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THE NEW ALBANY SHALE GROUP OF ILLINOIS

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Mark L. Reinbold
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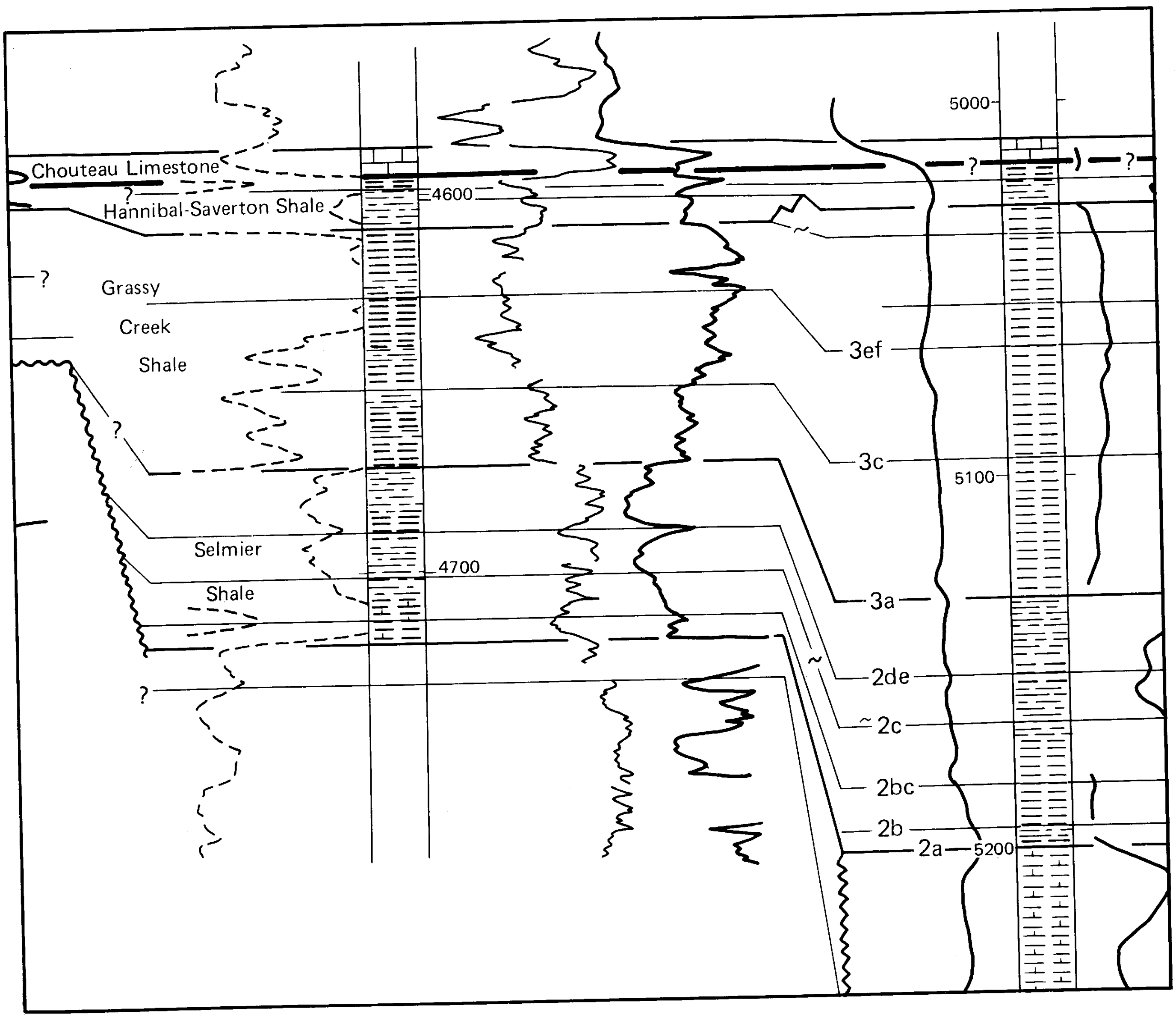

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COVER: Segment of stratigraphic cross section used in this study for basin-wide stratigraphic correlation. An informal numbering system is used to designate several key geophysical horizons, defined principally in terms of discontinuities in electrical resistivity, gamma-ray, bulk density, and sonic velocity values.

Cluff, Robert M.

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THE NEW ALBANY SHALE GROUP OF ILLINOIS

ABSTRACT

The New Albany Shale Group (Middle Devonian-Kinderhookian) consists of an essentially continuous body of black, gray, and greenish-gray shales found throughout the Illinois Basin portions of Illinois, Indiana, and western Kentucky. The New Albany Shale Group is subdivided into nine formations in Illinois; in ascending order, they are: (1) Blocher Shale: brownish-black, calcareous and dolomitic, pyritic, finely laminated shale; (2) Sylamore Sandstone: a single thin bed of pyritic, phosphatic, well-rounded quartz sandstone; (3 and 4) Selmier and Sweetland Creek Shales: interbedded greenish-gray bioturbated shales and olive-black laminated shales; (5) Grassy Creek Shale: brownish-black, pyritic, carbonaceous, finely laminated shale; (6) Saverton Shale: dark greenish-gray bioturbated shale; (7) Louisiana Limestone: gray to tan, lithographic, micritic limestone; (8) Horton Creek Formation: interbedded greenish-gray shales, siltstones, sandstones, micritic and dolomitic limestone, oolitic limestone, and limestone conglomerate; (9) Hannibal Shale: greenish-gray highly bioturbated mudstones, shales and siltstones, and a minor black shale. At no single location in the state are all nine formations present and to some extent each formation grades laterally into one or more of the others.

Brownish-black laminated shales are the predominant lithology in southeastern Illinois and adjacent Kentucky, where the New Albany Shale Group attains its maximum thickness of about 460 feet (140 m). A second depositional center lies in southeastern Iowa and adjacent west-central Illinois where the predominant lithology is bioturbated olive-gray to greenish-gray shale and the New Albany is more than 300 feet (90 m) thick. The two depocenters are separated by a northeast trending area of thin New Albany strata consisting mainly of interfingering gray and black shales.

The distribution and types of lithofacies in the New Albany Shale indicate that the shale was deposited across a shelf-slope-basin transition in a marine, stratified anoxic basin. In west-central Illinois moderately oxygenated (dysaerobic) conditions prevailed for long periods on a low-relief deep shelf area, with a water depth probably greater than 50 meters. Fully oxygenated (aerobic) conditions were established for only brief periods in the vicinity of the shelf-slope break and along local uplifts in western Illinois and adjacent Missouri, and are represented by only a few relatively thin limestones. In the slope region a thinner New Albany section was deposited and conditions fluctuated between dysaerobic and anaerobic. In the deep basin area of southeastern Illinois, anaerobic conditions prevailed throughout most of New Albany deposition in waters that probably exceeded 150 meters in depth.

INTRODUCTION

The New Albany Shale Group consists of an essentially continuous body of black, gray, and greenish-gray shales found throughout the Illinois Basin portions of Illinois, Indiana, and western Kentucky. The New Albany Shale Group ranges from Middle Devonian through Kinderhookian (lower Mississippian) in age, although most of the shale is Upper Devonian.

The New Albany Shale was named by Borden (1874) for exposures along the Ohio River in the vicinity of New Albany, Floyd County, Indiana. The New Albany was elevated to group status in Illinois by Collinson and Atherton (1975), but is still classified as a formation in Indiana (Shaver et al., 1970). Through the years, several schemes of classification have been used in subdividing the shales which constitute the New Albany Shale Group, and it is herein subdivided into nine formations in Illinois. In ascending order, these are: the Blocher Shale, Sylamore Sandstone, Selmier Shale, Sweetland Creek Shale, Grassy Creek Shale, Saverton Shale, Louisiana Limestone, Horton Creek Formation, and Hannibal Shale (Collinson and Atherton, 1975; Atherton, Collinson, and Lineback, 1975; Conkin and Conkin, 1973). At no single location in the state are all nine formations present, and, to some extent, each formation grades laterally into another. Each of these

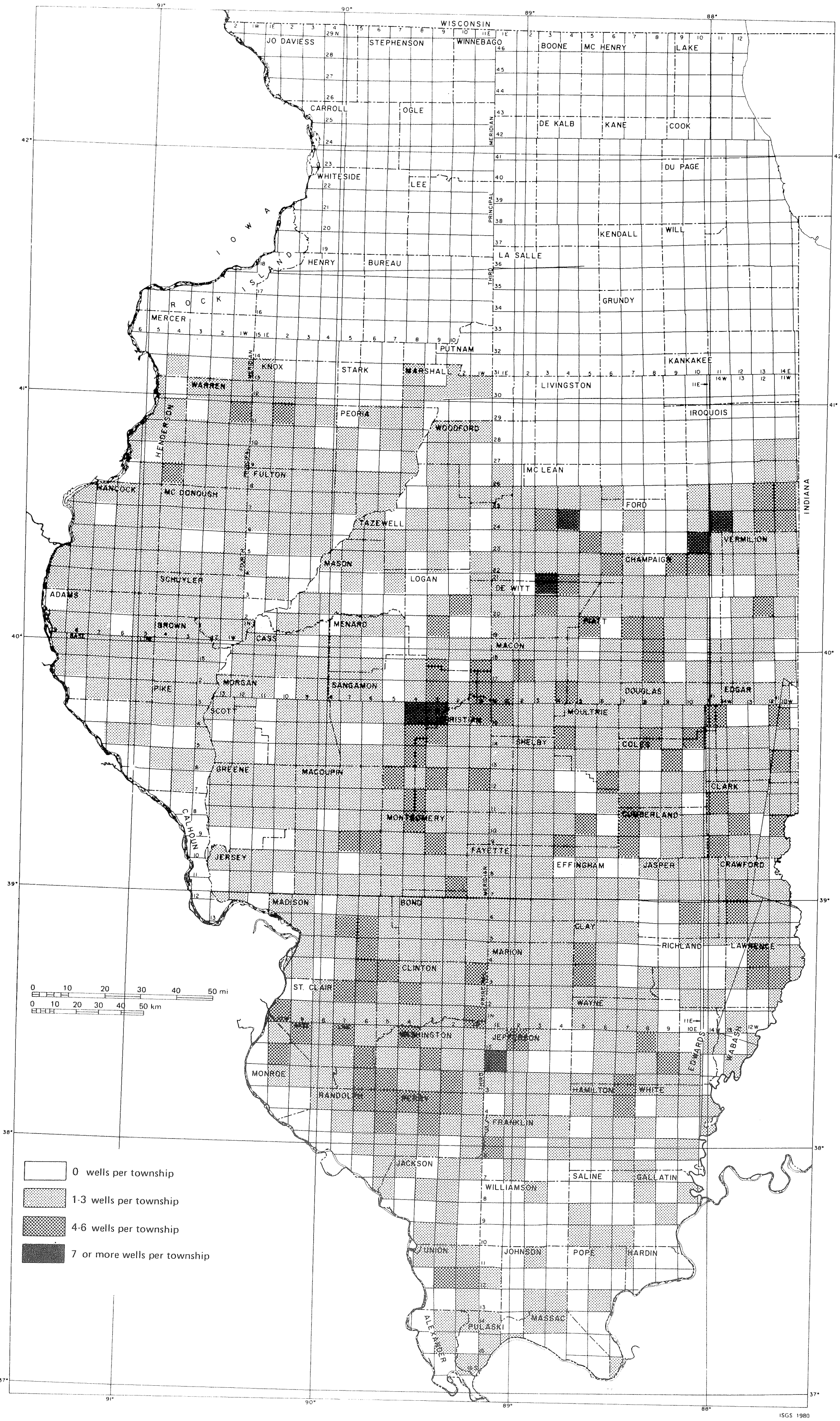


FIGURE 1. Density of wells that penetrate the New Albany Shale Group used in this study.

formational units is described in detail in the following sections of this report.

In mid-1976, the Illinois State Geological Survey, with partial support from the U.S. Department of Energy, began a detailed study of the geology and geochemistry of the New Albany Shale Group in Illinois to evaluate its potential for yielding hydrocarbons, particularly natural gas. Similar Devonian shales in the Appalachian Basin have yielded significant quantities of natural gas in many areas and about 9,600 wells currently produce gas from Devonian shale. One giant gas field alone, the Big Sandy field in eastern Kentucky, has produced more than 5.6×10^{10} m^3 (2 tcf) of gas from Devonian shale (Hunter and Young, 1953). Because of their great lateral extent and thickness, the Devonian shale formations of the Appalachian, Michigan, and Illinois Basins might constitute a vast gas resource if suitable extraction techniques could be developed.

Studies of the Devonian black shales are also pertinent to the origin and migration of oil in the Illinois Basin. Although the New Albany Shale has long been suspected of being a major source rock of petroleum, specific data pertaining to the quantity of oil generated, to areas where the oil may have been generated, and to subsequent migration pathways are quite scarce.

The objectives of the present study are:

1. To compile available drill-hole and outcrop data on the New Albany Shale Group in Illinois.

2. To evaluate the stratigraphy and structure of the New Albany Shale Group and determine their relationships to the occurrence of hydrocarbons.

