A FLUVIAL CHANNEL CONTEMPORANEOUS WITH DEPOSITION OF THE SPRINGFIELD COAL MEMBER (V), PETERSBURG FORMATION, NORTHERN WARRICK COUNTY, INDIANA

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A Fluvial Channel Contemporaneous with Deposition of the Springfield Coal Member (V) Petersburg Formation Northern Warrick County, Indiana

By DONALD L. EGGERT

DEPARTMENT OF NATURAL RESOURCES
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Contents

Illustrations

Illustrations

Table

A Fluvial Channel Contemporaneous with Deposition of the Springfield Coal Member (V), Petersburg Formation, Northern Warrick County, Indiana

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Abstract

The Springfield Coal Member (V) of the Petersburg Formation is split into two or more coal seams in northern Warrick County, Ind. This body of split coal is 1 to 4 miles (1.6 to 6 km) wide and more than 40 feet (12 m) thick in places and can be mapped from exposures in surface mines in sec. 7, T. 5 S., R. 7 W., and sec. 12, T. 5 S., R. 8 W., to secs. 2 and 3, T. 4 S., R. 9 W., where it enters Gibson County, a distance of 16 miles (26 km). The lithologies within the split consist of rash, gray mudstone, siltstone, and sandstone. Grain size of the clastic rocks increases from the flanks of the zone toward the center. The center of the zone is dominated by crossbedded sandstone that commonly shows cut-and-fill relationships, and in some places the upper seam of Springfield coal is absent. Plant fossils are present in all lithologies that split the Springfield. Sandstone rather than underclay occurs locally below the lower split coal. In the basal part of the Dugger Formation, several marine beds that normally overlie the Springfield thin or pinch out above areas where the split is thick and are replaced by thin marine mudstones.

The split beds of the Springfield in Warrick County are believed to have been formed by a fluvial-channel system that was partly contemporaneous with peat deposition and that was abandoned before the termination of peat accumulation. The term Folsomville Member is proposed for the group of clastic beds that split the Springfield Coal Member, and the term Leslie Cemetery Channel is proposed for the paleoenvironmental feature. Thicker high-sulfur Springfield coal was deposited in a trend paralleling this channel system. Where the Springfield coal is split by this channel system, the lower split of the seam may be a modest low-sulfur coal reserve.

Introduction

The primary objective of this study was to map and determine the nature of the sediments associated with an area in northern Warrick County where the Springfield Coal Member is split and low in sulfur. Almost half of Indiana's coal production to date has been from the Springfield Coal Member (V). Because of estimated recoverable reserves of about 6.1 billion short tons (5.5 billion metric tons), the Springfield seam has considerable economic potential. Sulfur in the Springfield commonly ranges from 3 to 7 percent, but coal containing less than 2-percent sulfur has been produced from two small surface mines in Warrick County. This report summarizes observations of the strata associated with this low-sulfur split-coal deposit as seen in surface mines and as traced through the subsurface in northern Warrick County (fig. 1).

ACKNOWLEDGMENTS

David McDonald, H. S. Richards, Howard Lamkin, and other staff member of the Peabody Coal Co. assisted this project by providing data, access to their mines, and useful advice. The staff of the Lemmons Coal Co. was also cooperative and helpful. W. A. DiMichele, J. F. Mahaffy, T. L. Phillips, B. M. Stidd, and L. Stidd provided advice related to the plant fossils observed during this project. Licia Weber and Kathy Fowler assisted in preparing maps and cross sections. Harold C. Hutchison, N. K. Bleuer, Henry H. Gray, and Robert H. Shaver provided encouragement and stratigraphic advice. I am grateful to all those who helped, for without their efforts I could not have completed this project.

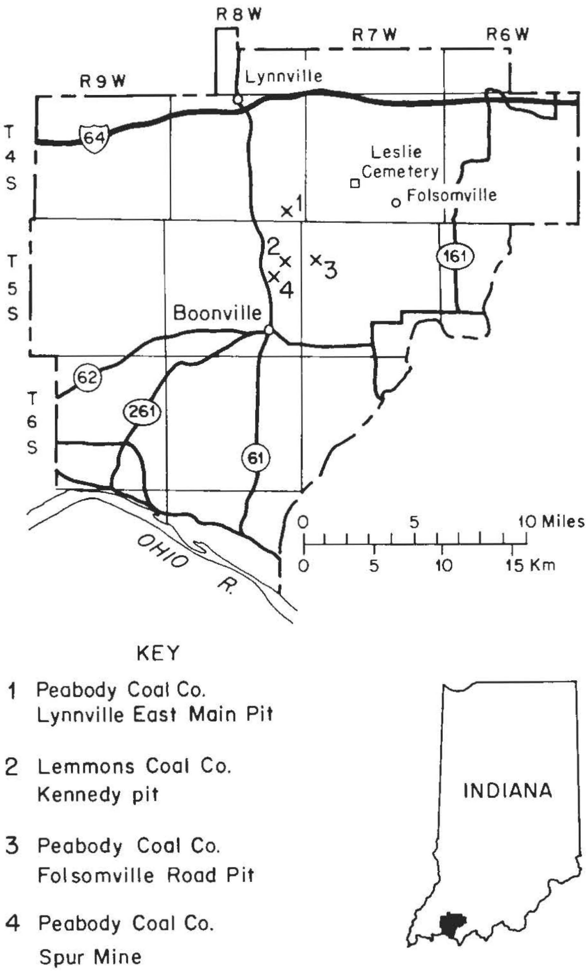


Figure 1. Map of Warrick County showing the study area.

SULFUR IN COAL

Sulfur, for many years considered a detrimental constituent of coal, is found in two forms: organic and mineral. Organic sulfur is incorporated within the organic molecules of the coal, and mineral sulfur occurs primarily as pyrite, gypsum, marcasite, elemental sulfur, and sphalerite. Pyrite is the most common sulfur-bearing mineral in midwestern coals. Primary sulfur, the type that forms or accumulates during peat deposition, and secondary sulfur, which is introduced after the peat has ceased to form, are temporal classifications of sulfur in coal or peat deposits.

Primary sulfur in a coal deposit is sulfur that becomes incorporated into the organic molecules of the plant tissues or that precipitates as a mineral within the peat during peat deposition. Casagrande and others (1977) has shown that less sulfur occurs in modern fresh-water peats than in marine-water peats. Fisk (1960) noted that the salinity of water in the modern Mississippi delta swamps and marshes increases away from the distributary or major channels. Therefore, a high-sulfur midwestern coal may have been exposed to marine or brackish water during peat deposition if it was deposited some distance from a channel environment.

Secondary sulfur in coal is believed to have originated after deposition and burial of peat. Evidence for secondary sulfur in coal rests mainly on greater concentrations of pyrite near the base and the top of a coal seam than elsewhere. Gluskoter and Simon (1968) and Gluskoter and Hopkins (1970) found that coals overlain by marine deposits are generally high-sulfur coals, and those overlain by 20 feet (6.5 m) or more of nonmarine gray shale are generally low-sulfur coals. Probably the sulfate is transported from overlying sediments to the peat by brines. It is commonly believed that gray shales associated with penecontemporaneous channel deposits act as barriers to prevent brines moving into a buried peat deposit.

PREVIOUS STUDIES

Sand bodies associated with the Springfield Coal Member have been mapped by geologists in Illinois and Indiana (Stanley, 1952; Wier and Stanley, 1953; Friedman, 1956 and 1960; Wier and Powell, 1967; Hopkins, 1968; and Brittain, 1975). The Springfield coal is generally split or absent near these channels. Stanley (1952) and Brittain (1975) believed that the sand bodies represent fluvial channels that eroded the coal and that the gray shale associated with the sand bodies represents rapid deposition in a subsiding basin, but Friedman (1956 and 1960) interpreted a channel near Terre Haute in Vigo County as clearly contemporaneous with the deposition of the Springfield peat. Wanless and others (1968) proposed that the Springfield coal was deposited on a delta plain. They believed that

