high-angle faults of the Wabash Valley Fault System that extend northward through this area. Coal depths range from approximately 700 feet below the surface to 250 feet in the east and are as shallow as 100 feet on the Omaha Dome in the west.

Hamilton County

Of all the counties included in this study, Hamilton County has the largest total reserves of the Herrin Coal (2,187 million tons). There are an estimated 178 million tons of coal more than 7½ feet thick; 730 million tons 5½ to 7½ feet thick; and 1,279 million tons 3½ to 5½ feet thick. Only the relatively small area where the coal is less than 3½ feet thick was excluded from calculations of reserves (approximately 77 square miles of a total area of 435 square miles). Many of the data in Hamilton County were obtained from drill logs and coal tests, in addition to electric logs.

In most of the county, the Anna Shale and a well-developed Brereton Limestone commonly form the immediate roof strata (pl. 2, cross-section B-B', nos. 3, 4, and 5). The Anvil Rock Sandstone, where it is thick, is often found within 10 feet of the Herrin Coal. The Anvil Rock Sandstone thickens to the north and northeast toward channel cutouts in Wayne County. Thick deposits of sandstone (40 to 60 feet) are also present in various other localities, especially in the southeastern part of the county; however, no cutouts were encountered. Energy Shale less than 20 feet thick was noted underlying Anna Shale in a few locations in the west and northwest part of the county.

Depth of coal ranges from about 550 feet below the surface in the south to 1,080 feet in the north. There is a basinward dip of approximately 15 to 20 feet per mile to the north, with coal elevations ranging from approximately 100 feet below mean sea level in the southeast to more than 600 feet below mean sea level in the north.

Jasper County

Jasper County has the largest area of reserves (379 square miles) of all of the counties considered in this study. Reserves total 2,139 million tons of coal, of which 817 million tons is estimated to be between 5½ and 7½ feet thick. Available electric logs indicate that large tracts of relatively thick coal occur in the central and southwest parts of the county.

Generally a normal, well-developed roof sequence of Anna Shale and Brereton Limestone occurs throughout most of the county in places where thicker coal is present. The Jamestown Coal and Conant Limestone Members also appear to be fairly well developed (pl. 2, cross-section A-A', nos. 6-9). The Brereton Limestone tends to thin east over the La Salle Anticlinal Belt into Crawford County (pl. 2, cross-section A-A', no. 10). Members of the Jamestown Cyclothem thin west in Effingham County (pl. 2, cross-section A-A', no. 5). Members of both the Brereton and Jamestown Cyclothems thin in western Effingham County as they rise over the Louden Anticline (pl. 2, cross-section A-A', nos. 2 and 3).

The greatest depth at which the Herrin Coal was found was 1,248 feet below the surface in Sec. 19, T. 6 N., R. 9 E. Coal at depths less than 400 feet occurs in the northeast corner of the county. The coal dips as much as 50 feet per mile west from Crawford County and 20 feet per mile east from Effingham County. Coal elevations below mean sea level range from more than 700 feet in the center of the basin to approximately 100 feet in the northeast.

Jefferson County (eastern half)

The eastern half of Jefferson County, the part of the county included in this study, is an area of 288 square miles, of which only 71 square miles were excluded in reserve calculations. There are relatively few oil-pool areas and no areas of coal less than 3½ feet thick. The coal reserves for the eastern half of Jefferson County are estimated to be 1,261 million tons. Large tracts of coal up to 10 feet thick occur in the southern and southwestern parts of the area. Only a little more than 1 square mile, south of Mt. Vernon, Illinois, has been mined out—that by the Mt. Vernon Coal Company (abandoned 1916), in Sec. 32, T. 2 N., R. 3 E.

The Energy Shale is found above the coal in much of the southwestern part of the area. It is up to 80 feet thick in southwestern parts of T. 4 S.,

R. 3 E. The Energy Shale is overlain by the Anna Shale and/or the Brereton Limestone, and it forms the immediate roof rock. The Anvil Rock Sandstone cuts out the Herrin Coal across parts of T. 1 S., Rs. 3 and 4 E., and the northwest part of T. 2 S., R. 3 E.

The coal has a general dip to the northeast at a rate of roughly 15 feet per mile. Coal elevations range from less than 300 feet below mean sea level in the west to more than 500 feet below mean sea level in the east. Coal depths range from approximately 600 feet below the surface in the southwest to 1,090 feet in the northeast.

Lawrence County

The estimated reserves of the Herrin Coal in Lawrence County total 263 million tons of coal 3½ to 5½ feet thick. The total area of reserves is only 53 square miles. A total of 312 square miles was excluded because major portions of the county have been heavily drilled for oil and gas and most of the area contains Herrin Coal that is less than 3½ feet thick. The Herrin Coal and the Brereton Limestone tend to thin and the Jamestown Coal to thicken as these strata rise east over the steep west flank of the La Salle Anticlinal Belt (fig. 6). In Secs. 24 and 25, T. 2 N., R. 13 W., sandstone occupies the horizon of the Herrin Coal.