3. To characterize the physical, mineralogical, and chemical properties of the New Albany Shale by detailed analyses of core materials, and to relate those properties to the potential of the New Albany Shale as a source rock for hydrocarbons.

4. To characterize the geochemistry of the New Albany Shale in order to facilitate: evaluation of its economic importance, exploration for hydrocarbons, and assessment of the possible effects the exploitation of this potential resource might have on the environment.

This report summarizes our findings relating to the stratigraphy, lithology, structure, depositional environment, and paleogeography of the New Albany Shale Group in Illinois. Studies of geophysical logs, subsurface drill cutting samples, and 14 cores through all or part of the New Albany Shale Group provide the principal data for the interpretations presented here (fig. 1; table 1). Numerous outcrops in western Illinois, southern Illinois, south-central Indiana, and west-central Kentucky were also studied and sampled.

Previous investigations of the geology of the New Albany Shale in the Illinois Basin include those by Campbell (1946); Collinson et al. (1967); Lineback (1968, 1970); North (1969); and Workman and Gillette (1956). These papers dealt primarily with the stratigraphy and correlation of the New Albany Shale; many of their findings are summarized in later sections of this report. Previous studies of the hydrocarbon producing potential of the New Albany Shale include those of Lamar et al. (1956), Stevenson and Dickerson (1969), Barrows et al. (1979), and Cluff and Dickerson (1980). Detailed data on the geochemistry, dispersed organic matter, and origin of hydrocarbons in the New Albany Shale are not discussed in this report, but will be summarized in forthcoming publications.

The geologic structure map (plate 4) and accompanying text (page 56-57) in this report have been reprinted for separate distribution by the Survey as Illinois Petroleum 121 (Stevenson, Whiting, and Cluff, 1981).

Table 1. New Albany Shale cores used in this study.

Core designation	Well name	Location	County
Illinois:			
01IL	Millar #1 G. W. Sample	SW SW NE 11-15N-3W	Sangamon
02IL	Tri Star Prod. #1D Lancaster	SE SW NW 31-9N-4E	Effingham
03IL	Superior Oil #C-17 H. C. Ford	C SW SE 27-4S-14W	White
04IL	No. Illinois Gas #1 RAR	SW SW NE 32-8N-4W	Henderson
05IL	Peoples Gas #1 Witt	SE SE SW 19-16N-13W	Edgar
06IL	No. Illinois Gas #1 MAK	NE NE NW 8-23N-2W	Tazewell
07IL	Benedum Trees #1 Van Zant	SW/C 24-6N-1W	Fayette
08IL	Midland Electric Coal #1 Peters	SW SW NE 11-7N-6E	Peoria
09IL	Coral Oil #1 Schroeder	SW NW SE 6-3S-6W	St. Clair
10IL	Helm Petroleum #1 Ballance	SW NE SW 12-4N-1W	Fayette
11IL	Rector & Stone #1 Missouri Portland Cement	NE NE NE 36-11S-7E	Hardin
12IL	Hobson Oil #2 Taylor	SE NE NW 34-1S-7E	Wayne
13IL	G. T. Jenkins #1 Simpson	SW SE SW 17-3S-8E	Wayne
Kentucky:			
01KY	Orbit Gas #1 Ray Clark	650'NL 90'EL 12-G-25	Christian

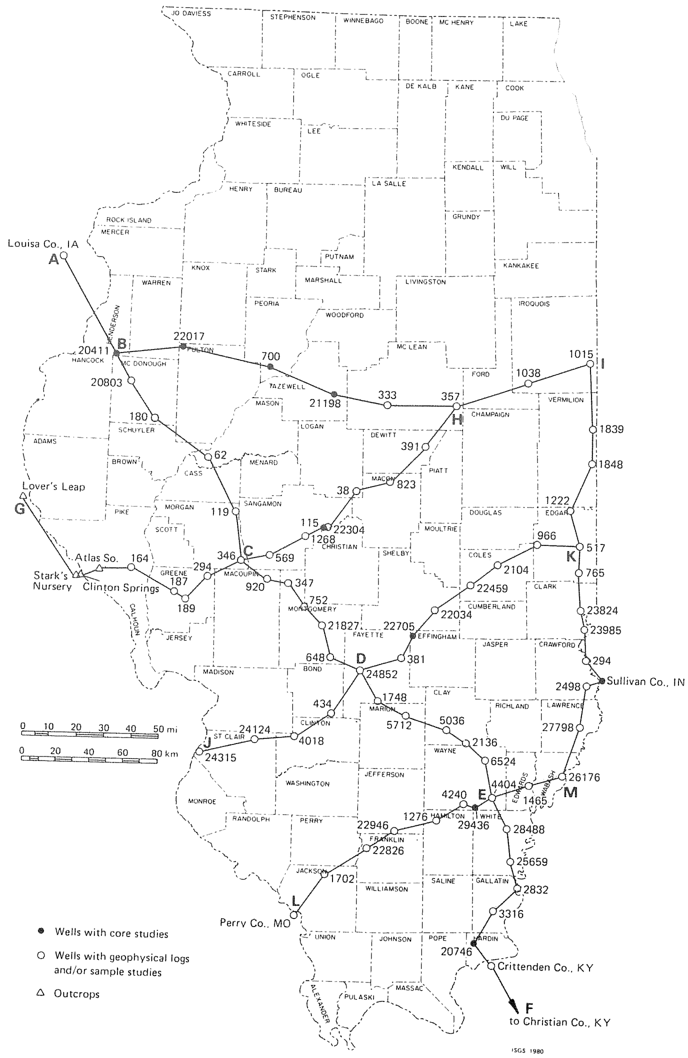


FIGURE 2. Index map to stratigraphic cross sections accompanying this report (plates 1 and 2).

STRATIGRAPHY OF THE NEW ALBANY SHALE GROUP

Methods of study

In this study, basin-wide stratigraphic correlation has been accomplished principally through preparation of a network of more than 25 cross sections available on open file at the Survey offices in Champaign. The cross sections rely primarily on the tracing of key geophysical horizons, but are supplemented with core and sample studies. Logs between the cross sections are compared to nearby cross sections for local correlation. Although some geophysical horizons are widely traceable, the horizons may vary greatly in relative prominence from one locality to another.

These geophysical horizons are defined principally in terms of discontinuities in electrical resistivity, gamma-ray, bulk density, and sonic velocity values. Generally, major lithologic changes within a well are reflected by sharp changes in one or more geophysical properties at very nearly the same log depth. An informal numerical system has been used in this study to designate several laterally persistent geophysical horizons within the New Albany Shale Group and adjacent strata. This numbering system is used on the stratigraphic cross sections (fig. 2; plates 1, 2) in this report. Boundaries of formations and other stratigraphic units are defined in terms of significant lithologic changes and their associated geophysical horizons.

The Collins Brothers Oil #1 Hill well in Wayne County, Illinois (fig. 3), has been utilized as a main subsurface reference section for defining geophysical horizons in the lower part of the New Albany Shale Group. In this well, horizons 1a, 2a, and 3a are sharp geophysical discontinuities which represent the bases of the Blocher, Selmier, and Grassy Creek Shales, respectively. The 4a horizon is defined as the base of the Saverton Shale in western Illinois, in the Mobil Oil #1 Dewerff well in Montgomery County, Illinois (fig. 4). The 5a horizon is generally the base of the Chouteau Limestone.

Additional horizons (2b, 2c, etc.) represent other fairly abrupt changes in one or more geophysical properties, but are not of sufficient magnitude to be considered formational boundaries in the reference section wells. Many of these horizons are widely traceable; in some areas they may become discontinuities of greater magnitude than, for instance, the 2a horizon. A formation boundary may then be adjusted to one of these horizons. In some areas, two or more closely spaced sub-horizons may define small-scale interbedding or gradational changes from one bulk lithology to another.

The formations in the New Albany Shale Group are defined in terms of dominant lithologies. The major lithologic types within the New Albany, however, demonstrate considerable large- and small-scale interbedding, lateral intertonguing, and gradational changes from one lithology to another. Furthermore, major bulk lithologic changes (as inferred from geophysical discontinuities) do not always persist laterally along precisely the same geophysical horizons. These geophysical horizons are considered to approximate bedding planes, and for practical purposes are considered isochronous surfaces (see discussion under Depositional Environment, p. 57). Lithologies characteristic of one formation grade laterally into those characteristic of another formation; consequently, to maintain the basic lithologic uniformity of defined formations, arbitrary vertical cutoffs must be used to adjust to formational boundaries upward or downward (fig. 5).

Lithologic interpretations of geophysical logs are based on direct comparison of the logs to studied core

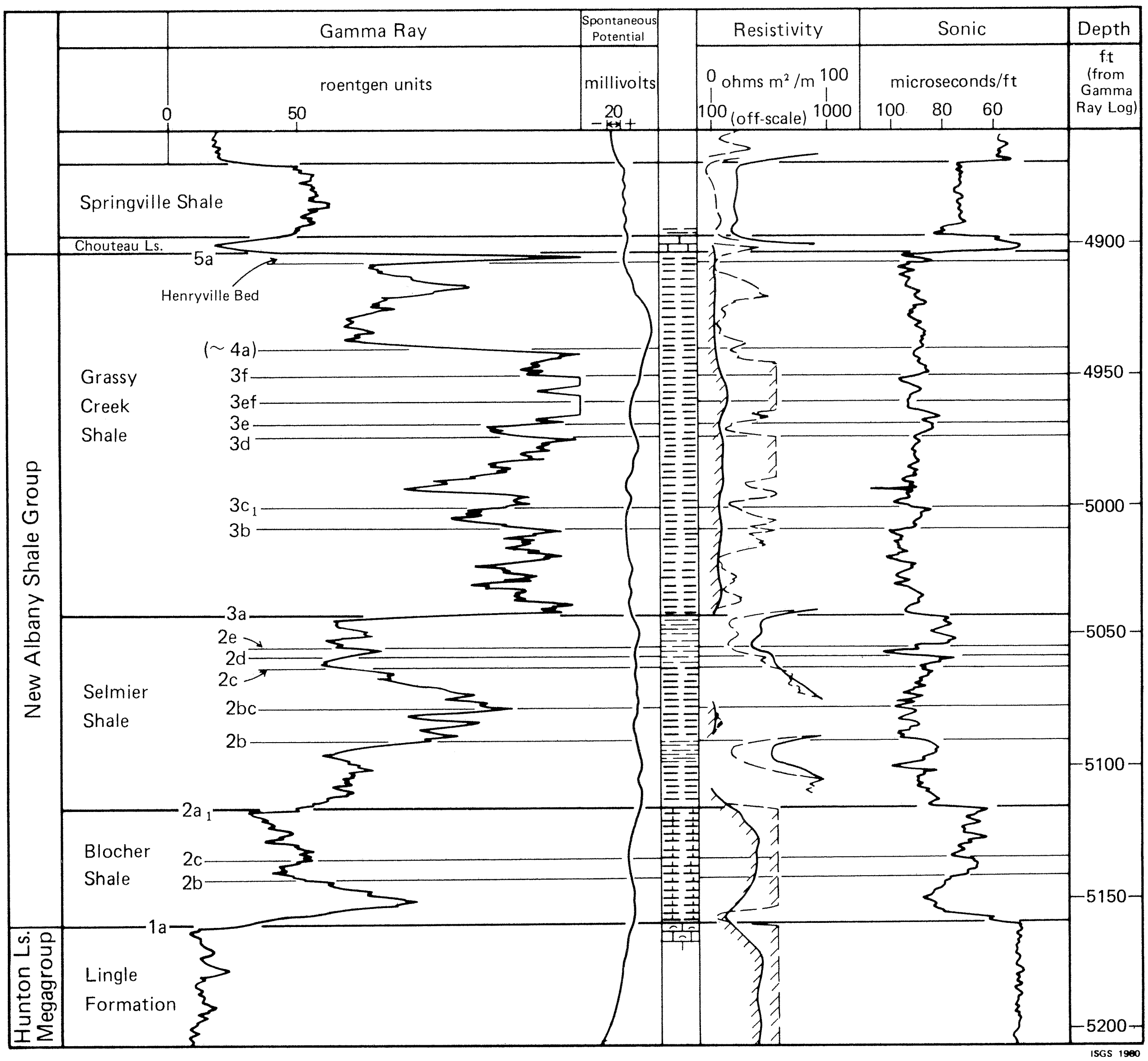


FIGURE 3. Subsurface reference section for southeastern Illinois. Collins Brothers Oil #1 Hill, Sec. 29, T. 2 S. - R. 9 E., Wayne County, Illinois.

or sample intervals. Unfortunately, a full suite of geophysical logs is not usually available for any given well. Gamma-ray logs, which are particularly useful for identifying shale lithologies, are available for relatively few wells. In Illinois, electrical logs (resistivity and spontaneous potential) are more common than any other type of log. The characteristics of the major lithologies recognizable on geophysical logs of the New Albany are summarized in table 2.