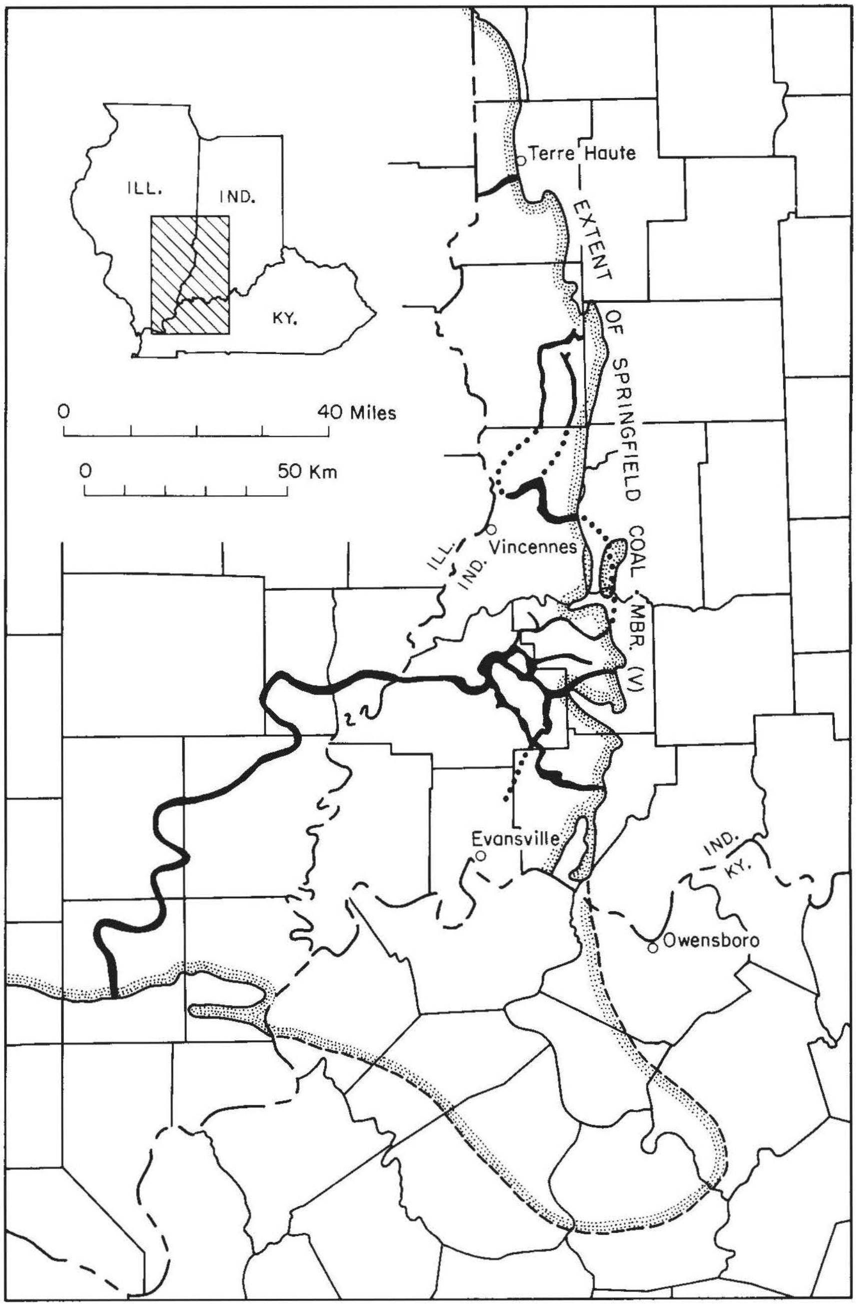


Figure 2. Map of southeastern Illinois, southwestern Indiana, and northwestern Kentucky showing extent of the Springfield Coal Member, its equivalent coals, and known contemporaneous channels. Modified from Friedman (1956 and 1960), Wier and Powell (1967), Brittain (1975), Wier and Stanley (1953), Hopkins (1968), and Eggert and Adams (in preparation).

INDIANA			ILLINOIS		WESTERN KENTUCKY	
CARBONDALE GROUP	DUGGER FORMATION	Danville Coal Mbr. (VII)	CARBONDALE FORMATION	Danville (No. 7) Coal Mbr.	CARBONDALE FORMATION	
		Universal Ls. Mbr.		Bankston Fork Ls. Mbr.		Bankston Fork Ls. Mbr.
		Hymera Coal Mbr. (VI)		Jamestown Coal Mbr.		
		Providence Ls. Mbr.		Brereton Ls. Mbr.		Providence Ls. Mbr.
		Herrin Coal Mbr.		Herrin (No. 6) Coal Mbr.		No. 11 Coal Bed
		Bucktown Coal Mbr. (Vb)		Briar Hill (No. 5A) Coal Mbr.		No. 10 Coal Bed
		Antioch Ls. Mbr.				
		Alum Cave Ls. Mbr.		St. David Ls. Mbr.		
	PETERSBURG FORMATION	Springfield Coal Mbr. (V) and Folsomville Mbr.		{ Dykersburg Shale Mbr. / Springfield and Harrisburg (No. 5) Coal Mbrs. }		No. 9 Coal (Mulford) Bed
		Stendal Ls. Mbr.				
		Houchin Creek Coal Mbr. (IVa)		Summun (No. 4) Coal Mbr.		Upper Well (No. 8b) Coal Bed
	LINTON FORMATION	Survant Coal Mbr. (IV)				No. 8 Coal Bed
		Velpen Ls. Mbr.				
		Colchester Coal Mbr. (IIIa)		Colchester (No. 2) Coal Mbr.		Schultztown Coal Bed?
		Coxville Ss. Mbr.				

Figure 3. Rock stratigraphic classification of selected units of the Carbondale Group in Indiana and correlation with equivalent strata in Illinois and western Kentucky.

a sandstone body in Gibson County, Ind., and southeastern Illinois was a distributary channel contemporaneous with the delta plain on which the Springfield coal formed. If the Springfield Coal Member was deposited on a delta platform, other interconnected contemporaneous channels may also have been present. A parting as much as 10 feet (3 m) thick was reported in the study area by Ashley (1899), Fuller and Ashley (1902), and Burger and Wier (1970), but no genetic explanations for this deposit were proposed.

Criteria for recognizing channel systems contemporaneous with a coal seam were presented by Friedman (1956 and 1960) and Johnson (1972). The principal criteria include (1) abnormally thick coal adjacent and parallel to sandstone-cutout areas, (2) interbedding of coal and fluvial sediments, (3) clastic wedges that extend from the sand bodies across the peat swamp and that predate the normal marine roof strata, and (4) low-sulfur coals associated with the clastic wedges. Reexamination of known sand bodies associated with the Springfield Coal Member in Indiana indicates an intricate system of channels contemporaneous with the deposition of the Springfield coal (fig. 2).

Stratigraphy

The Springfield Coal Member of the Petersburg Formation in Indiana is correlative with the Springfield and Harrisburg (No. 5) Coal Members of the Carbondale Formation in Illinois and with the No. 9 Coal (Mulford) of the Carbondale Formation in Kentucky (fig. 3). The Springfield is overlain by the Dugger Formation; the typical stratigraphic sequence above the Springfield includes black fissile shale, dark-gray marine shale, and the Alum Cave Limestone Member, which is overlain by sandstone and shale of the Dugger Formation. The strata above the Springfield where the coal is not split consist generally of black