The coal has a general dip to the west at rates that range from approximately 10 feet per mile in the east to approximately 50 feet per mile in the western part of the county. Coal elevations range from more than 100 feet above mean sea level in the east to more than 400 feet below mean sea level in the west. Corresponding depths of coal range from 270 feet below the surface in the east to more than 930 feet below the surface in the west part of the county near the western extremity of the La Salle Anticlinal Belt.

Marion County (eastern half)

The eastern half of Marion County, included in this study, is bordered on the west by the Salem Anticline (fig. 1). The estimated reserves of Herrin Coal in the part of Marion County covered in this report total 138 million tons; however, most of this part contains coal that is estimated to be less than 3½ feet thick. The coal appears very thin or absent in T. 4 N., Rs. 3 and 4 E.

A thick sequence interpreted as silty shale is found in place of the Herrin Coal in Sec. 3, T. 2 N., R. 4 E. The roof of the coal in most of the area appears to consist of calcareous or sandy shale. The more typical roof material of Anna Shale and Brereton Limestone is common where the coal thickens to more than 4 feet.

In a general way, the coal dips eastward; elevations range from less than 100 feet below mean sea level in the northwest to more than 450 feet below mean sea level in the east. The depth of the Herrin Coal ranges from approximately 700 feet below the surface in the northwest to more than 975 feet in the eastern part of the county.

Richland County

A major part of Richland County contains Herrin Coal estimated to be more than 3½ feet thick. Heavily drilled areas of oil pools are relatively small and scattered. The reserves of Herrin Coal total 1,443 million tons, of which 107 million tons are estimated to be coal more than 5½ feet and possibly up to 7 feet thick.

The roof sequence usually consists of Anna Shale and Brereton Limestone; however, the Anna Shale is commonly thin and often absent whereas the Brereton Limestone tends to be thick (pl. 2, cross-section B-B', no. 10). Sandstone was found at the horizon of the Herrin Coal in Sec. 14, T. 2 N., R. 14 W.

The coal dips basinward, occurring at elevations of less than 400 feet below mean sea level in the southeast to more than 600 feet below mean sea level in the northwest. The depth of coal likewise ranges from approximately 900 feet below the surface to 1,150 feet.

Saline County

For Saline County, only the northern tier of townships (T. 7 S.) was included in this study. The majority of the Herrin Coal in this area is between 3½ and 5½ feet thick, with a normal roof of well-developed Anna Shale and Brereton Limestone (pl. 2, cross-section C-C', no. 6). The reserves of Herrin Coal contained in this 54 square mile area total 229 million tons.

The depth of coal increases to the north and is generally between 450 and 650 feet below the surface. There is a basinward dip of an average of 50 feet per mile. Coal elevations range from less than 100 feet above mean sea level in the southeast, where the coal is only 300 feet below the surface in Sec. 36, T. 7 S., R. 7 E., to more than 200 feet below mean sea level in the northwest corner of the county, where the coal lies at a depth of approximately 690 feet.

Wabash County

The estimated reserves of Herrin Coal in Wabash County total 217 million tons. Most of the coal greater than 3½ feet thick is located in the central part of the county. The Brereton Limestone can be recognized in many of the localities where the coal tends to be thicker. Both members, however, thin to the north and the Jamestown Coal and/or the Conant Limestone appear to become thicker. Sandstone occupies the position of the Herrin Coal in several locations in the northern part of the county. The Herrin Coal generally thins toward the south also, but the limestone above it remains relatively thick; it appears that the thick limestone sequence may contain both the Brereton and Conant Limestone Members.

There is a general dip westward, which is interrupted by faults of the Wabash Valley Fault System in the southern part of the county. Coal is present at elevations that range from slightly above mean sea level in the east to more than 400 feet below mean sea level in the west. Depths range from approximately 390 feet below the surface in the east to as low as 850 feet in the west.