Methods used for detailed study of the lithology and mineralogy of the New Albany Shale include binocular microscopic examination of core and outcrop samples, x-ray radiography, thin section petrography, and x-ray mineralogy. Five major lithofacies have been recognized in these studies (Cluff, 1980):) (1) limestones and dolomites; (2) bioturbated mudstones (including siltstones and shales); (3) indistinctly bedded shales; (4) thickly laminated shales; and (5) finely laminated shales (table 3). Each of the shale lithologies may be locally calcareous or dolomitic and in some areas may grade into carbonate rocks. The bioturbated mudstone and indistinctly-bedded shale facies recognized in core and outcrop studies cannot be distinguished using geophysical logs alone; both would be identified as organic poor (gray) shales on logs. Similarly, the thickly laminated and finely laminated shale facies would be identified only as organic rich (black) shales in the subsurface unless core studies were available. Most of the thick siltstone beds in the New Albany are included in the bioturbated mudstone lithofacies.

Distribution and thickness

The New Albany Shale Group reaches a maximum thickness of more than 460 feet (140 m) in Hardin County in southeastern Illinois and in adjacent western Kentucky (plate 3). Laminated black shale is the predominant lithology in this area, which was apparently the depositional center of the ancestral Illinois Basin during the middle and late Devonian. We refer to this region of very thick New Albany sedimentation as the "southern depocenter" (fig. 6).

A second depositional center lay in southeastern Iowa and adjacent west-central Illinois, where the shales are Upper Devonian and Kinderhookian. Thicknesses of more than 300 feet (90 m) are attained in Henderson and Han-

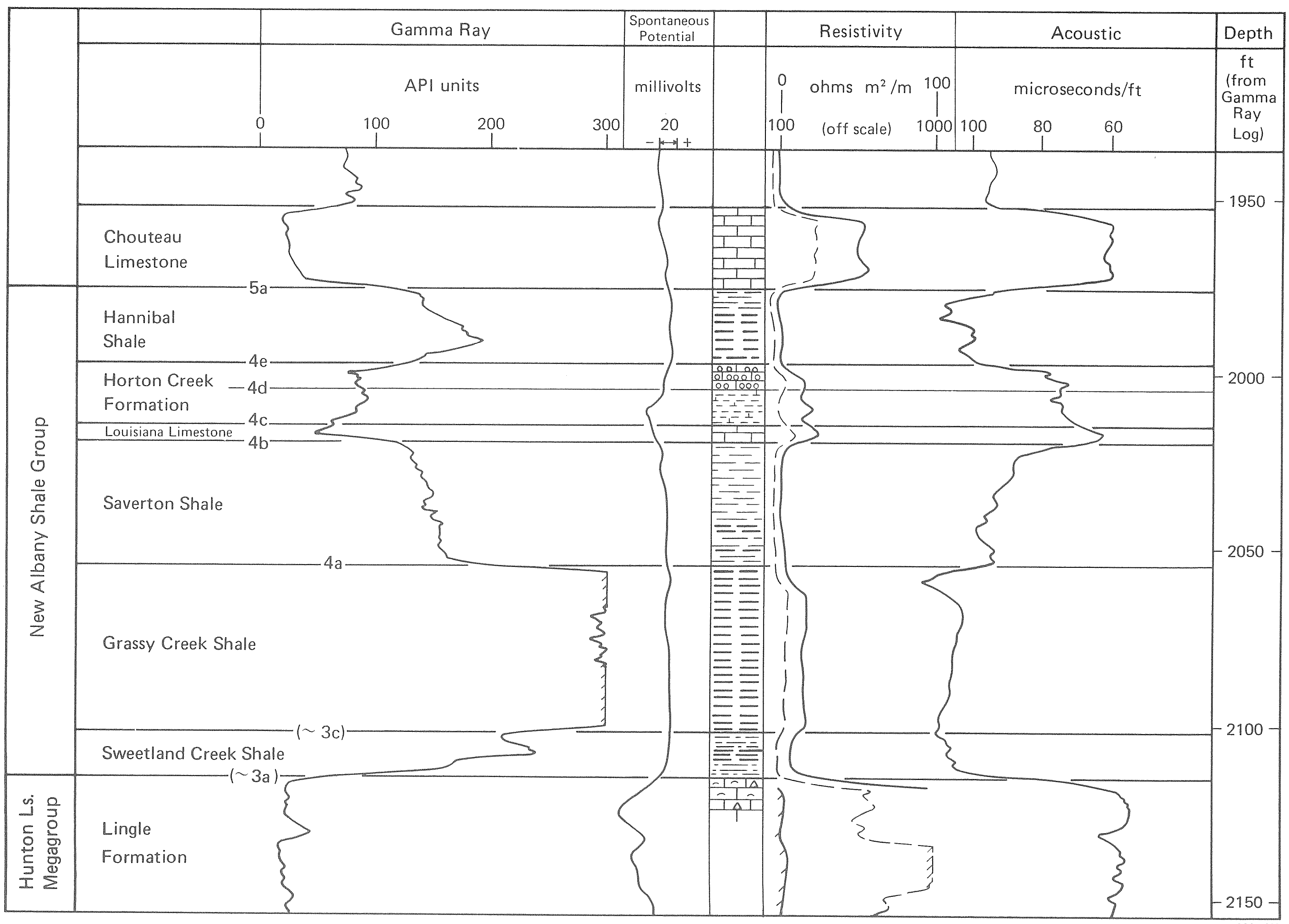


FIGURE 4. Subsurface reference section for western Illinois. Mobil Oil #1 Dewerff, Sec. 11, T. 9 N. - R. 3 W., Montgomery County, Illinois.

cock Counties, Illinois and extend northwestward into Iowa as a thick tongue. Bioturbated olive-gray and greenish-gray shales are the predominant lithologies in this region. Workman and Gillette (1956) referred to this region as the Petersburg Basin; however, this region may not have been a topographic depression or partially closed basin during New Albany deposition. For this reason we prefer to use a purely descriptive term, the "western depocenter" (fig. 6), although we recognize that the area of thickest shale deposition was probably centered in Iowa near the eastern edge of the Forest City Basin (Collinson et al., 1967, fig. 2). In most of west-central Illinois, the New Albany Shale has been truncated and is unconformably overlain by the Burlington Limestone, the Fern Glen Formation, or the Meppen Limestone (all Valmeyeran). Extrapolation of

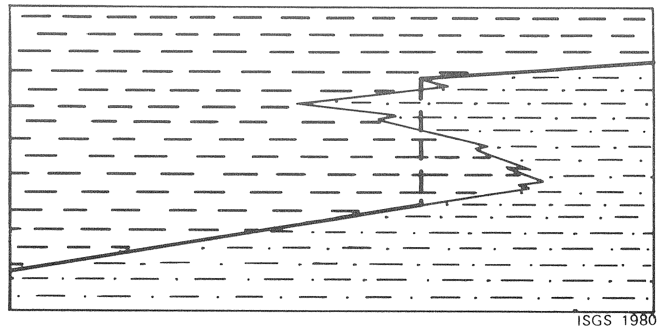


FIGURE 5. Use of an arbitrary vertical cutoff to adjust formation boundaries. In this hypothetical example a laminated black shale (at left) overlies and interfingers with a silty greenish-gray shale (at right). When the thickness of the upper gray shale tongue is greater than, or equal to, the thickness of the lower black shale tongue a vertical cutoff is used to adjust upward the contact between the two units. In map view the cutoff would be represented as a line, and thickness contours would be truncated against it.

Table 2. Typical geophysical characteristics of major lithologies of the New Albany Shale Group.

	LITHOLOGY				
	Limestone and dolomite	Organic poor (gray) shales	Organic rich (black) shales	Calcareous or dolomitic shale	Siltstone
ELECTRICAL RESISTIVITY					
very low		X			
low		X			X
moderate	X		X	X	X
high	X		X	X	
very high	X		X		
SPONTANEOUS POTENTIAL					
–	X				
↓			X	X	X
			X		
			X		
+		X			
GAMMA RAY					
very low	X				
low	X	X		X	X
moderate		X		X	X
high			X		
very high			X		
NEUTRON					
very low					
low		X	X		
moderate		X		X	X
high	X			X	X
very high					
BULK DENSITY					
very low					
low			X		
moderate		X		X	X
high	X	X		X	X
very high					
SONIC VELOCITY					
very low					
low			X		
moderate		X		X	X
high	X	X		X	X
very high					

thickness contours beyond the erosional boundary suggests that original shale thicknesses in west-central Illinois may have been substantially greater than present thicknesses.

The two depocenters are separated by a northeast-trending area of thin New Albany strata consisting of inter-fingering gray and black shales. Although this area was termed the Vandalia Arch by Workman and Gillette (1956), we have found little evidence in this study for the existence of any such Devonian tectonic feature. We refer to the region extending from southwestern through central and east-central Illinois where the New Albany is generally less than 125 feet (38 m) thick (fig. 6) as the "central thin."

In east-central Illinois a small area of thin New Albany extending southward from Champaign County to Clark County is believed to be related to early upwarping along the La Salle Anticlinal Belt (plate 3). The New Albany thins abruptly westward from the southern depocenter across the Du Quoin Monocline and then, much more gradually, across Clinton, Washington, Perry, Jackson, St. Clair, Monroe, and Randolph Counties (plate 2, J-K, L-M). This area was recognized as an extension of the Ozark Uplift by Workman and Gillette (1956), and was later named the Sparta Shelf (fig. 6) by Meents and Swann (1965).

Stratigraphic relations to overlying and underlying units

Across most of Illinois the New Albany Shale overlies Middle Devonian limestones belonging to the Hunton Limestone Megagroup. In southern and eastern Illinois this relationship appears generally conformable and we are in partial agreement with North (1969) that the Blocher Shale grades laterally into the limestones of the Lingle Formation and the Alto Formation. North (1969) also

Table 3. New Albany Shale lithofacies characteristics

	LITHOFACIES				
	Limestones and dolomites	Highly bioturbated mudstones	Indistinctly bedded shales	Thickly laminated shales	Finely laminated shales
COLOR					
gray or brownish gray	X	O			
greenish gray		X			
olive-gray			X		
olive-black			O	X	
brownish black				O	X
BEDDING AND LAMINATION					
massive	X	X			
indistinctly bd.	O		X		
thickly or poorly laminated			O	X	
finely laminated				O	X
BIOTURBATION					
very extensive or total	X	X			
extensive	O		X		
moderate			X	O	
sporadic				X	
PYRITE					
fine hair-like features (burrows?)		X	X		
large burrow fillings	O	X	X	O	
nodules			O	X	X
laminae				X	X
ORGANIC CARBON					
<1%	X	X			
1-5%			X	O	O
5-10%				X	X
>10%					X

X = major or common O = minor or rare

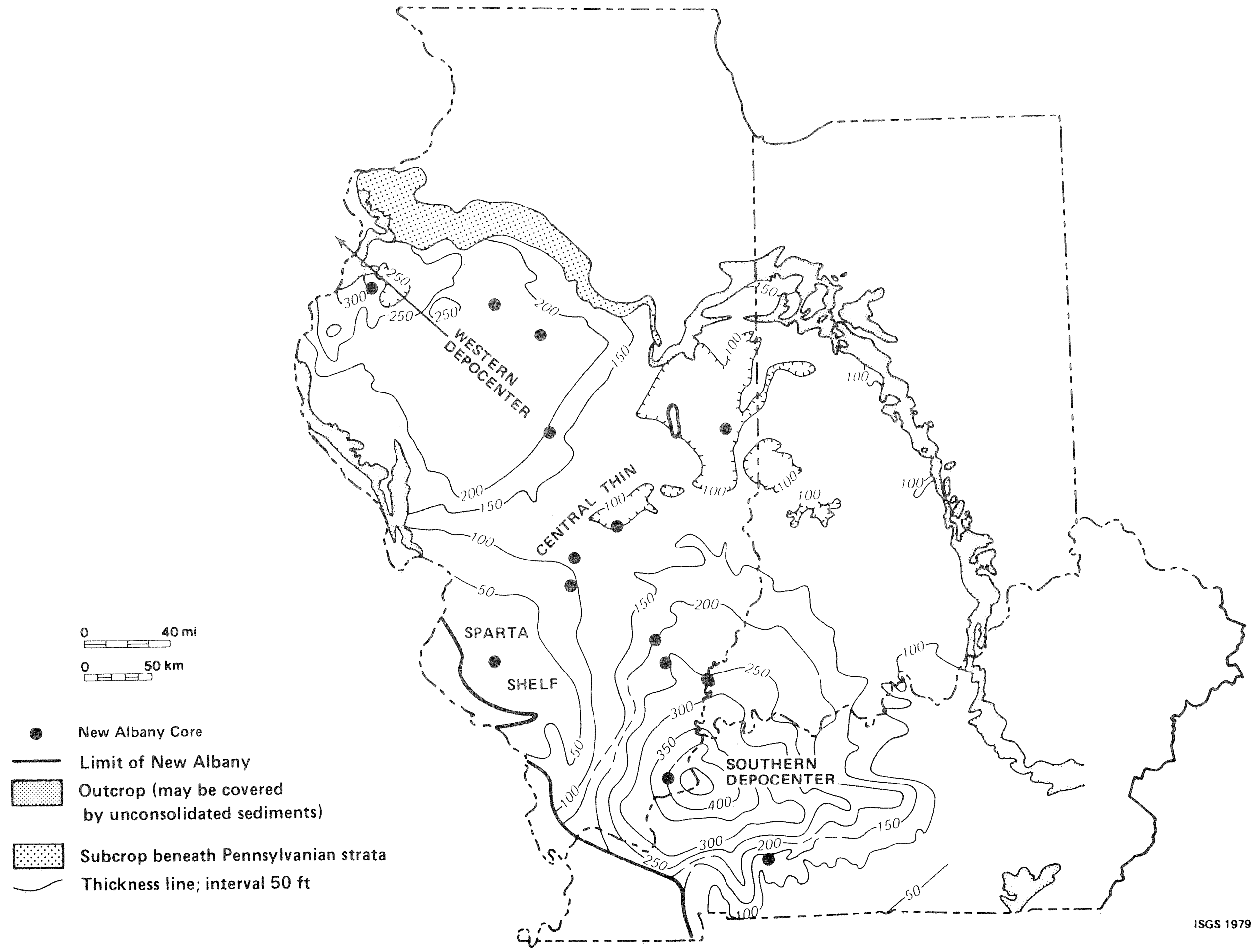


FIGURE 6. Thickness of the New Albany Shale Group in the Illinois Basin, with locations of cores used in this study and terminology for major depositional patterns (thickness map after Reinbold, 1978; Bassett and Hasenmueller, 1978; Schwalb and Potter, 1978).