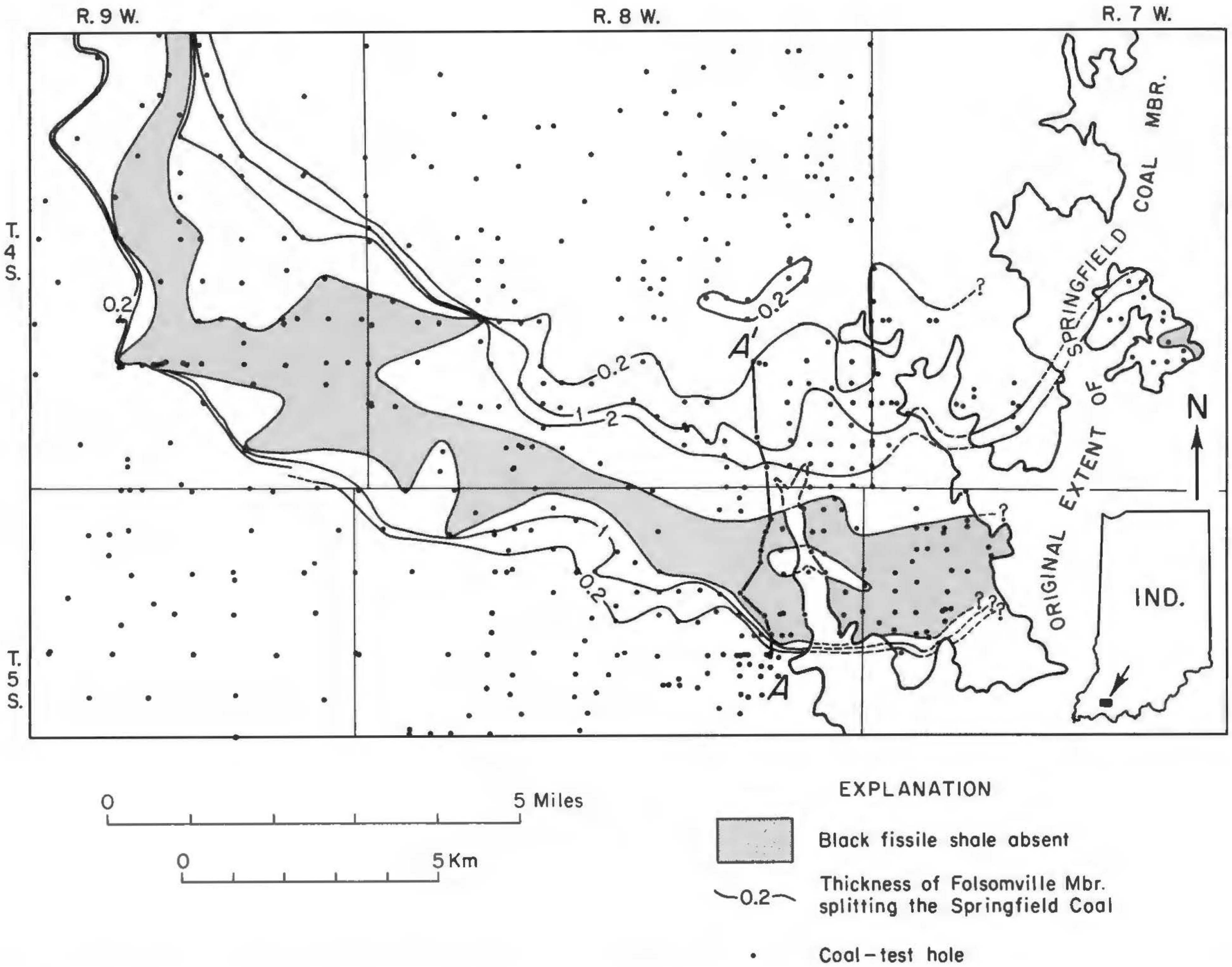


Figure 4. Map showing extent of the Springfield Coal Member, thickness of the Folsomville Member, and extent of black fissile shale.

fissile shale, 0 to 5 feet (0 to 1.5 m) thick, dark-gray marine shale, 2 to 12 feet (0.6 to 3.6 m) thick, and in places the Alum Cave Limestone Member, 0 to 1 foot (0 to 0.3 m) thick. Both the dark-gray marine shale and the Alum Cave contain abundant crinoid and brachiopod fragments.

The black fissile shale is the most persistent unit above the coal, but it thins and pinches out in places where the coal is split. The dark-gray marine shale and the Alum Cave also pinch out where the coal is split, and in places they are replaced by medium- to dark-gray mottled marine mudstone, less than 0.5 foot (.15 m) thick and containing many poorly preserved casts of crinoid columnals.

The Springfield Coal Member in Warrick County ranges from 0 to 12 feet (4 m) in thickness and is split in some areas into two or more seams. The split interval is elongate and sinuous and was traced 16 miles (26 km) in the subsurface. It is lenticular in cross section, feathers to a thin medial parting, and has bilateral symmetry (figs. 4, 5, and 6). In some areas the split interval is more than 40 feet (12 m) thick and 2 to 4 miles (2 to 6 km) wide (fig. 7). Generally the coal is split into two major seams, but some minor split seams are also present. The upper seam of the Springfield thins as the thickness between it

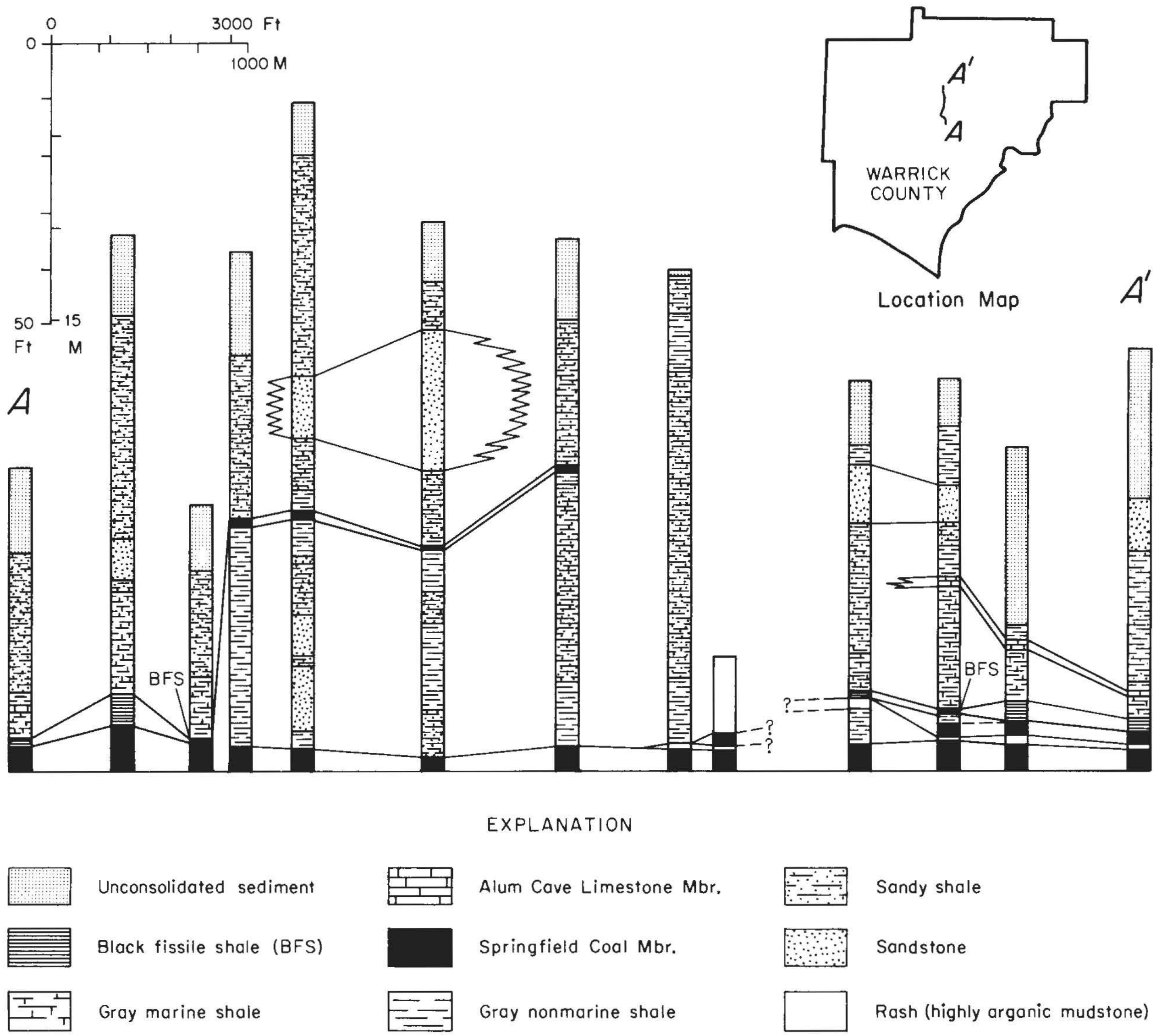


Figure 5. Cross section *A*-*A*′ showing configuration of stratigraphic units within the study area.

and the lower seam increases; in some places the upper coal is absent where the parting is thick. The lower seam of the Springfield also thins toward the center of the split-coal zone. The Springfield coal is thinnest near the center of the split-coal zone and thickest adjacent to the zone. In the latter place it may be more than 6 feet (2 m) thick. Coal balls are found in both the upper part of the Springfield where it is not split and the upper seam of the split Springfield. Normally the Springfield developed on an underclay, but in some drill holes the coal rests on or near sandstone.

The lithologies that split the Springfield coal consist mainly of rash (dark-gray organic shale interbedded with thin vitrain bands), gray shale, siltstone, and sandstone. Rash occurs at the edge of the split-coal zone, and it is normally at the base of the upper seam or above the top of the lower seam (fig. 8). Commonly the contact between rash, coal, and gray shale is gradational, but in some areas the contact with gray shale is sharp.

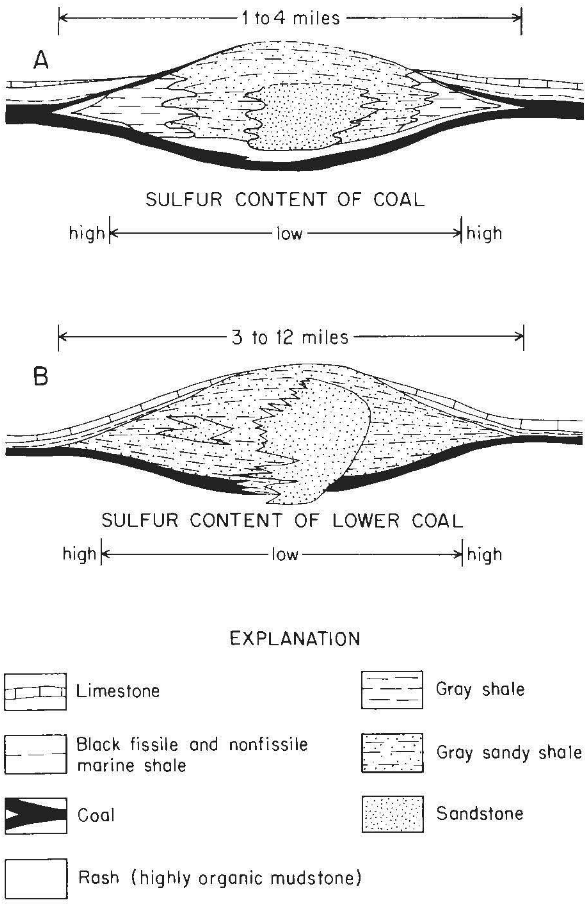


Figure 6. Diagrammatic cross sections of the abandoned channel contemporaneous with deposition of the Springfield Coal Member in Warrick County and of the major contemporaneous channel in the equivalent coal of southeastern Illinois. *A*, Folsomville Member splitting the Springfield Coal Member and thinning of basal marine beds of the Dugger Formation over the split-coal zone. *B*, Dykersburg Shale Member overlying the Springfield (Harrisburg) Coal Member in southeastern Illinois.