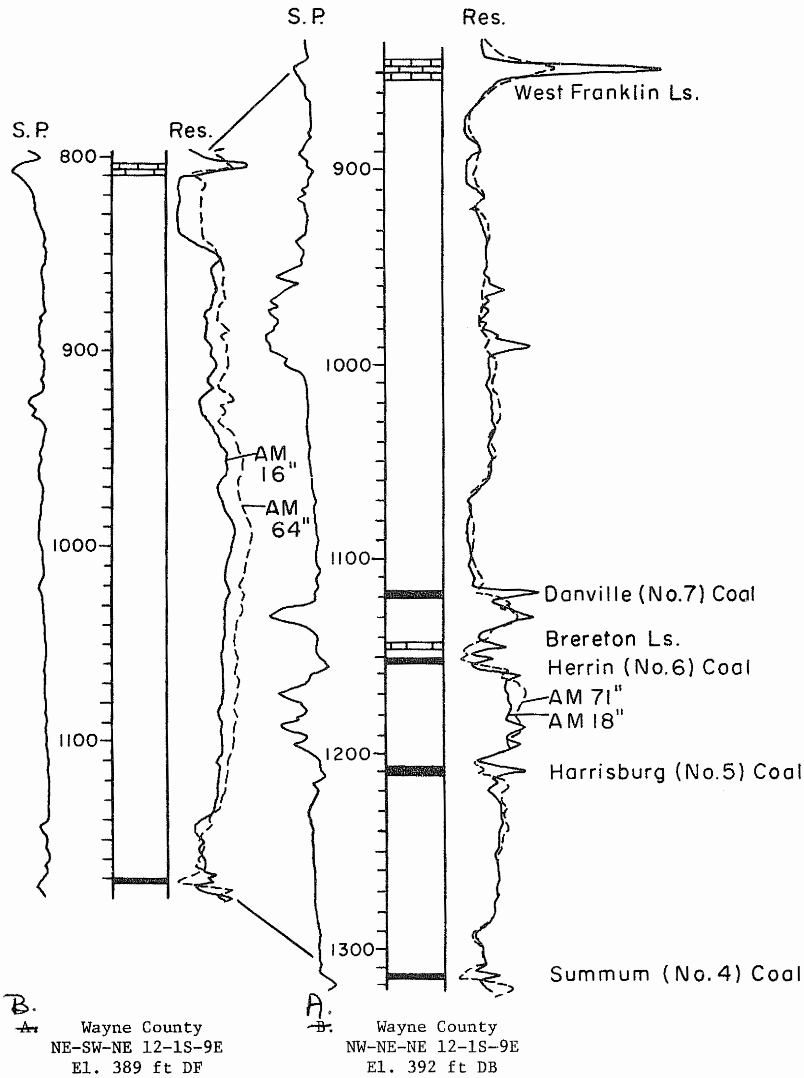

Fig. 13 - Electric logs showing local structure (possible fault) in Wayne County. A. Lowest elevation of Herrin (No. 6) Coal observed in Illinois. B. Upper part of Carbondale Formation replaced by shale in adjacent location.

Wayne County

Wayne County is the largest county that is included in this report (715 square miles). Reserves of Herrin Coal are estimated at 1,440 million tons. The thickness of the Herrin Coal is more varied in Wayne County than it is in counties previously discussed, because the areas of designated thickness are not as persistent as those observed in adjacent counties. Estimated thicknesses range from 0 to 8 feet.

In contrast to the relationship between coal thickness and the Walshville Channel (fig. 8), there is no observed relationship between coal thickness and the Anvil Rock Sandstone Channel, which cuts out the coal in a 1-mile wide strip across the county. The Anna Shale and the Brereton Limestone are not well developed or typically present in many parts of the county and especially in the vicinity of the Anvil Rock Channel. Shale and argillaceous limestone or sandstone appear to compose the principal lithologies of the roof sequence in these areas. In most places where the Brereton Limestone is recognizable on an electric log, it appears thin and poorly developed (pl. 2, cross-section B-B', nos. 6-8).

The depth of the Herrin Coal ranges from 1,000 feet below the surface to 1,150 feet. Coal elevations usually range only from a little less than 500 feet below mean sea level to a little more than 600 feet below mean sea level. However, the lowest elevation of the Herrin Coal encountered was 759 feet below mean sea level in Sec. 12, T. 1 S., R. 9 E. (fig. 13A). Faulting would be a reasonable explanation for this abrupt drop in elevation, although presence of a fault is not certain. An electric log taken from an adjacent drill hole also in Sec. 12, T. 1 S., R. 9 E., shows a very thick shale sequence in place of the Herrin Coal (fig. 13B).

White County

The Herrin Coal in White County has been estimated to be 8 feet thick at some localities; however, thicknesses tend to be quite varied. An abandoned shaft mine at Norris City mined approximately 0.80 square miles. Estimated remaining classified reserves of Herrin Coal in the county total 1,246 million tons.

The Herrin in White County has a generally northwest dip that is interrupted by several northeast-trending faults of the Wabash Valley Fault System in the south and east parts of the county (fig. 2). Coal elevations range from less than 100 feet below mean sea level to more than 600 feet below mean sea level. Coal depth varies from as little as 410 feet below the surface in the southeast corner to 470 feet in the southwest to as much as 1,150 feet on downthrown sides of faults.

The Anvil Rock Sandstone Channel cuts out the coal along a ½- to 1-mile wide strip that runs through parts of eastern White County (pl. 1). Sandstone and siltstone make up the principal roof lithologies near the channel cutout, but the normal roof sequence of Anna Shale and Brereton Limestone is persistent elsewhere (pl. 2, cross-section C-C', no. 9).

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