illustrates an unconformity separating the lower part of the Lingle from the Blocher in the deep part of the basin. We have found geophysical and sample study evidence, however, for gradational lithologic changes along the Blocher-Lingle boundary in southeastern Illinois, suggesting that the relationship is a conformable one (Reinbold, 1978). The Sylamore Sandstone marks the base of the New Albany Shale Group across much of Illinois beyond the limit of the Blocher Shale, and the basal New Albany strata unconformably overlap carbonates of the Hunton Limestone Megagroup toward the north and west. North (1969) suggested that the basal portion of the Sweetland Creek Shale of southeastern Illinois grades laterally westward into the upper portion of the Lingle Formation and the Alto Formation. The presence of the Sylamore Sandstone throughout this area, however, demonstrates the unconformable nature of the Sweetland Creek-Hunton contact across most of western and central Illinois.

In much of the northwestern area of New Albany occurrence in Illinois, the group unconformably overlies the Cedar Valley Limestone (Middle Devonian to lowermost Upper Devonian). Paleontologic evidence suggests only a brief hiatus at this unconformity (Collinson and Atherton, 1975). In west-central Illinois, on the ancient Sangamon Arch (Whiting and Stevenson, 1965), the New Albany unconformably overlies areas of Silurian strata (predominately carbonates) and one small area of Ordovician strata (Workman and Gillette, 1956). In southwestern Illinois, on the Sparta Shelf, the New Albany overlaps Lower Devonian, Silurian, and Ordovician strata (Workman and Gillette, 1956).

Throughout most of its occurrence in Illinois, the New Albany Group is overlain by Mississippian (Kinderhookian and Valmeyeran) strata. Over most of southern, central, and eastern Illinois the New Albany Shale is conformably overlain by the Chouteau Limestone (Kinderhookian), the westward extension of the Rockford Limestone of Indiana (Buschbach, 1952). The New Albany is directly overlain by the Springville Shale (Valmeyeran)—the distal bottomset beds of the Borden Siltstone delta (Lineback, 1966)—in a few areas of southeastern Illinois where the Chouteau has depositionally thinned and pinched out. A substantial period of very slow sedimentation, perhaps most of the Kinderhookian, is then represented by the Springville-New Albany contact. In these areas a thin greenish-gray shale bed similar or equivalent to the Jacobs Chapel Bed in Indiana (Campbell, 1946; Lineback, 1968; Rexroad, 1969) may have been deposited at the top of the New Albany; however, the only horizon which can be consistently recognized on geophysical logs and in samples is the top of the black Grassy Creek Shale. Therefore, in these areas the top of the Grassy Creek is treated as the top of the New Albany Group.

In extreme western Illinois the McCraney Limestone conformably overlies the Hannibal Shale. The McCraney is laterally equivalent to the upper part of the Hannibal in places and the lower portion of the Chouteau Limestone in others (Atherton et al., 1975). Across most of western Illinois the New Albany, and the Chouteau and equivalents, have been erosionally truncated and are unconformably overlain by Valmeyeran strata (Atherton et al., 1975). In portions of this area, the basal Valmeyeran is the Meppen Limestone or Fern Glen Formation; but over most of the area it is the Burlington Limestone. The northern limit of the New Albany Shale coincides with the area where it has been erosionally truncated and overlapped by Pennsylvanian strata, and in some places by Pleistocene glacial deposits. In a small area of extreme southern Illinois, the New Albany is overlain by Cretaceous strata (Collinson and Atherton, 1975).

BLOCHER SHALE

The Blocher Shale (Campbell, 1946; Lineback, 1968) is named for the town of Blocher in Scott County, Indiana (appendix 10). Lineback (1968, 1970) and Collinson et al. (1967) traced the Blocher from its outcrop in southeastern Indiana through the subsurface into Illinois on the basis of well cutting studies and geophysical logs. North (1969), using geophysical logs, mapped the Blocher in the subsurface of Illinois.

The Blocher Shale as mapped by North (1969) and used in this study, is a calcareous or dolomitic black shale throughout its subsurface extent in Illinois, Indiana, and Kentucky. It is the only shale in the New Albany that contains much calcite; the rest of the shale is dolomitic to varying degrees and contains very little calcite. The high carbonate content of the Blocher gives the distinctive geophysical characteristics (table 2) that permit it to be traced throughout the southern part of the Illinois Basin. The Blocher is also believed to grade laterally westward into limestone in Illinois.

Campbell (1946) originally placed the lower 8 feet (2.4 m) of the New Albany in the Blocher at the type section (appendix 10). However, only the lowermost 2.2 feet (0.65 m) of the shale at that section are calcareous. The calcareous Blocher approximates Campbell's bed A1 and contains calcareous brachiopods and other fossils. Lineback (1968, 1970) revised the Blocher by placing its top at the base of the Selmier Member (Campbell's bed B3 of his Blackiston). However, at the type section, Campbell also included all shale to the base of bed B3 in the Blocher as he apparently believed that beds 1 and 2 of the Blackiston were absent.

The Blocher is redefined in this paper (appendixes 10 and 11) to include only the calcareous black shale at the base of the New Albany; thus, the Blocher is 2.2 ft (0.65 m) thick at the type section and 4.9 ft (1.5 m) thick at the type section of the Selmier Member. The restriction of the Blocher to calcareous black shale on the outcrop creates a unit with basin-wide lithologic homogeneity. The dolomitic black shale overlying the Blocher and underlying the greenish-gray shale of the Selmier is reassigned to the Selmier Member on the outcrop and in the subsurface (as that unit is redefined and expanded in this study).

On the outcrop and in cores the black shale of the Selmier and that of the Blocher appear similar. The Selmier may be slightly softer and more fissile. Both contain carbonate lenses, dolomite in the Selmier and dolomitic limestone in the Blocher. Both contain thin lenses or beds of fine-grained sandstone. However, the two shales can be distinguished easily by the application of dilute hydrochloric acid: the Blocher reacts sharply, especially if the shale is powdered, and the Selmier reacts only slowly. The transition is sharp, often taking place within a centimeter or less.

The Blocher, as revised, is a member of the New Albany Shale (formation) in Indiana and Kentucky. The occurrence of the Blocher in Illinois is restricted to the southeastern part of the state, where it is the basal formation of the New Albany Group. Farther to the north and west, the Blocher grades laterally into the upper portion of the Lingle Limestone (North, 1969).

Lithology

The Blocher Shale consists of brownish-black (5YR2/1) to grayish-black (N2), finely-laminated, carbonaceous, calcareous, and dolomitic shales. The abundance of organic matter in the Blocher (approximately 5 to 10 percent organic carbon by weight) is responsible for the dark color of the shales. The major clay component is illite, with a small percentage of expandable mixed-structure clays. Chlorite and kaolinite have not been detected in any of the Blocher samples studied to date.

The most abundant non-clay components of the shale are calcite, dolomite, and quartz. X-ray diffraction analysis indicates that dolomite is several times more abundant than calcite in most samples. A fairly high amount of dolomite persists into the shales overlying the Blocher; however, calcite is virtually absent in the higher units in southern Illinois. The carbonate in the shale occurs mainly as rhombohedral silt-sized grains, both randomly dispersed in the clay matrix and concentrated along numerous thin, even, parallel, and closely spaced laminae (fig. 7). Small pyrite nodules and lenses are also typically concentrated along each lamina (fig. 8). Coarse silt- and sand-sized (>50 μm) terrigenous detritus is very rare. Fine-grained quartz and feldspar are fairly uniformly dispersed in the clay matrix, and much of the quartz detected by x-ray diffraction is almost certainly present as clay-sized grains (Blatt and Schultz, 1976).

Thin beds of fine-grained limestone, dolomite, calcareous sandstone, and phosphatic sandstone are also present in the Blocher. Campbell (1946) and Lineback (1970) reported faint cross-stratification in some of these beds in Indiana. Similar beds in the Jenkins #1 Simpson core, Wayne County, Illinois, are massive to wavy laminated. The fine grain size, even laminations, and scarcity of current-formed sedimentary structures suggest that the Blocher Shale was deposited in quiet water by hemipelagic sedimentation.

Fossils are relatively common in the Blocher Shale and are predominantly planktonic and nektonic taxa. *Tasmanites*, presumably a marine algal reproductive body (Winslow, 1962), occurs throughout the shale. Fish debris, pteropods (*Tentaculites* and *Styliolina*), conodonts, and other resistant phosphatic fragments are scattered along some bedding planes in the shale, but are not abundant. A dwarf fauna of small calcareous brachiopods (*Leiorhynchus, Chonetes*), and *Lingula* are also found along some bedding planes, but these appear to have been either epiplanktonic or transported by other means to their burial sites (Lineback, 1970). No evidence of sediment disturbance by burrowing organisms has been found in the Blocher Shale.

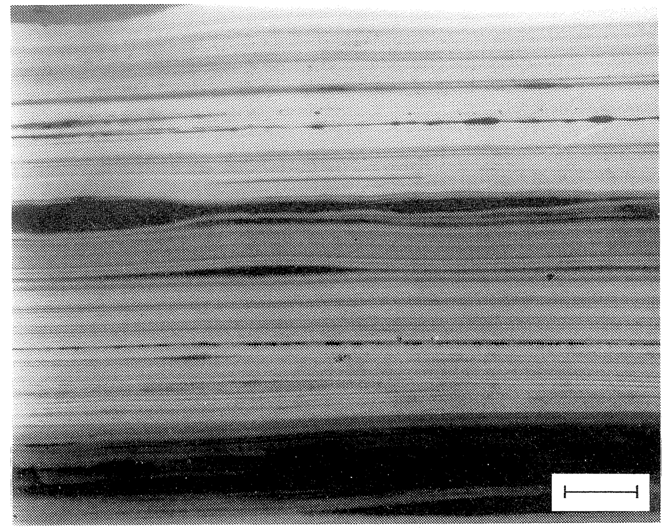


FIGURE 7. Finely laminated shale. Blocher Shale; radiograph, Orbit Gas #1 Clark core, 2312.6 ft (sample 1KY13L1), Christian County, Kentucky. Bar scale = 1 cm.

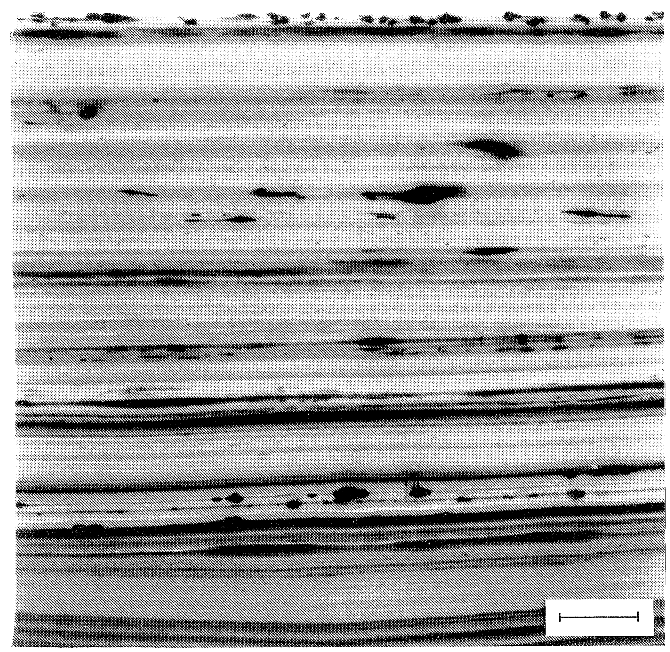


FIGURE 8. Finely laminated shale with small pyrite nodules (black) scattered along bedding planes. Blocher Shale; radiograph, Orbit Gas #1 Clark core, 2311.1 ft (sample 1KY12L1), Christian County, Kentucky. Bar scale = 1 cm.