Toward the central part of the split zone, gray shale rapidly increases in thickness between the upper and lower rash. This gray shale contains many well-preserved fossils of the genera *Annularia*, *Calamostachys*, *Lepidodendron*, *Leipdophylloides*, *Neuropteris*, *Pecopteris*, *Psaronius*, *Sigillaria*, *Sphenopteris*, and others, but no marine fossils were observed. *Neuropteris* leaves and pteridosperm stems were the most common plant megafossils observed in the clastic sediments. As the thickness of the parting increases, the particle size increases: shale changes to sandy shale and siltstone and then to sheet or tabular sand bodies interbedded with mudstone. Massive sand bodies become the dominant lithology in the center of the zone. Many of these sandstones exhibit cross-stratification and cut-and-fill relationships with other beds (fig. 9).

Folsomville Member

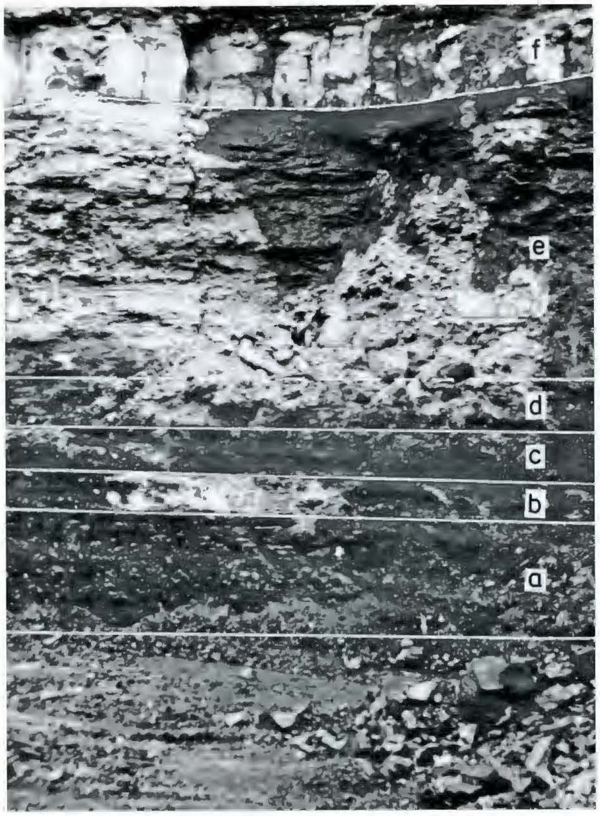
The name Folsomville Member is here given to the sequence of interrelated lithologies of rash, gray shale, siltstone, and sandstone that extensively split the Springfield Coal Member (fig. 6). This unit can be traced by using coal-drilling data from northeast of Boonville to the Gibson-Warrick county line in the northwest corner of Warrick County (fig. 4). The Folsomville can be identified in Gibson County in electric logs and can be traced as a split-coal zone from the county line to southeast of Princeton (Eggert and Adams, in preparation; fig. 10). The Folsomville Member is variable in thickness and may range from tenths of feet (mm) to 65 feet (18 m) in thickness in a short distance.

The type section and reference localities are here designated as the SW¼NE¼ sec. 7, T. 5 S., R. 7 W., and the NW¼SW¼ sec. 12, T. 5 S., R. 8 W. Both sites are final cuts in former surface mines close to Folsomville, from which the name is derived (fig. 1).

Coal drilling and electric logs indicate that a fining-upward sand body generally less than 60 feet (18 m) thick underlies the lower seam of the split Springfield coal. The Folsomville Member roughly parallels the trend of this earlier sand body.

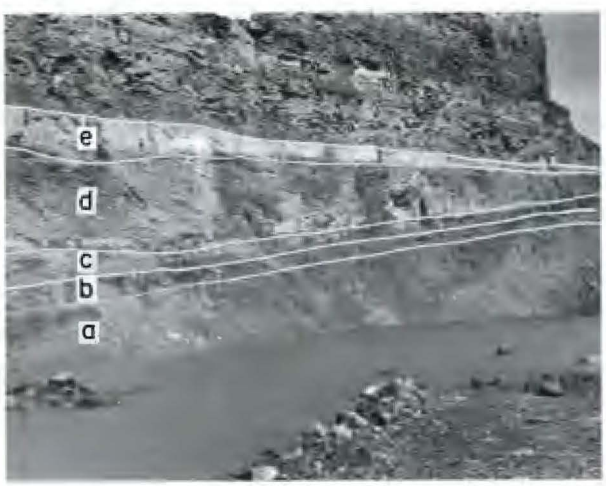
Because the upper seam of the split Springfield coal is absent from a limited area within the extent of the Folsomville Member, emending the definition of the top of the Petersburg Formation is necessary. Where the upper seam of the Springfield coal is absent, the top of the Folsomville Member is the top of the Petersburg Formation.

Hopkins (1968) proposed the term Dykersburg Shale Member for a gray-shale wedge in Illinois between the top of the Springfield and



A

Figure 7. Springfield Coal Member split by the Folsomville Member of the Petersburg Formation at the Kennedy Pit, Lemmons Coal Co. *A*, West end E-W highwall showing edge of the split coal: *a*, lower seam of the Springfield coal; *b*, gray organic mudstone of the Folsomville Member; *c*, upper seam of the Springfield coal; *d*, black fissile shale; *e*, gray marine mudstone; *f*, Alum Cave Limestone Member. *B*, East end of E-W highwall showing thinning marine strata and thickening gray organic mudstones of the Folsomville Member: *a*, gray mudstone and gray organic mudstones of the Folsomville Member; *b*, upper seam of the Springfield Coal Member; *c*, black fissile shale; *d*, gray marine shale; *e*, Alum Cave Limestone Member. Lower seam of the Springfield coal is below water level. *C*, View looking north along N-S highwall showing the Springfield coal split by about 35 feet (11 m) of sandstone and shale of the Folsomville Member: *a*, top of low-sulfur lower seam of the Springfield coal; *b*, Folsomville Member; *c*, upper seam of the Springfield Coal Member.



B

C

Harrisburg (No. 5) Coal Members and an overlying black fissile shale and limestone in southeastern Illinois (fig. 6). The feature described here, however, although it is associated with the same coal member, is smaller in width and exhibits a distinctly different sedimentologic and stratigraphic relationship with both the coal and overlying strata. The sediments that split the Springfield coal in Warrick County consist of several

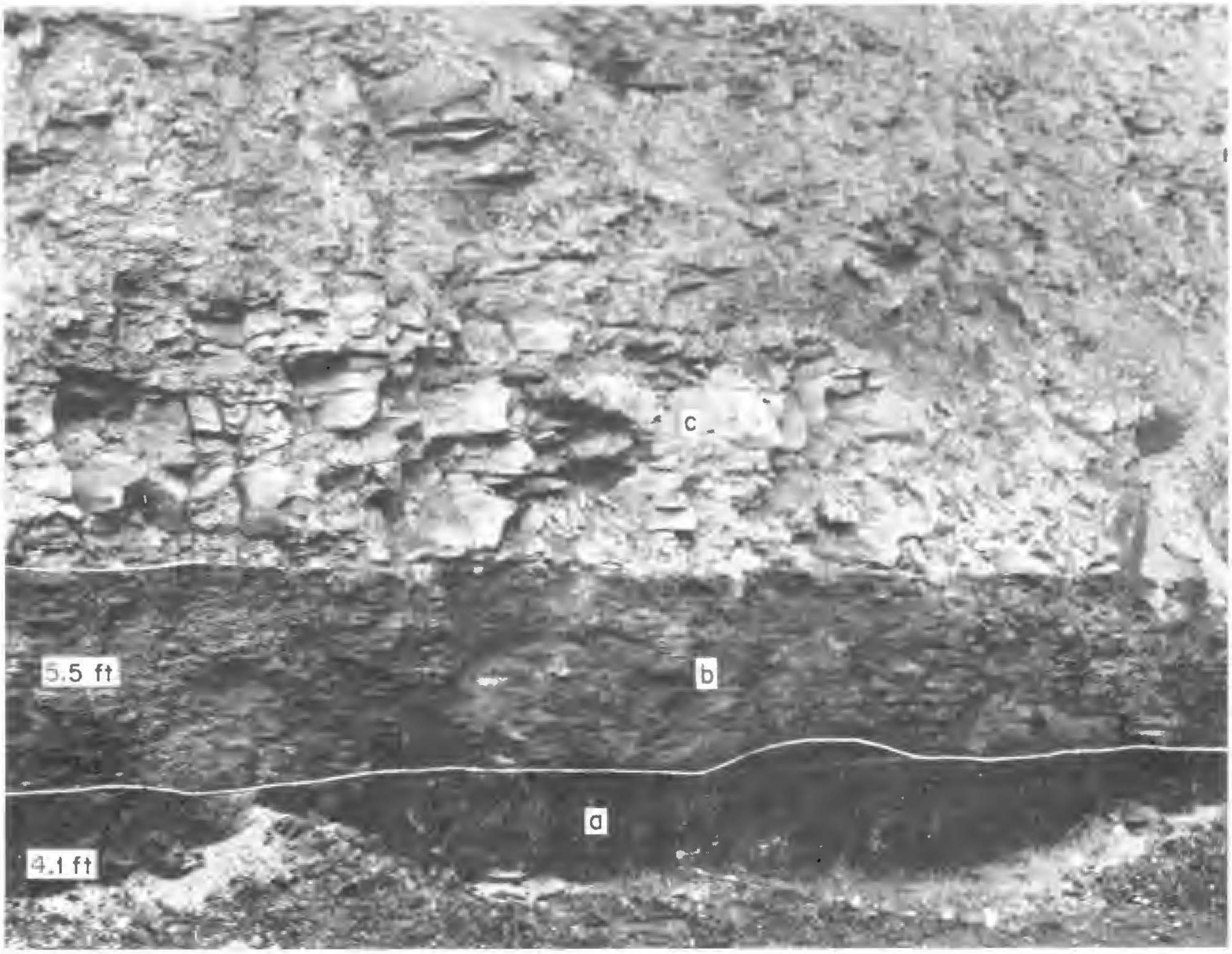


Figure 8. Rash, organic mudstone of the Folsomville Member, overlying the Springfield Coal Member. Peabody Coal Co. Lynnville Mine, Folsomville Road Pit (111), where the lower seam of the split Springfield coal is a low-sulfur coal: *a*, Springfield coal; *b*, rash; *c*, sandstone.

distinct interrelated lithologies, each of which is lenticular in transverse section but which together are a continuous unit laterally. Therefore, the term Dykersburg Shale Member seems inappropriate.

Depositional Model of the Folsomville Member

The Folsomville Member consists of fluvial sediments deposited before termination of Springfield peat accumulation. The Springfield split coal is a sinuous lenticular zone containing sediments suggestive of deposition within a fluvial-channel system. The rash along the edges of the zone suggests that fine sediments periodically entered the coal swamp from an outside source. These may represent flood-plain backswamp sedimentation close to the natural-levee and crevasse-splay environment. Gray shales interbedded with sheet sands that thicken toward the center of the split-coal zone may signify natural-levee or distal crevasse-splay sedimentation. Crossbedded sand bodies, which exhibit cut-and-fill relationships with other beds, may represent laterally shifting channel sedimentation or proximal crevasse-splay deposition. Additional evidence for lateral shifting of the fluvial-channel environment includes coarsening-upward sand bodies and

Figure 9. Sand body exhibiting cut-and-fill relationship within the Folsomville Member. North end of the Peabody Coal Co. Lynnville Mine, Folsomville Road Pit (111), which is believed to be near the center of the Leslie Cemetery Channel.

an erect tree-fern stump extending from rash into one of the channellike sand bodies (fig. 11). Preservation of this tree stump required quick burial before decay could destroy it.

The Folsomville Member has a rough bilateral symmetry in which sediments in the center represent the channel environment, sediments on the flanks represent the crevasse-splay and natural-levee environment, and sediments still farther from the center represent the overbank flood-plain environment. This distribution of environments is similar to the distribution associated with fluvial channels in modern deltas. Folsomville sediments are interbedded with, and do not have an erosional relationship with, the Springfield Coal Member; they are partly contemporaneous with peat accumulation. Folsomville sediments can be traced through southeastern Gibson County to the place where they merge with the larger Gallatia Channel (Hopkins and others, 1979) southeast of Princeton. Eggert and Adams (in preparation) report a complicated bifurcating

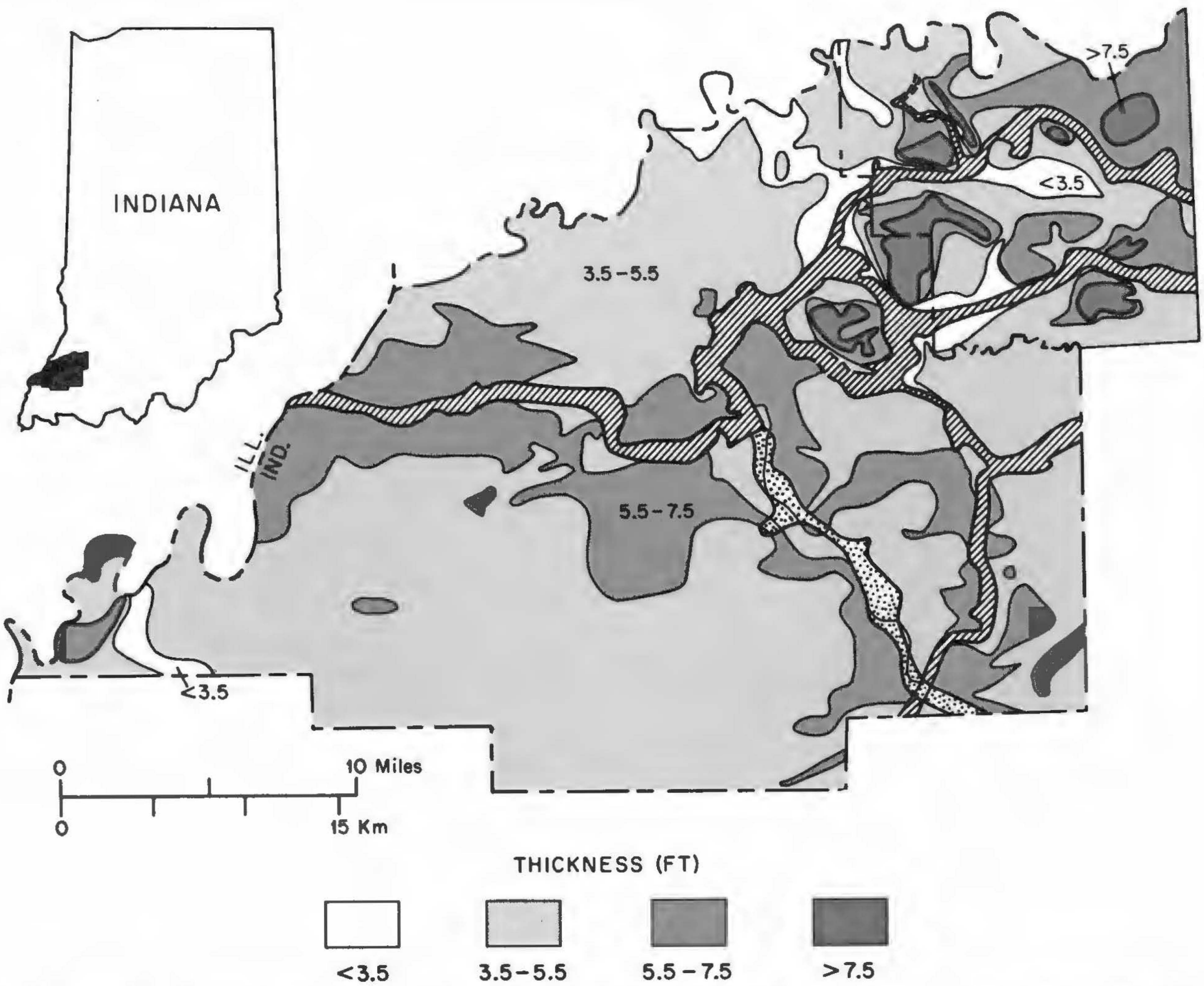


Figure 10. Map of Gibson County and northwestern Pike County showing the distribution of the Springfield Coal Member (in feet). Springfield coal is absent in the area with a diagonal-line pattern. The Folsomville Member and the split Springfield coal are present within the stippled area.

interconnected system of fluvial channels in southeastern Illinois and southwestern Indiana. The sediments represented by the Folsomville Member are believed to represent a secondary channel of this channel complex.