Geophysical characteristics

Typical geophysical characteristics of the Blocher Shale are shown in figure 3. The high carbonate content of the Blocher is reflected in its generally high electrical resistivity, and it may be very difficult to distinguish from the underlying limestone on the basis of resistivity alone. The spontaneous potential is generally a little more negative than that of the overlying Selmier Shale, but may be distinctly more positive than that of the underlying limestone. Lower gamma-ray values suggest that, in general, the upper part is more carbonate rich, whereas the lower, more radioactive part is more organic rich. Density and sonic velocity values are moderate to moderately high, with the highest values generally in the upper portion. Gamma ray, density, and sonic logs provide the best means of distinguishing the the Blocher from overlying and underlying units (fig. 3).

Distribution and thickness

According to Lineback's boundaries for the Blocher (1970), the Blocher ranges from 3 to 15 feet (1 to 5 m) thick in


INDIANA
41°
40°
GRUNDY
KANKAKEE
IROQUOIS
VERMILION
EDGAR
CLARK
CHAMPAIGN
FORD
COLES
PIATT
MOULTRIE
LIVINGSTON
MC LEAN
DE WITT
MACON
SHELBY
CHRISTIAN
LOGAN
WOODFORD
MARSHALL
PUTNAM
BUREAU
STARK
PEORIA
TAZEWELL
MASON
MENARD
SANGAMON
MACOUPIN
HENRY
KNOX
FULTON
CASS
MORGAN
SCOTT
WARREN
MERCER
MC DONOUGH
SCHUYLER
BROWN
PIKE
HANCOCK
E

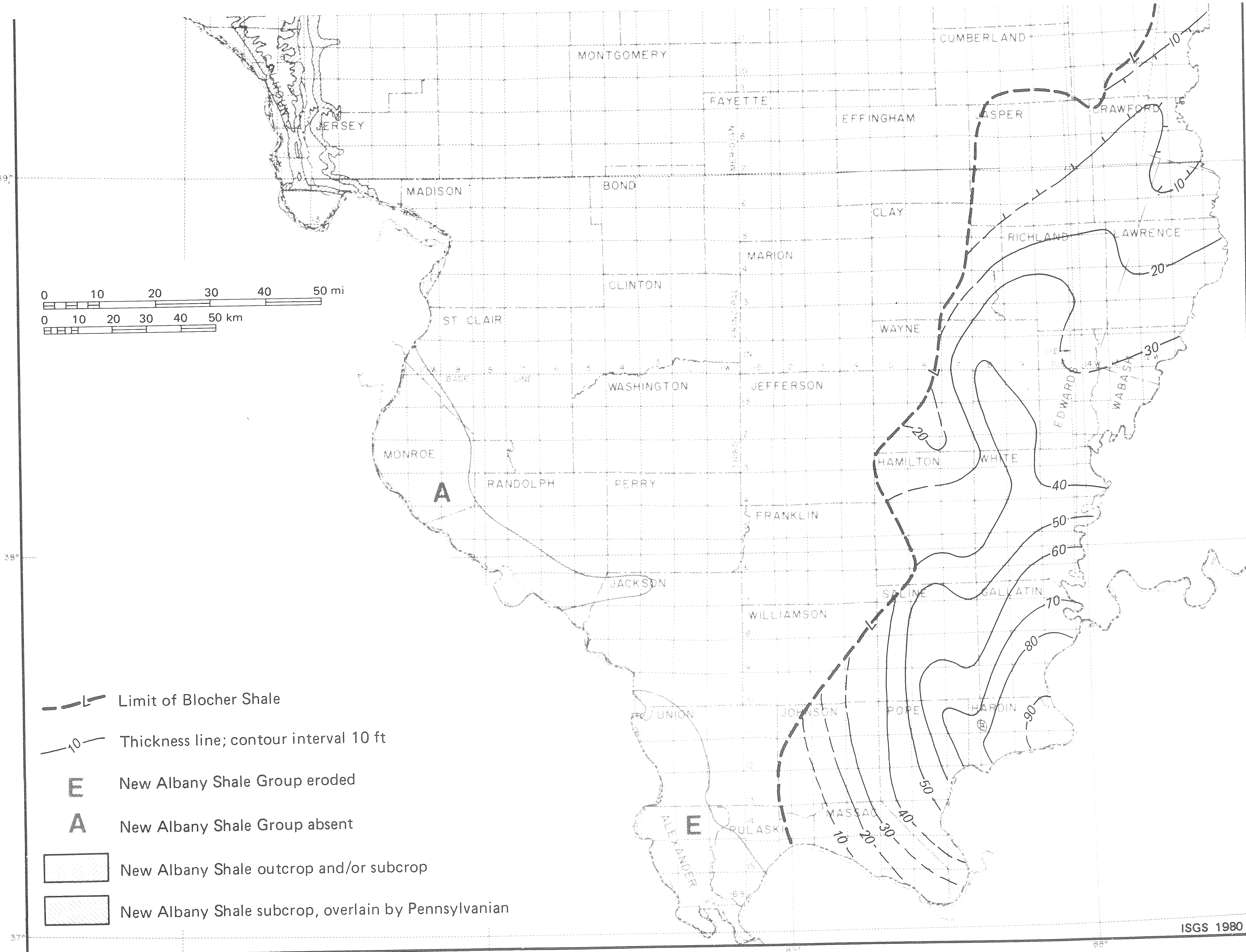


FIGURE 9. Thickness of the Blocher Shale.

outcrops in Indiana and gradually thickens to more than 80 feet (24 m) in southwestern Indiana. In the current, more restricted usage the Blocher reaches a maximum thickness of about 70 feet (21 m) in southwestern Indiana (Bassett and Hasenmueller, 1977), and reaches its maximum thickness of more than 80 feet (24 m) in eastern Hardin County, Illinois, and adjacent Kentucky (fig. 9).

The exact lateral extent of the Blocher Shale is problematic. Because the Blocher grades laterally into the upper portion of the Lingle Formation, its western mapped limit is shown as a single vertical cutoff. The Blocher distribution shown by this study is similar to that of North (1969) and Collinson et al. (1967); however, this study suggests that the Blocher extends farther to the north than shown by North (1969), but perhaps not so far as shown by Collinson et al. (1967).

The westward thinning of the Blocher across Illinois results partly from the gradual nature of the Blocher-Lingle facies transition and partly from depositional thinning.

Stratigraphic relationships

The Blocher Shale overlies and grades laterally northward and westward into the upper portion of the Lingle Formation (North, 1969). The Blocher disconformably overlies the North Vernon Limestone in Indiana and the Sellersburg Limestone in western Kentucky, both of which are equivalent to the Lingle Formation of Illinois. The nature of the facies relationship between the Blocher and the underlying carbonates is very poorly understood, partly because of the lack of reliable subsurface data and samples.

Geophysical cross sections suggest that the contact between the Blocher and Lingle becomes progressively younger towards the west. Because the spacing between wells is relatively wide and the quality of geophysical logs is not uniform, we cannot demonstrate lateral interfingering between the two formations; however, the geophysical characteristics of the lower part of the Blocher generally show a progressive and gradual transition into limestone westward. The facies relationship could probably be most accurately portrayed as a series of minor, stairstep-like vertical cutoffs, although this type of portrayal would result in very complex maps. For this reason we have represented the Blocher-Lingle transition as a single major boundary on the maps and cross sections accompanying this report (fig. 9; plates 1, A-F, I-M; 2, L-M; 3).

Cores through the Blocher-Lingle transition in Illinois are rare. Samples from central Indiana suggest that in some areas the Blocher grades into the underlying Middle Devonian limestone through an intermediate facies consisting of very finely laminated, argillaceous, micritic limestone (mapped by Lineback, 1970). This facies appears to have been deposited in a bottom environment similar to most of the Blocher, but in an area receiving a high influx of carbonate sediment relative to clastic detritus. It contrasts sharply with the fossiliferous and bioturbated carbonates of the Lingle, North Vernon, and Sellersburg Limestones.

A thin (2-15 cm), dark, argillaceous, and coarsely crinoidal limestone bed lies at the base of the Blocher in samples from the Orbit Gas # 1 Clark core, Christian County, Kentucky (figure 10); Jenkins #1 Simpson core, Wayne County, Illinois; and Superior Oil # 1 Braselton Comm. core, Gibson County, Indiana. The upper contact of this bed with the black shale is sharp, whereas the lower contact is rapidly gradational into the underlying Middle Devonian limestone. The uppermost limestone is dark gray and shaly in these cores, grading downward into lighter and less argillaceous carbonate. Prominent beds of Blocher lithology, however, have not been observed in the upper part of the Lingle.

Throughout the area of southeastern Illinois where the Blocher is recognized, it is overlain with apparent conformity by the Selmier Shale, or, in the northernmost area of its extent, by the Sweetland Creek Shale (which includes the Selmier equivalents). In Edgar County, Illinois the upper portion of the Blocher appears to grade laterally into the base of the Sweetland Creek Shale. The evidence for this transition is relatively poor, but both geophysical correlations and sample studies indicate that the Blocher Shale becomes unrecognizable north of Edgar County and an equal thickness of Sweetland Creek Shale apparently takes its place. We have been unable to trace key beds through this interval.

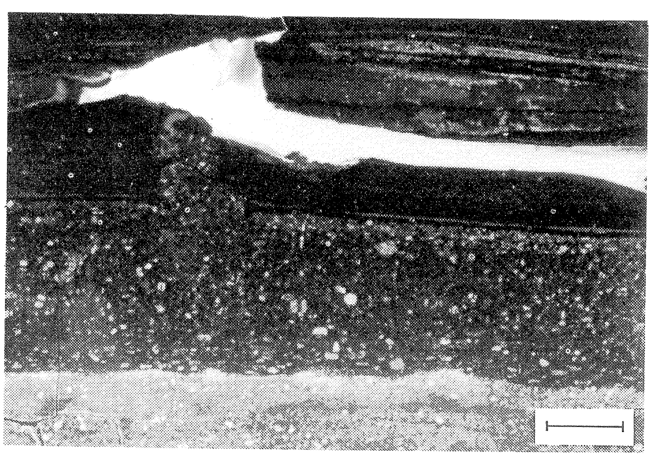


FIGURE 10. Thin bed of dark, argillaceous, crinoidal wackestone at the Blocher Shale-Sellersburg Limestone contact. Bar scale = 1 cm. Core slab, Orbit Gas #1 Clark core, 2319.9 ft (sample 1KY13P7), Christian County, Kentucky.

Age and correlation

The Blocher Member as defined by Lineback (1968, 1970) correlates with the Blocher Shale of Illinois and the lower, primarily black shale, portion of the Selmier Shale (through the 2c horizon). The Blocher Member of current usage in Indiana (Bassett and Hasenmueller, 1977) is nearly the same as Illinois usage in this report and that of North (1969), although there are minor discrepancies in some areas.

Conodont studies suggest a middle Devonian age for most of the Blocher Member of Lineback (1968, 1970), but conodonts in the upper part are earliest late Devonian (Collinson et al., 1967; Lineback, 1970). The current, more restricted, definition of the Blocher probably places almost the entire unit within the Middle Devonian. No conodont data are presently available for the Blocher in the subsurface of Illinois.

North (1969) correlated the Blocher with the Tripp Member of the Lingle Formation and the upper members of the Lingle and the Alto Formation with the Sweetland Creek Shale on the basis of geophysical evidence. Collinson et al. (1967) and Collinson and Atherton (1975) cited conodont evidence suggesting that the Blocher is correlative with the entire upper Lingle through Alto interval.

SYLAMORE SANDSTONE

The Sylamore Sandstone (Penrose, 1891), the basal Upper Devonian formation in parts of central and western Illinois (Workman and Gillette, 1956), is named for Sylamore Creek, Stone County, Arkansas. The sandstone occurs widely in the northern and western portions of the Illinois Basin. Rarely more than one meter thick, it is more commonly only a few centimeters and may be only a thin, sandy, or pyritic layer at the base of the Sweetland Creek or Grassy Creek Shales (Collinson and Atherton, 1975). Furthermore, the Sylamore is difficult or impossible to distinguish on geophysical logs. For these reasons, the Sylamore has not been mapped as a separate unit in this study.

Lithology

The Sylamore Sandstone is typically a thin bed of rounded to subrounded, medium- to fine-grained quartz sand cemented by calcite, dolomite, or pyrite. The matrix may be silty or shaly and is very commonly phosphatized. Phosphatic nodules (fig. 11), conodonts, fish teeth, phosphatic brachiopods, and other resistant skeletal fragments are commonly abundant. Fragmented crinoids, bryozoans, and calcareous brachiopods have been noted in some samples and the Sylamore is highly bioturbated in most areas. The basal contact of the sand is often very sharp (fig. 12).