Other possible explanations for the origin of the Folsomville Member include tidal-channel and barrier-island environments. A tidal-channel environment should produce sediments with bimodal current indicators and marine fossils, but these were not observed. The large volume of sediment and the evidence for crevasse-splay activity are unlikely in a tidal-channel deposit. Paleolatitude studies of deposits of Carboniferous age place the Midwest near the equator at the time of deposition, and as tidal intensity is least near the equator in the modern environment, the possibility of Pennsylvanian tidal sedimentation in Indiana is small. A barrier island is the least likely depositional environment for the Folsomville Member because no large-scale aeolian sedimentary structures, marine megafossils, or marine trace fossils were observed. Besides, the sinuous elongate form of the deposit is not what one

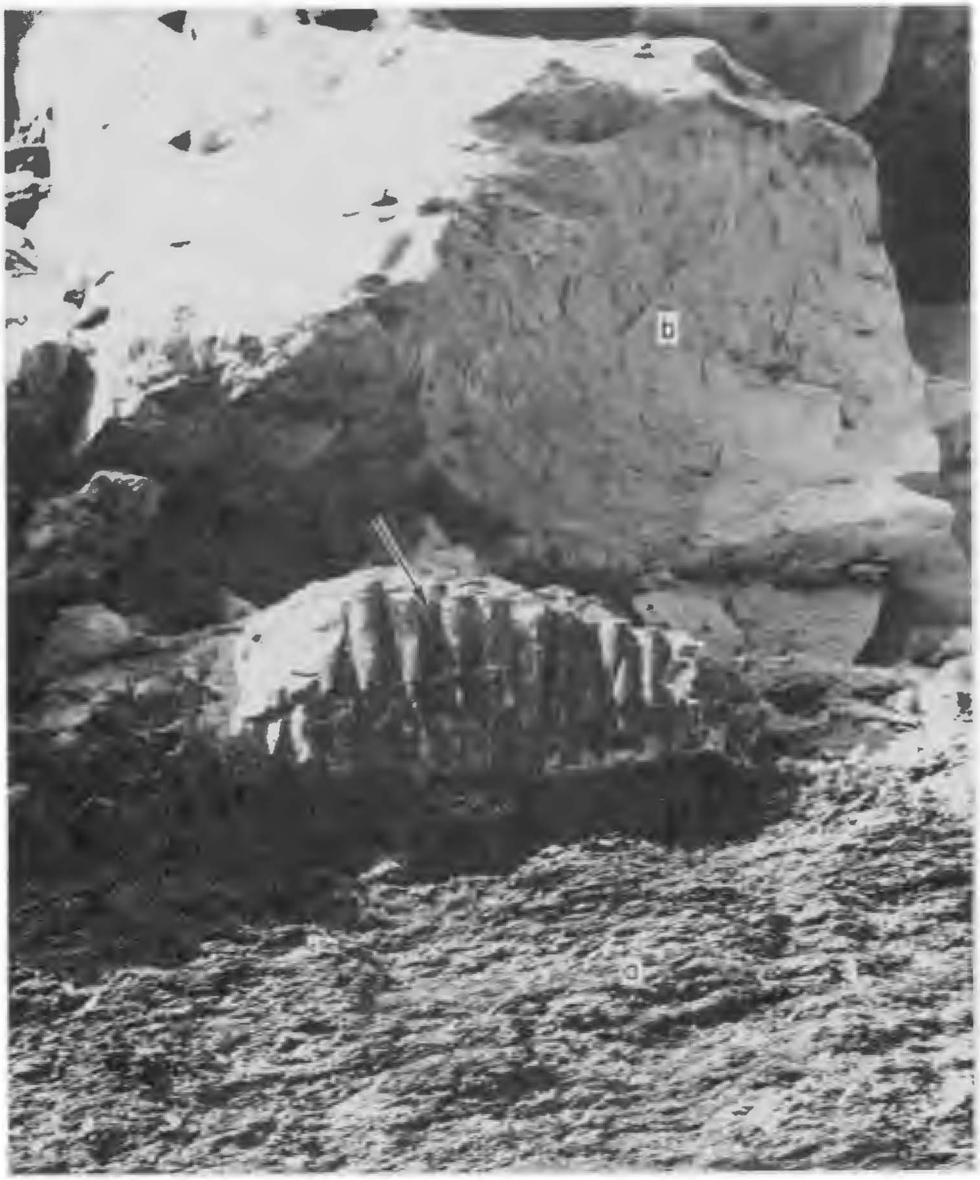


Figure 11. Erect *Psaronius* trunk (arrow) in the Folsomville Member. This photograph was taken a short distance from figure 9 at the Folsomville Road Pit. Unit *a* is dark-gray organic-rich mudstone rash, and unit *b* is buff to white sandstone. The sandstone is believed to have been rapidly deposited, perhaps because of a crevasse splay and diversion of the Leslie Cemetery Channel, burying the erect tree trunk.

would expect in a barrier-island system. The proximity of the Folsomville Member to what are believed to be major distributary channels (fig. 2) and the lack of tidal or barrier-island sedimentologic evidence strongly suggest that the depositional environment of the Folsomville was that of a fluvial channel.

Modern fluvial channels within a deltaic system form a complicated web of bifurcating distributary channels in many places. This must be considered when names are given to paleoenvironmental features, such as a channel. Friedman (1956 and 1960) assigned paleoenvironmental nomenclature to other

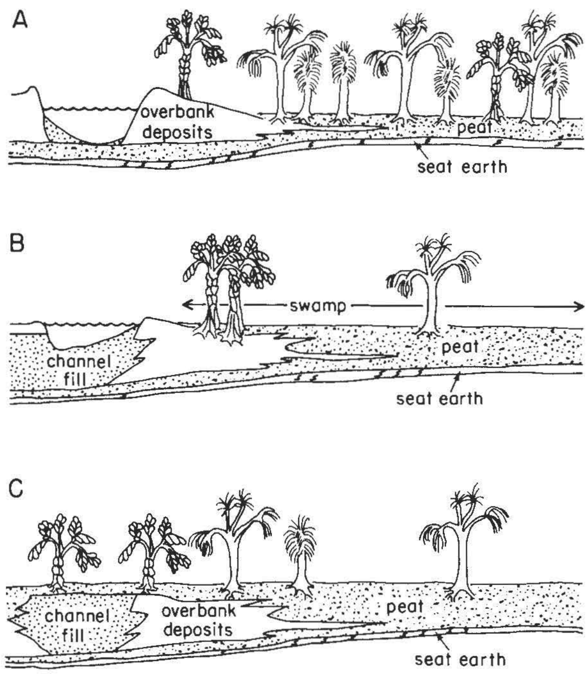


Figure 12. Progressive stages of peat accumulation and deposition of fluvial sediments that may resemble the development and abandonment of the Leslie Cemetery Channel. *A*, Establishment of a secondary channel into the peat swamp. *B*, Abandonment of the secondary channel, system, channel filling, and encroachment of the peat swamp on the subsiding overbank deposits. *C*, Encroachment of the peat swamp across the fluvial sediments.

similar and dissimilar channel deposits of Pennsylvanian age in Indiana. The Terre Haute and Winslow Channels named by Friedman are contemporaneous with the deposition of the Springfield coal but represent separate distributary channels within the larger deltaic system. Therefore, a new paleoenvironmental term, the Leslie Cemetery Channel, is proposed for all the paleoenvironmental features represented by the Folsomville Member in southeastern Gibson County and northern Warrick County. Leslie Cemetery is in the SE¼NE¼NW¼ sec. 28, T. 4 S., R. 7 W., Warrick County.

Since the lower Springfield coal persists across the split-coal zone and the contact between the lower seam and the Folsomville is mostly gradational, the lower part of the Springfield was deposited before the Leslie Cemetery Channel was established. Unlike other reported Pennsylvanian channels and their contemporaneous coals, the Leslie Cemetery Channel is extensively overlain in its areal extent by a split seam of its contemporaneous coal (fig. 6). The contact between the upper seam of the Springfield Coal Member and the uppermost beds of the Folsomville Member is gradational. This suggests that the Leslie Cemetery Channel was abandoned before the end of peat deposition in the Springfield swamp and that the swamp gradually transgressed onto the flanks of the subsiding channel deposits (fig. 12).

The Leslie Cemetery Channel provides further evidence that the Springfield coal was deposited within a deltaic setting. Fisk (1960) and Frazier and Osanik (1968) have suggested stratigraphic and sedimentologic similarities between the modern Mississippi River delta and Carboniferous coal deposits. The Yoredale Series of Great Britain, studied by Moore (1958 and 1959), seems similar to such a model. Friedman (1956 and 1960), in his discussion of the Terre Haute Channel, noted many similarities to Fisk's studies of modern deltas. Wanless and others (1968) used the Springfield Coal Member and its correlative coals in Illinois and western Kentucky as their model of a coal deposit on a large delta platform, complete with a distributary-channel complex contemporaneous with peat deposition. The apparent transgression of peat onto the Leslie Cemetery Channel after its abandonment is similar to processes observed by Fisk (1960) in the modern Mississippi delta. Eggert and Adams (in preparation) found that multiple periods of contemporaneous channel development and interdistributary-bay deposits suggest that the Springfield coal was indeed deposited within a deltaic milieu.

Economic Geology

The Leslie Cemetery Channel significantly affected development of the Springfield Coal Member. This coal in Warrick County averages about 4 feet (1 m) thick, but adjacent to the channel are areas of thicker than average coal. Several sections of abnormally thick Springfield coal were reported by Ashley (1899) and

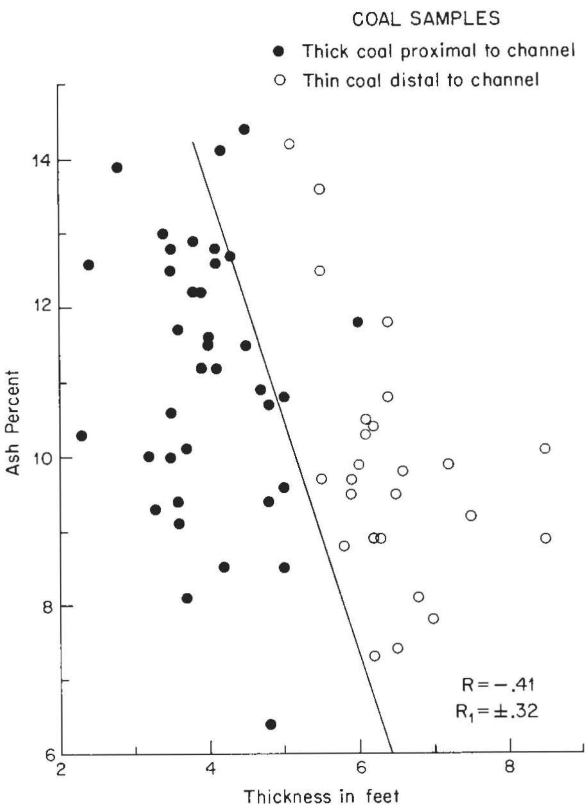


Figure 13. Relation of high-temperature ash (moisture free) to coal thickness in 62 samples of the Springfield coal unsplit by the Folsomville Member in Warrick County.

Fuller and Ashley (1902) in northern Warrick County. At one mine adjacent to the Leslie Cemetery Channel, the coal was 12 feet (4 m) thick and had a black fissile mudstone roof. Generally less than average thicknesses of Springfield coal occur in areas where the coal is split or overlain by the Folsomville Member. The distribution of the Folsomville Member and the Leslie Cemetery Channel is believed to be related to variation in thickness of the Springfield Coal Member.

Why is there a zone of thicker than average Springfield coal proximal and parallel to the Leslie Cemetery Channel? Thick coal adjacent to penecontemporaneous channels has been reported by Hopkins (1968), Johnson (1972), Allgaier and Hopkins (1975), Brittain (1975), and Eggert and Adams (in preparation). In Knox County, the Springfield coal is thick near a channel that was shown by Wier and Powell (1967) and that I believe is a contemporaneous channel. Neavel (1961) reported abundant thin clay laminae in the upper part of the thick coal in a mine near this channel, and other geologists have suggested that thick coal adjacent to contemporaneous channels is the result of dilution of peat by deposition of clastic sediments. If this hypothesis is correct, the thick coal should have significantly more clastic mineral matter than thin coals distal to the channel do.

High-temperature ash is the material remaining after coal is ignited to constant weight at a temperature of 750°C. It consists of altered or unaltered clay minerals, quartz, and other mineral matter and metal and nonmetal oxides. Therefore, if the peat adjacent to the Leslie Cemetery Channel was diluted with clastic sediment, a significant increase in high-temperature ash would be observed in the thick coal near the channel. Sixty-two channel samples from areas proximal and distal to the channel (appendix) show a negative correlation, statistically significant at the 1-percent level, between coal thickness and ash (fig. 13).

Metal oxides derived from the sulfide minerals in coal are major constituents of high-temperature ash. To determine the relation of sulfide minerals to coal thickness, data from the same samples were compared. A statistically insignificant positive trend is indicated. Therefore, the observed decrease in high-temperature ash close to the channel reflects a decline in mineral matter other than sulfides in the thick coal zone. This suggests that the coal adjacent to the channel is thicker because more organic matter accumulated there during peat deposition, and not because the peat was diluted by the addition of clastic sediments.

Several factors may have acted together or separately to produce a habitat particularly favorable to the accumulation of thick peat near the channel. These are: longer duration of peat deposition, lower salinity, more abundant plant nutrients, and rapid subsidence. If peat deposition first began close to the contemporaneous channels, which is reasonable to expect with time-transgressive

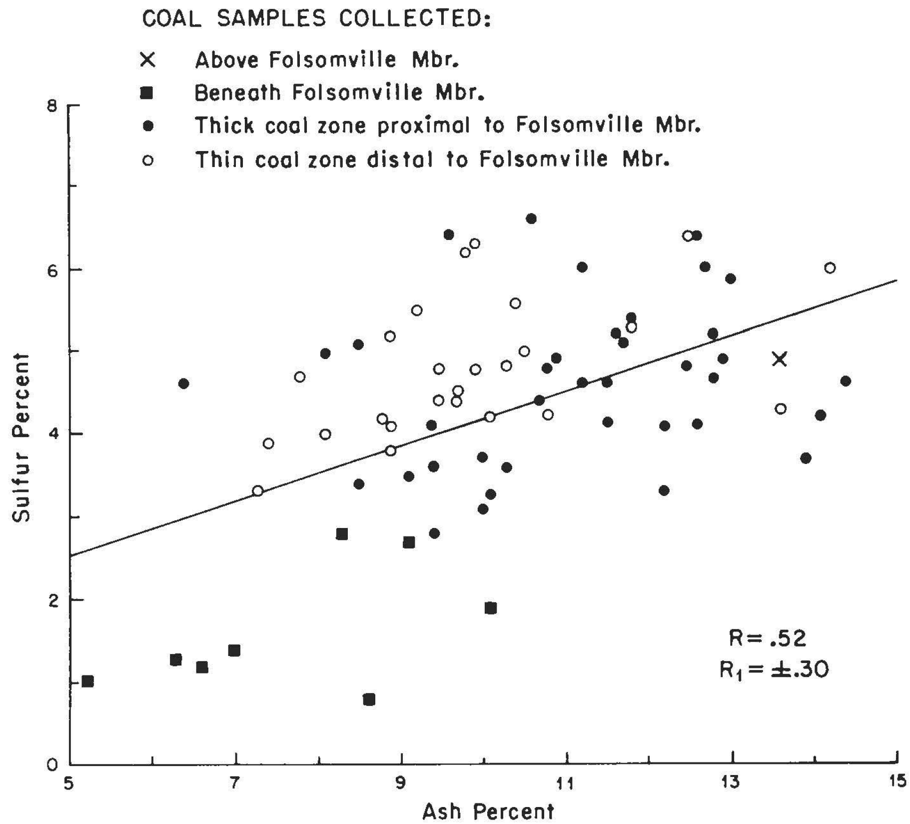


Figure 14. Relation of total sulfur (moisture and ash free) to high-temperature ash (moisture free) in 71 samples of the Springfield coal from Warrick County.

deposition, a longer period of time would have existed for peat deposition adjacent to the channels. Lower salinities are observed along modern distributary channels, and the distribution of boron, an indicator of salinity, in low-temperature ash from the Herrin Coal Member (Carbondale Formation) in Illinois suggests that a salinity gradient may have been present in swamps lateral to contemporaneous channels (Bohor and Gluskoter, 1973). Whether rate of subsidence affected the availability of nutrients is difficult to establish in ancient sediments, but this factor may also have contributed to the thick coal adjacent to the Leslie Cemetery Channel.

As a further test of the effects of the Leslie Cemetery Channel on coal quality, high-temperature ash and sulfur content of all samples of Springfield coal from Warrick County were compared (fig. 14). These data included samples that were distal or proximal to the channel and samples that were above or beneath the Folsomville Member in the split-coal zone. A significant statistical relationship exists between high-temperature ash and sulfur. Samples that underlie the Folsomville appear to be distinct from those that are proximal or distal or that overlie the Leslie Cemetery Channel. A statistical T-test found that samples of Springfield coal beneath the Folsomville Member are significantly lower in sulfur and ash than samples adjacent to or overlying the Folsomville Member. Unlike the extensive low-sulfur coal in the Springfield and Harrisburg (No. 5) Coal Members of Illinois, reported by Hopkins (1968), the low-sulfur coal associated with the Leslie Cemetery Channel and the Folsomville Member is modest in extent.