Geophysical characteristics

The Sylamore Sandstone is usually too thin to be resolved on geophysical logs.

Distribution and thickness

Workman and Gillette (1956) mapped the Sylamore Sandstone over a wide area of western and central Illinois on the basis of sample studies. Their map shows numerous areas where the Sylamore is absent. W. F. Meents (personal communication, 1978), however, has studied more than 100 oil exploration cores throughout this region and concludes that the Sylamore is essentially a continuous sheet, too thin to be recognized without cores in most areas.

Figure 13 shows the approximate extent of the Sylamore Sandstone as inferred from cores and sample studies. The paucity of core data makes it impractical to map the thickness of the sand. In cores, the Sylamore ranges from very thin pyritic and sandy streaks a few millimeters thick to a layer of one meter or more in a few areas. Closely spaced cores in some oil fields reveal that the thickness is quite variable over short distances.

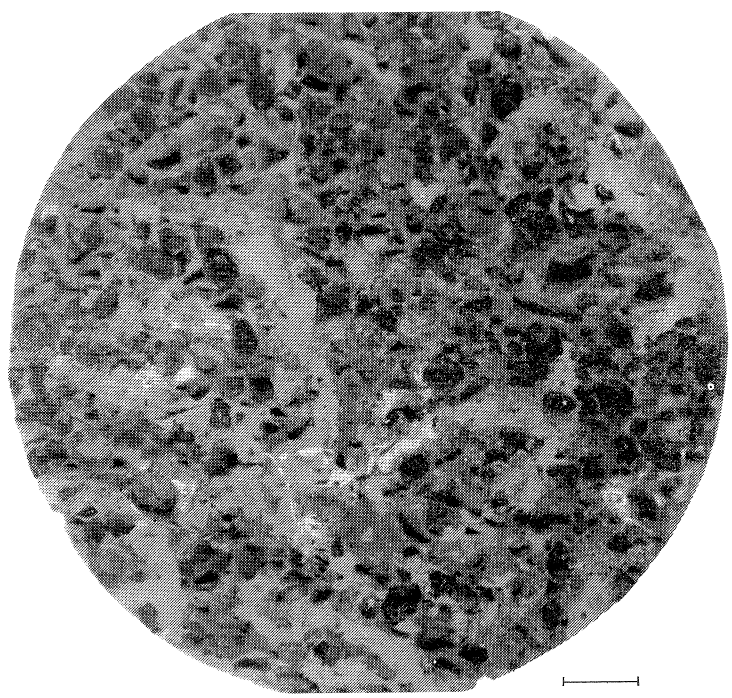


FIGURE 11. Phosphatic nodules at the base of the Sweetland Creek Shale. Northern Illinois Gas #1 RAR core, 603.7 ft (sample 4IL29L1), Henderson County, Illinois. Bar scale = 1 cm.

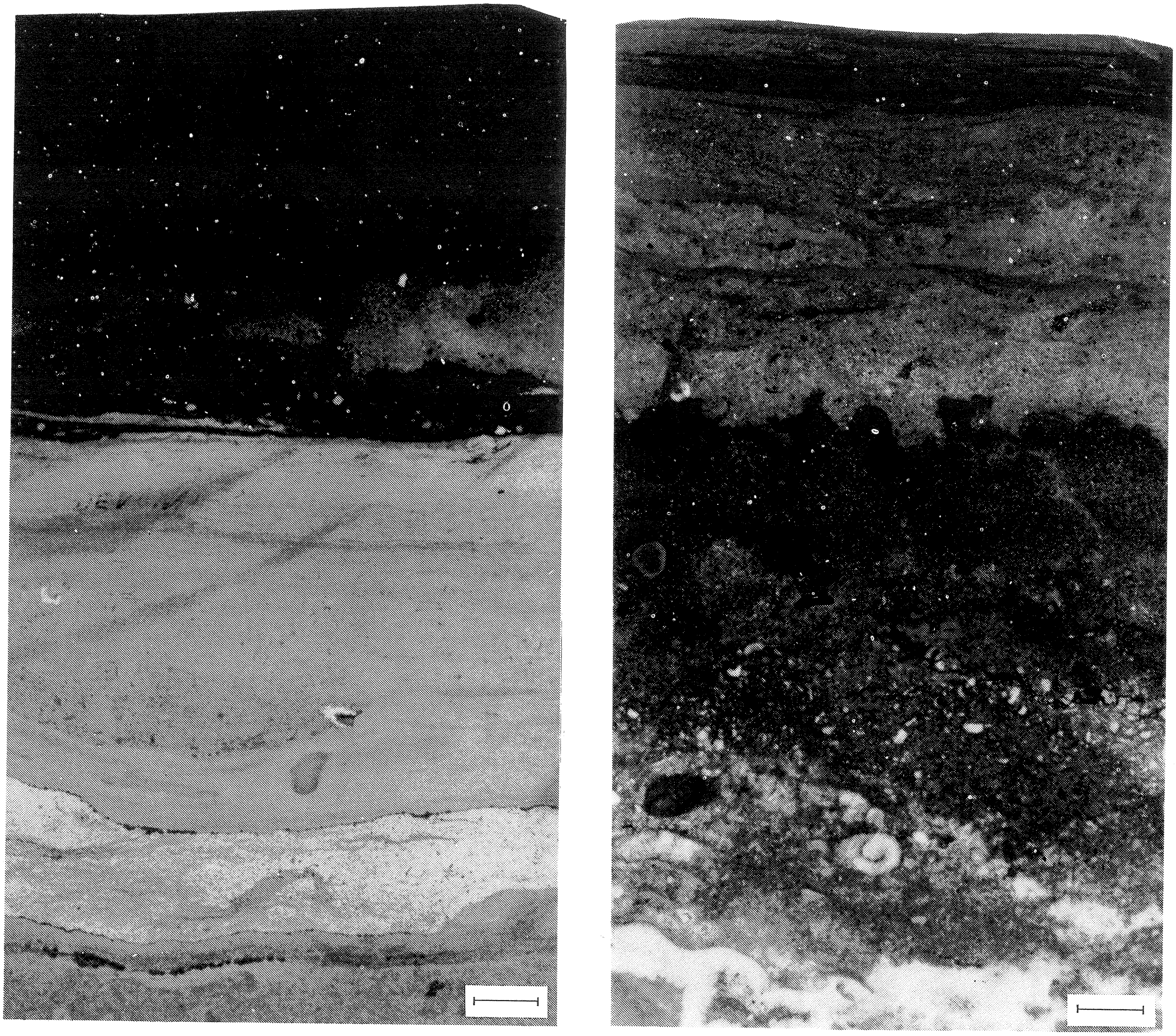


FIGURE 12. Polished core slabs of the Sylamore Sandstone, showing sharp basal contact and bioturbation: (a) T. Doran #1 Koch, 2126 ft, Sec. 34, T. 1 S. - R. 5 W., Washington County, Illinois; (b) Jet Oil #3 Edmiston, 2202 ft, Sec. 16, T. 4 S. - R. 5 W., Randolph County, Illinois. Bar scales = 1 cm.

Stratigraphic relationships

The Sylamore Sandstone marks the basal unconformity of the New Albany Shale over a wide area and rests on rocks of different ages. In most areas it rests unconformably on Middle Devonian limestone (Lingle Formation; Cedar Valley Limestone; and Waspsipinicon Limestone). In southwestern Illinois the Sylamore is found directly on top of Silurian reefs, and it rests on Silurian limestones across the Sangamon Arch (Whiting and Stevenson, 1965).

The Sylamore typically grades upward into the overlying shale. Because geophysical correlations demonstrate that the basal shales of the New Albany become younger towards the north and west, it is apparent that the Sylamore Sandstone is a transgressive unit.

Although the Sylamore clearly marks a transgressive unconformity, the nature of the unconformity and the mechanism which produced this thin, laterally persistent sandy zone are unclear. The limestone surface below the Sylamore lacks obvious evidence for subaerial exposure (such as soil or karst development, paleocaliche, or laminated crusts). Although the phosphatization and pyritization at the contact might be the result of a prolonged period of submarine nondeposition, the surface lacks borings and encrusting fauna commonly associated with ancient submarine hardgrounds.

Age and correlation

The Sylamore underlies and grades upward into Upper Devonian shales. Collinson et al. (1967) reported early late Devonian conodonts from the Sylamore and suggested that the Sylamore may correlate with one or more thin sandy beds in the upper Blocher or lower Selmier (Sweetland Creek) Shales in southeastern Illinois. Lineback (1970) described several sandy and phosphatic beds at the base of the Selmier Member in central Indiana; one or more of these may also correlate with the Sylamore. Collinson et al. (1967) also correlated the Sylamore with the Hardin Sandstone, the basal member of the Chattanooga Shale in some areas of Tennessee (Conant and Swanson, 1961). The term "Hardin" is commonly used in Illinois by drillers and appears on many well records.

The Sylamore does not correlate with the phosphatic sandy zone at the base of the New Albany Shale in the outcrop region of central Indiana; this zone lies at the base of the Middle Devonian Blocher Shale and probably records an older event.

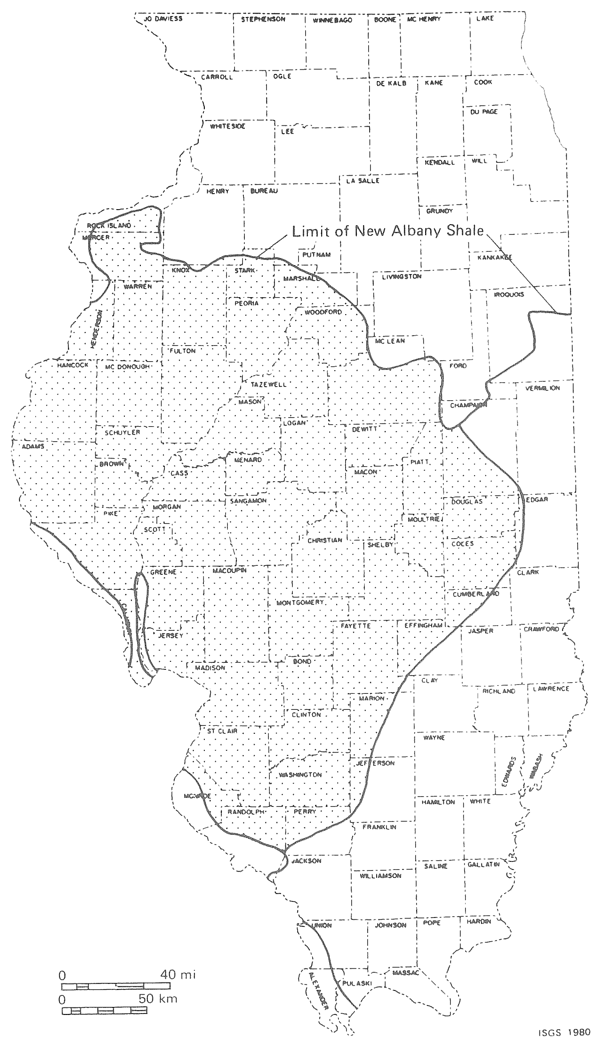


FIGURE 13. Approximate extent of the Sylamore Sandstone. (After Workman and Gillette, 1956; W. F. Meents, personal communication, 1979; and core descriptions in Illinois State Geological Survey files.)

FIGURE 14. Poorly laminated Selmier Shale. Laminae are discontinuous and widely spaced; the large lenticular feature near the base of the sample may be a soft sediment deformation structure. Several faint silt filled burrows cut across the bedding and truncate laminations. Radiograph, Orbit Gas #1 Clark core, 2270.2 ft (sample 1KY8C1), Christian County, Kentucky. Bar scale = 1 cm.

The Selmier Member of the New Albany Shale was named by Lineback (1968, 1970) for the Selmier State Forest in Jennings County, Indiana. The type section is nearby in the Berry Materials Company quarry at North Vernon, Indiana (appendix 11). In this report, the underlying Blocher Member at the Selmier type section is restricted to calcareous black shale 4.9 feet (1.5 m) thick at the base of the New Albany and the Selmier is expanded to include the 5.1 feet (1.55 m) of black dolomitic shale between the restricted Blocher and the original Selmier base. Thus, at the type section, the Selmier Member is 27.1 feet (8.25 m) thick; it consists of greenish-gray, dolomitic, bioturbated mudstone at the top and grades downward through an interbedded zone to black dolomitic laminated shale at the base.

A distinctive body of alternating olive-gray and black shale lies between the Grassy Creek and Blocher Shales in southeastern Illinois. These shales were called the "unnamed shale" by Meents and Swann (1965) and were assigned to the Sweetland Creek Shale by Collinson et al. (1967) and North (1969). Correlations by Bassett and Hasenmueller of the Indiana Geological Survey (personal communication 1979) demonstrate that the Selmier of Lineback (1968, 1970) on the Indiana outcrop is physically traceable into only the upper portion of this body of alternating olive-gray and black shale in southwestern Indiana and southeastern Illinois. The black shale reassigned to the Selmier in this report is probably traceable into the middle black shale unit of the Sweetland Creek Shale of North (1969). The lower olive-gray shale unit of southeastern Illinois apparently pinches out eastward or becomes unrecognizably thin before reaching the Indiana outcrop.