Several studies have demonstrated that in areas where midwestern coals are overlain by nonmarine shales and sandstones, the coal is

Table 1. Slaking-index values of selected lithologies of the Folsomville Member

Sample No.	Location	Lithology	Slaking index
DE-77-2	Folsomville Road Pit (111), 1 to 2 ft (0.3 to 0.6 m) above lower Springfield coal	Rash	71
DE-77-1	Folsomville Road Pit (111), to 1 ft (0.3 m) above lower Springfield coal	Rash	73
DE-76-201	Folsomville Road Pit (111), just above lower Springfield coal	Rash (highly organic shale)	67
DE-76-203	Kennedy Pit, 10 ft (3 m) above sample 202	Dark-gray shale	67
DE-76-204	Kennedy Pit, below upper split Springfield coal 3 ft (1 m) above sample 202	Rash	78
DE-76-202	Kennedy Pit, above lower split Springfield coal	Rash	84

generally a low-sulfur coal. These nonmarine deposits are commonly overbank deposits of a distributary-channel system that was penecontemporaneous with the peat swamp. As mentioned earlier, Bohor and Gluskoter's (1973) findings suggest that a salinity gradient may have been present and the salinity increased distally from the channel system that was contemporaneous with the Herrin Coal Member in southern Illinois. This evidence, combined with Fisk's (1960) observation of similar distribution of salinities in the modern Mississippi River delta and with the work of Casagrande and others (1977) on the distribution of sulfur in modern peats in relation to salinity, suggests that during the Pennsylvanian aged peat was deposited in fresh water adjacent to a contemporaneous distributary, such as the Leslie Cemetery Channel. Therefore, the resulting coal is significantly lower in primary sulfur than that deposited distally to the channel. Low-sulfur peat that was later covered by overbank shales derived from a contemporaneous channel was not likely to be mineralized by postdepositional secondary sulfide mineralization. Therefore, this accounts for the origin of the low-sulfur Springfield coal underlain by the Folsomville Member.

Overburden samples from the Kennedy Pit and the Folsomville Road Pit (111) show a strong tendency to slake (table 1). Although slaking index is not a measure of rock strength, a rock that slakes easily will likely have low cohesive strength when saturated or partly saturated and will perform poorly as a roof material. The high slaking-index values for lithologies of the Folsomville Member suggest that roofs in mine areas subjected to fluctuations in relative humidity may be prone to failures. Slaking-index tests of black fissile shales conducted at the Indiana Geological Survey generated values less than 20. Black fissile shales are normally a good roof lithology for underground coal mines.

In transitional areas of split Springfield coal, where thin beds of gray shale and rash occur above the lower seam and below the upper seam, the probability of roof failure is high. Mining experience has shown that planes of weakness develop between the different rock units at contacts between beds of different lithologies. These planes of weakness are commonly saturated with ground water, which lubricates the contact and therefore increases the probability of failure. The low cohesive strength of rash, some gray shale, and overlying split coal would make these strata undesirable anchors for roof bolts for mining the lower seam of the coal. The upper split of the Springfield coal may have adequate roof conditions when it is overlain by several feet of black fissile shale. When the black shale is absent or thin, poor roof conditions are likely to exist.

Summary and Conclusions

Folsomville sediments are believed to have been deposited by a small channel that was contemporaneous with the deposition of the lower part of the Springfield peat. The crossbedded sand bodies with cut-and-fill relationships in the central zone of the Folsomville Member represent a fluvial-channel environment; rash associated with the upper or lower splits of the Springfield coal represents a flood-plain environment; and gray mudstones and thin sheetlike sand bodies represent levee and crevasse-splay environments. Some of the peat that was covered with gray mud of the crevasse splays or natural levees later became low-sulfur coal. Unlike previously described channels associated with midwestern low-sulfur coal deposits, the Leslie Cemetery Channel was narrow and its activity terminated before peat accumulation ceased.

Under present economic conditions, the Springfield Coal Member is surface minable only in the eastern part of the study area; most of the remaining normal-sulfur Springfield coal is deep minable in the western half of the study area. Roof conditions of the normal-sulfur coal are expected to be adequate for underground mining, but the roof conditions of the low-sulfur coal may be inadequate. Low-sulfur coal associated with the Folsomville Member is not a significant reserve because of the small areal extent of the coal, the high probability of poor roof conditions, and the places where coal is thin. Economically, the thicker than average coal adjacent to the channel may be the most significant development resulting from the influence of the Leslie Cemetery Channel on coal deposition in northern Warrick County.

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APPENDIX—SAMPLES OF SPRINGFIELD COAL IN WARRICK COUNTY

Sample No.	Sulfur (moisture and ash free) (pct)	High-temperature ash (moisture free) (pct)	Coal thickness	
			(ft)	(m)
		Distal thin high-sulfur coal		
76 X 122	5.9	13.0	3.4	1.0
76 X 56	6.6	10.6	3.6	1.1
75 X 121	2.8	9.4	3.3	1.0
75 X 96	4.1	12.2	3.8	1.2
75 X 95	4.6	14.4	4.5	1.4
75 X 66	5.1	8.5	5.0	1.5
75 X 65	6.4	9.6	5.0	1.5
75 X 37	4.7	12.8	3.5	1.1
75 X 3	5.0	8.1	3.7	1.1
72 X 33	4.8	10.8	5.0	1.5
72 X 27	3.3	10.1	3.7	1.1
72 X 26	3.5	9.1	3.6	1.1
72 X 20	4.2	14.1	4.2	1.3
70 X 17	4.8	12.5	3.5	1.1
70 X 16	5.1	11.7	3.6	1.1
69 X 28	6.0	11.2	3.9	1.2
67 X 21	3.4	8.5	4.2	1.3
67 X 16	5.2	11.6	4.0	1.2
67 X 8	4.6	11.5	4.0	1.2
65 X 31	5.2	12.8	4.1	1.2
65 X 28	6.0	12.7	4.3	1.3
63 X 9	3.1	10.0	3.5	1.1
59 X 17	4.6	11.2	4.1	1.2
59 X 16	4.9	12.9	3.8	1.2
59 X 15	4.9	10.9	4.7	1.4
58 X 50	4.1	9.4	3.6	1.1
58 X 41	4.4	10.7	4.8	1.5
58 X 40	3.3	12.2	3.9	1.2
57 X 74	4.6	6.4	4.8	1.5
56 X 115	3.6	12.6	4.1	1.2
56 X 16	5.4	11.8	6.0	1.8
56 X 15	4.1	11.5	4.5	1.4
55 X 109	3.7	13.9	2.8	0.8
55 X 108	3.6	10.3	2.3	0.7
55 X 104	3.6	9.4	4.8	1.5
55 X 83	6.4	12.6	2.4	0.7
55 X 80	3.7	10.0	3.2	1.0

APPENDIX—Continued

Sample No.	Sulfur (moisture and ash free) (pct)	High-temperature ash (moisture free) (pct)	Coal thickness (ft)	Coal thickness (m)
		Proximal thick high-sulfur coal		
55 X 78	4.8	10.3	6.1	1.9
55 X 81	6.0	14.2	5.1	1.6
55 X 101	5.0	10.5	6.1	1.9
55 X 102	6.4	12.5	5.5	1.7
55 X 103	4.5	9.7	5.5	1.7
55 X 105	3.9	7.4	6.5	2.0
55 X 106	4.3	9.9	6.0	1.8
55 X 107	4.0	8.1	6.8	2.1
56 X 17	4.7	7.8	7.0	2.1
57 X 44	5.3	11.8	6.4	2.0
57 X 45	3.3	7.3	6.2	1.9
56 X 46	4.4	9.5	6.5	2.0
57 X 47	4.2	8.8	5.8	1.8
56 X 48	4.4	9.7	5.9	1.8
57 X 49	4.8	9.5	5.9	1.8
65 X 30	5.5	9.2	7.5	2.3
75 X 104	5.6	10.4	6.2	1.9
75 X 105	4.8	9.9	7.2	2.2
75 X 106	3.8	8.9	8.5	2.6
57 X 107	4.2	10.1	8.5	2.6
76 X 34	4.2	10.8	6.4	2.0
76 X 55	4.1	8.9	6.2	1.9
78 X 15	4.3	13.6	5.5	1.7
79 X 1	5.2	8.9	6.6	2.0
79 X 2	6.2	9.8	6.3	1.9
		High-sulfur coal above the Folsomville Member		
76 X 57	4.9	13.6	2.3	0.7
		Low-sulfur coal beneath the Folsomville Member		
57 X 70	1.9	10.1	6.5	2.0
76 X 28	1.4	7.0	5.7	1.7
76 X 33	1.2	6.6	5.7	1.7
76 X 52	1.3	6.3	2.9	0.9
76 X 62	1.0	5.2	3.7	1.1
76 X 63	2.8	8.3	6.3	1.9
77 X 7	2.7	9.1	4.1	1.2
77 X 8	0.8	8.6	3.5	1.1

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