Tracing of key beds westward and northward indicates that the Sweetland Creek Shale of western Illinois is mostly, if not entirely, stratigraphically higher than is the "unnamed shale" of southeastern Illinois. Certainly most of the Sweetland Creek grades laterally eastward (along bedding planes) into the lower portion of the Grassy Creek Shale of southeastern Illinois. Therefore, the use of the name Sweetland Creek for the "unnamed shale" in southeastern Illinois is considered inappropriate. The name Selmier Shale, as revised in this paper, is extended into Illinois and elevated to formation rank in Illinois. It includes alternating greenish-gray, gray, and black shales which underlie the dominantly black Grassy Creek Shale and overlie the calcareous black shale of the Blocher. Thus, over most of the southern depocenter, the expanded Selmier includes all the 2a-3a interval where those geophysical markers can be recognized. The use of the term Sweetland Creek Shale is hereby restricted to western and central Illinois and is separated from any equivalent Selmier by a vertical cutoff.

Lithology

The Selmier Shale consists of alternating beds of brownish-black (5YR2/1), grayish-black (N2) and olive-gray (5Y4/1) to olive-black (5Y2/1) shales. The organic carbon content of these shales is variable, but is generally high, ranging from 5 to 12 percent by weight.

The clay composition of the Selmier Shale is predominantly illite, with minor amounts of expandable mixed-structure clays. Chlorite is present only in trace quantities and kaolinite is absent in the Selmier (and most of the rest of the New Albany Shale) in southern Illinois and western Kentucky. The major components of the silt- and sand-sized fractions of the Selmier are quartz, feldspar, and coarse mica. The coarsest terrigenous clastic material is coarse silt to fine sand. Dolomite is present throughout the Selmier Shale as widely dispersed rhombs, as finely crystalline concretion-like beds, and as coarsely crystalline cement in silt laminae and thin beds. Calcite is present in only very small quantities in a few beds.

The dark shales in the Selmier are generally thickly or poorly laminated. The laminae are thick, discontinuous, and widely spaced, and they commonly pinch and swell irregularly to form small irregular lenses (figs. 14, 15). Numerous small burrows are common and frequently truncate the laminae. Most of the laminae are composed of quartzose silt cemented by sparry calcite or pyrite, and small pyrite nodules are common.

Silt beds as much as several centimeters thick are present in the Orbit Gas #1 Clark core, Christian County, Kentucky; they may have low amplitude symmetrical ripples along the top (fig. 16) and are usually cross laminated (fig. 17). These structures demonstrate the infrequent presence of low velocity sea floor currents. Graded bedding has not been observed in any of these silt beds.

Several portions of the Selmier Shale consist of indistinctly bedded shale. The indistinctly bedded shales are typically dark greenish-gray to olive gray and are slightly lower in organic content than are the thickly laminated shales described above. These shales are typically burrowed; the burrowing is extensive but not total (fig. 18), as bedding is usually still preserved. *Chondrites, Zoophycos,* and *Planolites* are the only identifiable trace fossils present.

FIGURE 15. Thickly laminated Selmier Shale. The base of the granular appearing calcareous silt bed at the top of the sample pinches and swells, probably because of soft sediment deformation. Several pyritic burrows, deformed by compaction, are present in the massive central portion of the sample. Radiograph, Orbit Gas #1 Clark core, 2263.7 ft (sample 1KY7L1), Christian County, Kentucky. Bar scale = 1 cm.

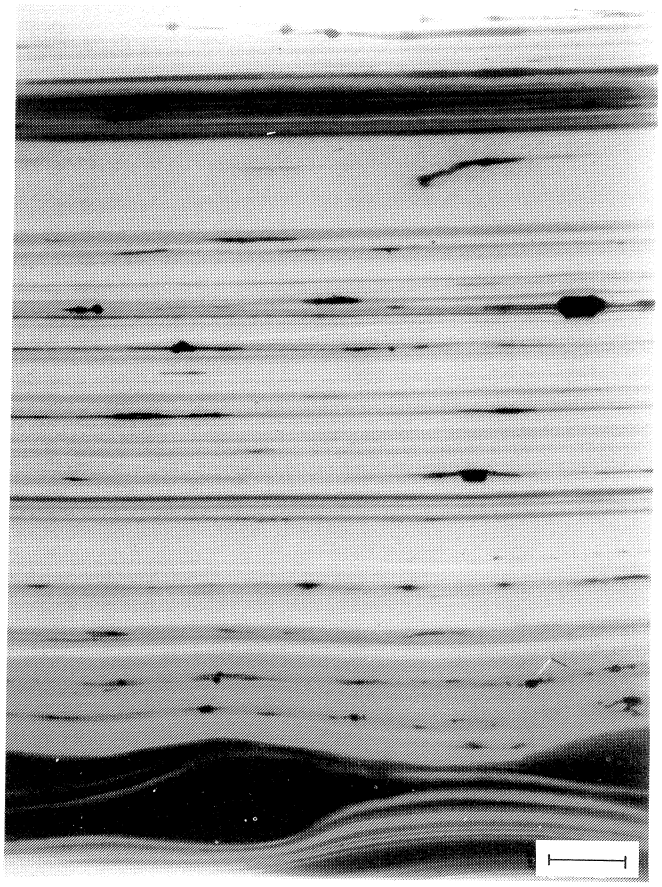


FIGURE 16. Rippled and poorly cross-laminated siltstone bed in thickly laminated Selmier Shale. Radiograph, Orbit Gas #1 Clark core, 2299.7 ft (sample 1KY11C1), Christian County, Kentucky. Bar scale = 1 cm.

Benthic invertebrate fossils are extremely rare or absent in both the thickly laminated and indistinctly bedded shales. Conodonts, fish skeletal debris, and fragments of phosphatic brachiopods have been noted in a few samples.

Geophysical characteristics

Geophysical characteristics typical of the Selmier Shale are shown in figure 3. The Selmier is bounded by the persistent 2a and 3a horizons over most of the deeper parts of the Illinois Basin. The section reflects interbedding of gray and black shales, whose general geophysical characteristics are described in table 2. The high gamma-ray and high-resistivity middle unit is typical of the Selmier throughout the southern depocenter. North (1969) recognized and widely correlated several informal subunits within his Sweetland Creek Shale (our Selmier) which he defined in terms of the same geophysical horizons. In the southern depocenter, the contact with the overlying Grassy Creek Shale is marked by abrupt dramatic increases upward in the gamma-ray and resistivity values (3a horizon). The contact with underlying Blocher Shale generally shows a moderate increase downward in resistivity, as well as a fairly abrupt downward increase in sonic velocity (2a horizon). The upper part of the Blocher has notably lower gamma ray values than does the lower part of the Selmier.

Distribution and thickness

The Selmier Shale extends throughout much of the southern and eastern portions of the Illinois Basin, and is thickest in eastern Hardin County, Illinois and in adjacent Kentucky (fig. 19) where it exceeds 200 feet (60 m). Westward from this depocenter, the Selmier Shale thins rapidly across the DuQuoin Monocline to become very thin and indistinguishable from the overlying Grassy Creek Shale on the Sparta Shelf. The Selmier thins more gradually northward and most of the unit eventually pinches out against the basal unconformity of the New Albany Shale Group. A thin interval at the top of the Selmier may be partly equivalent to the lowermost portion of the Sweetland Creek Shale in western Illinois.

Stratigraphic relationships

In southeastern Illinois the Selmier Shale conformably overlies the Blocher Shale, with apparent minor interfingering of the lithologies.

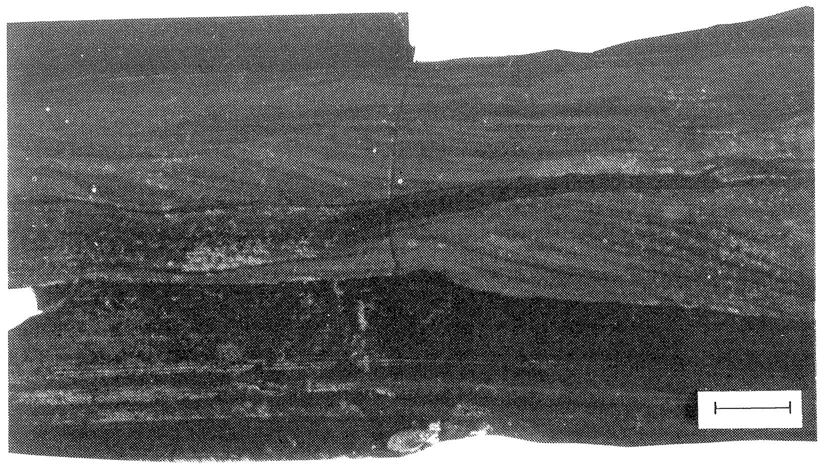
The Selmier is conformably overlain by the Grassy Creek Shale. The Selmier-Grassy Creek contact is one of the sharpest and most persistent geophysical horizons (3a) in the

New Albany Shale Group (plate 1, A-F) and has therefore been used as a datum plane for some of the stratigraphic cross-sections in this and previous reports (Reinbold, 1978; 1979).

Age and correlation

The upper olive-gray shale of the Selmier persists to the Indiana outcrop, as does the middle black shale unit. The lower interbedded olive-gray and black shale unit thins eastward and near the outcrop it may pinch out or become too thin to identify. The Selmier is only partly equivalent to the Sweetland Creek Shale and is separated from that formation by a vertical cutoff in western and central Illinois (fig. 19).

Conodonts from the upper part of the Selmier from Indiana indicate correlation with German Late Devonian zone *to*I (Lineback, 1970), and possibly the lower part of zone *to*II (Collinson et al., 1967).



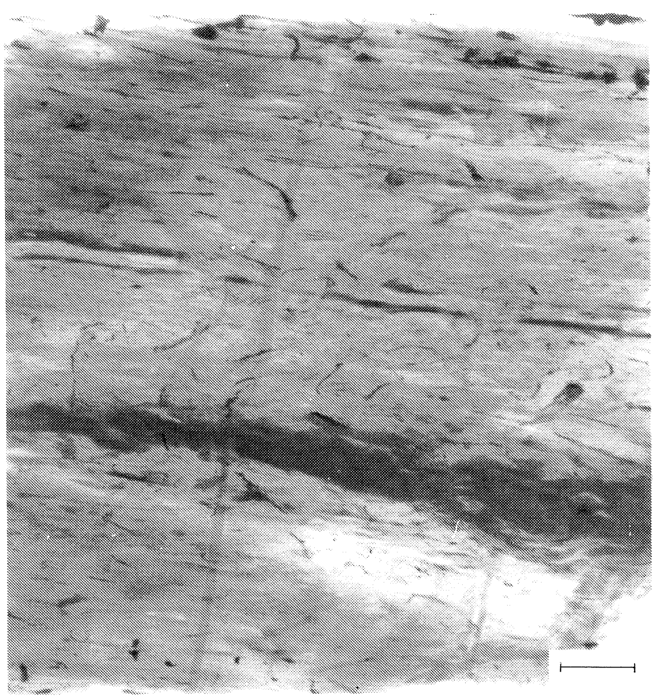
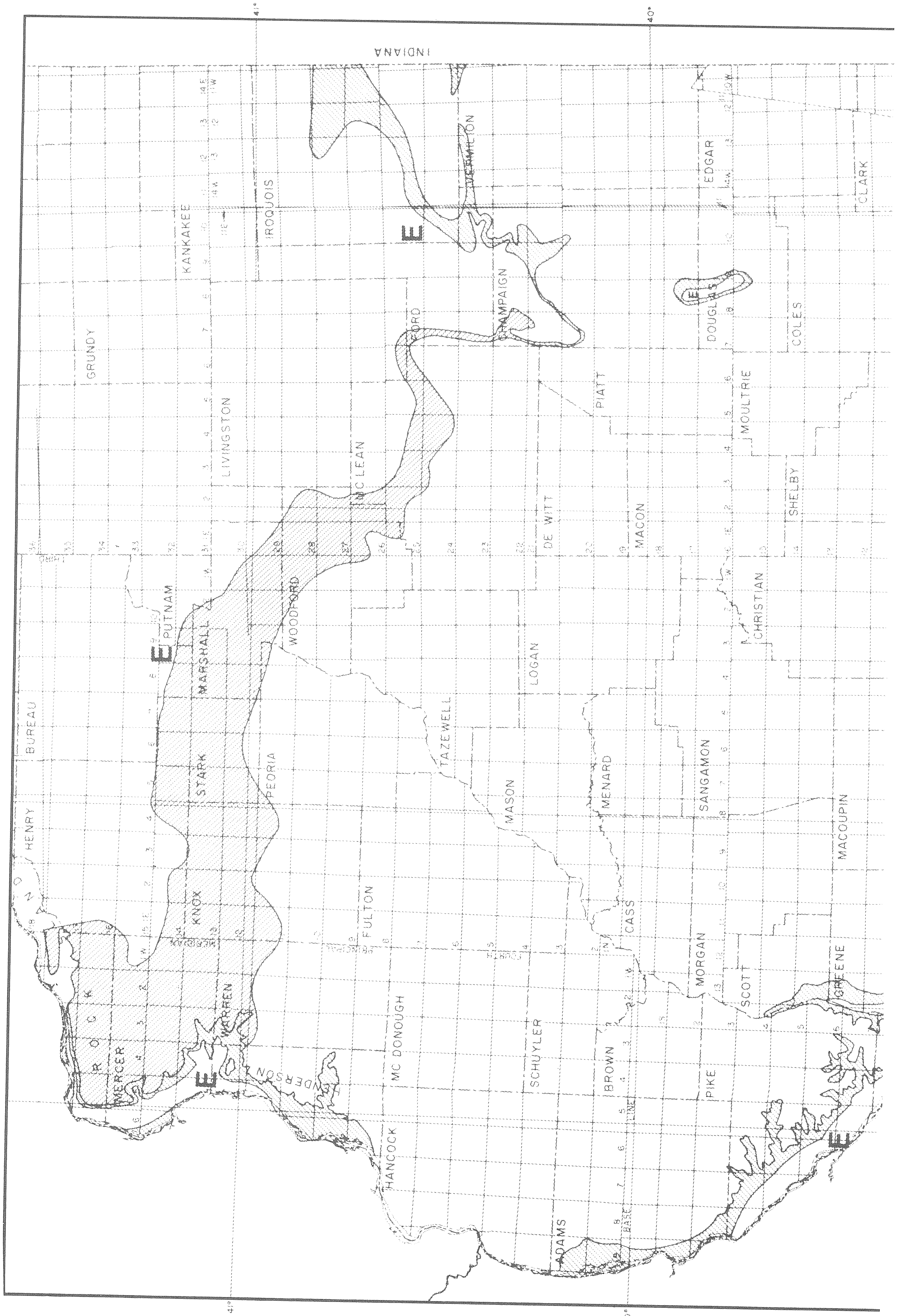


FIGURE 17. Cross-laminated fine siltstone bed in the Selmier Shale. Core slab, Orbit Gas # 1 Clark core, 2265.6 ft (sample 1KY7B5), Christian County, Kentucky. Bar scale = 1 cm.

FIGURE 18. Indistinctly bedded and bioturbated Selmier Shale. The short black streaks are pyrite-filled burrows; the general swirling texture is characteristic of bioturbation. Radiograph, Rector and Stone #1 Missouri Portland Cement core, 120.2 ft (sample 11IL8C1), Hardin County, Illinois. Bar scale = 1 cm. ←



INDIANA
VERMILION
EDGAR
CLARK
KANKAKEE
IROQUOIS
E
CHAMPAIGN
DOUGLAS
COLES
GRUNDY
FORD
PIATT
MOULTRIE
LIVINGSTON
MC LEAN
DE WITT
MACON
SHELBY
PUTNAM
MARSHALL
WOODFORD
CHRISTIAN
LOGAN
BUREAU
TAZEWELL
STARK
PEORIA
MENARD
SANGAMON
HENRY
MASON
MACOUPIN
KNOX
FULTON
CASS
MORGAN
GREENE
ROCK
WARREN
MC DONOUGH
SCHUYLER
SCOTT
MERCER
HENDERSON
BROWN
PIKE
HANCOCK
ADAMS

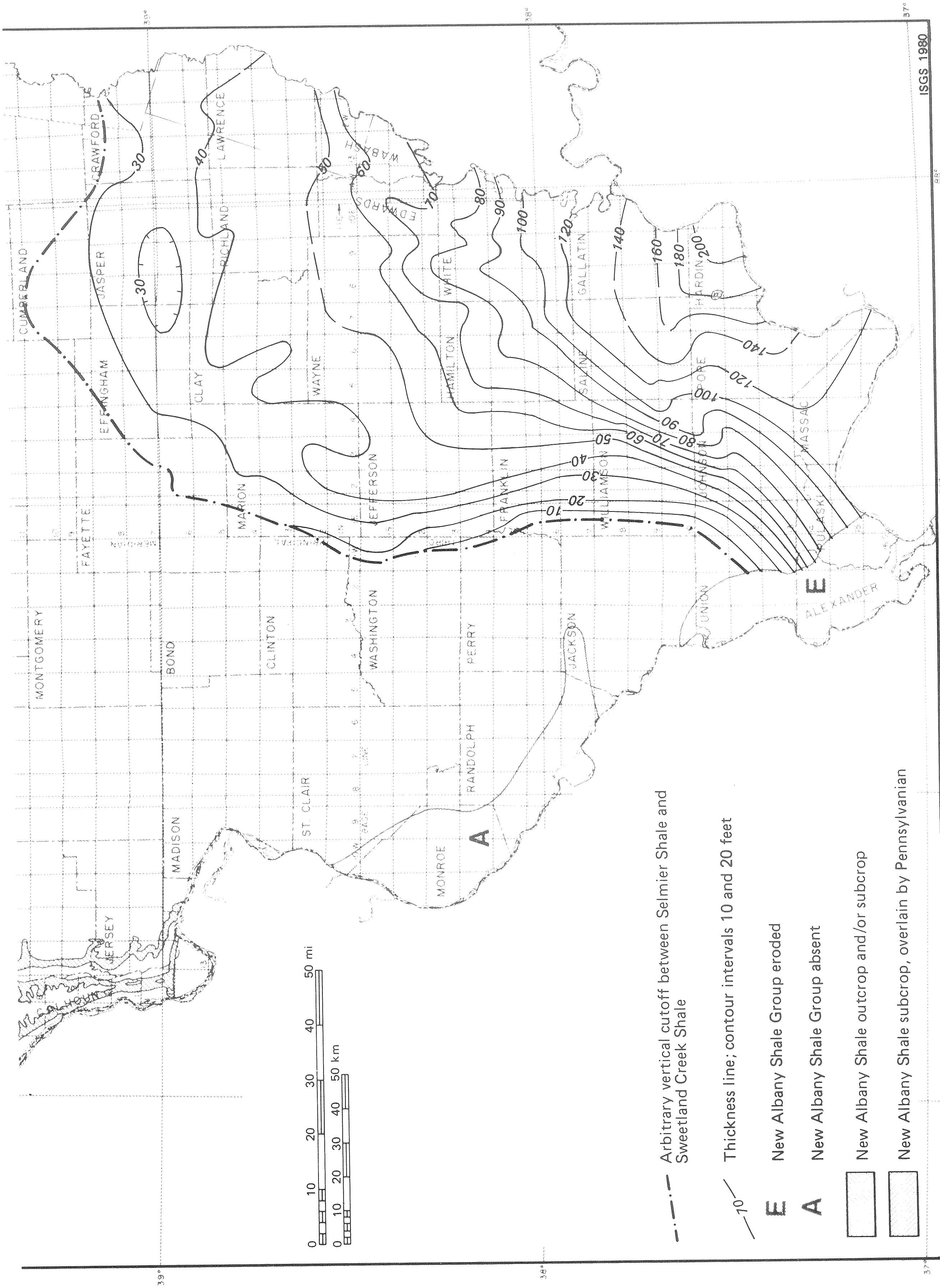


FIGURE 19. Thickness of the Selmier Shale.

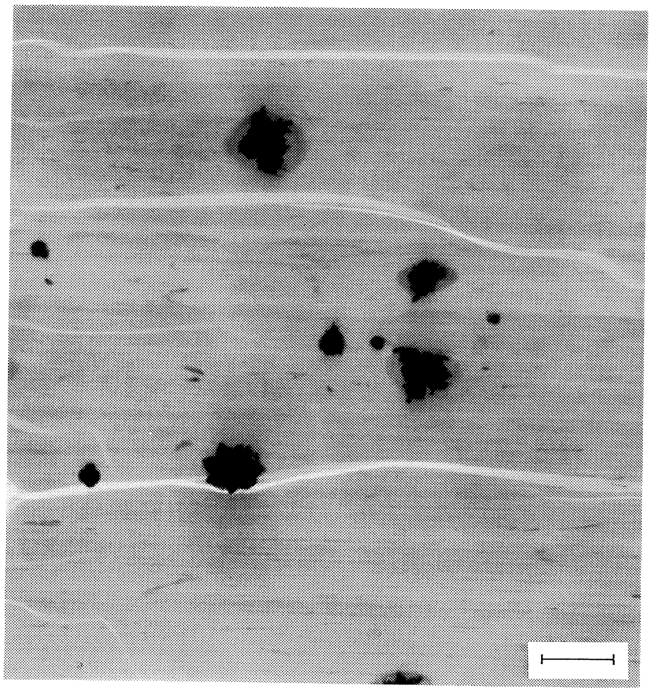


FIGURE 20. Very indistinctly bedded Sweetland Creek Shale. Large black angular features are euhedral pyrite crystals. Although the sediment has been extensively bioturbated, no compositional difference exists between the burrows and the surrounding sediment, and individual burrows are therefore not resolved by the x-rays. Radiograph, Northern Illinois Gas #1 RAR core, 553.4 ft (sample 4IL24C1), Henderson County, Illinois. Bar scale = 1 cm.

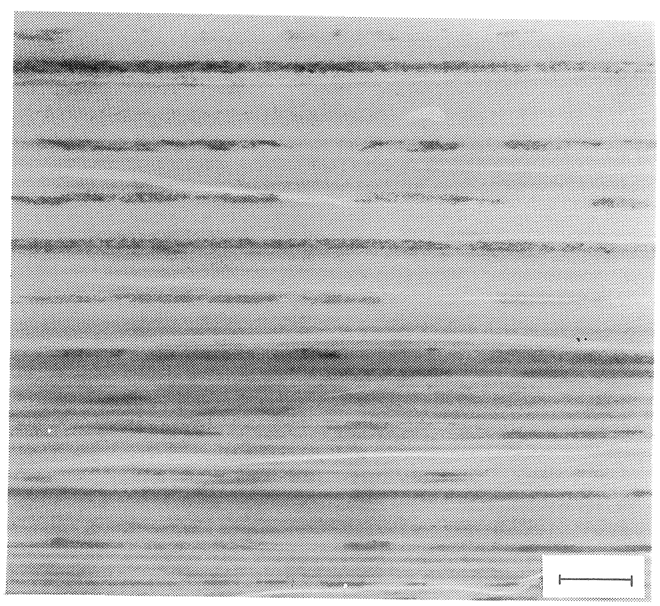


FIGURE 21. Thick, discontinuous, even-parallel laminations in poorly laminated Sweetland Creek Shale. Radiograph, Peoples Gas #1 Witt core, 655.9 ft (sample 5IL1L1), Edgar County, Illinois. Bar scale = 1 cm.

The Sweetland Creek Shale (Udden, 1899) is named for Sweetland Creek in Muscatine County, Iowa. As originally described, it included all the Devonian shale at that locality.

Workman and Gillette (1956) discarded the name Sweetland Creek Shale and extended the definition of the Grassy Creek Shale to include all these beds. Collinson et al. (1967) later restricted the Grassy Creek to the dominantly black and brownish-black shales and reinstated the name Sweetland Creek for the underlying olive-gray and green shales. They also extended the term Sweetland Creek eastward into the Illinois Basin to include the "unnamed shale" of Meents and Swann (1965), which we have in this report placed in the Selmier Shale.

Lithology

The Sweetland Creek Shale consists of alternating beds of dark greenish-gray (5GY4/1), greenish-gray (5GY6/1), and grayish-green (10GY5/2) shales with minor amounts of olive-gray (5Y4/1) to olive-black (5Y2/1) shale. The organic carbon content of these shales varies but is generally low, ranging from 1 to 3 percent.

The major clay component of the Sweetland Creek Shale is illite, with minor expandable mixed-structure clays and chlorite also present. A small amount of kaolinite, (approximately 5 percent of the < 2 μm fraction of the shale) was detected in several samples from Edgar County, Illinois and in one sample from Henderson County, Illinois.

The dominant lithofacies of the Sweetland Creek Shale are indistinctly-bedded, moderately-bioturbated shale (fig. 20) and thickly- or poorly-laminated shale (fig. 21) with few or no burrows. Very pronounced interbedding of the burrowed, indistinctly bedded greenish-gray shales with thickly laminated olive-black shales occurs throughout the Sweetland Creek Shale (fig. 22). Typically, the color contrast between the two shales is very striking and the bottom contact of the laminated black shales is sharp, whereas the top contact is burrowed (figs. 23 and 24). The burrows in the laminated shales clearly penetrate down from the overlying gray shale and are filled with lighter colored shale. The underlying black mud was apparently relatively toxic to burrowers as evidenced by the very shallow depth of penetration, a few centimeters at most. Large compressed *Zoophycos* (fig. 23), *Planolites, Teichichnus,* and *Chondrites* (fig. 24), are the most common trace fossils found along the interface between these shales. Several different kinds of large unidentified oblique burrows are also present.

This type of interbedding is especially characteristic and abundant in the uppermost Sweetland Creek, where it is a transitional facies into the finely laminated shales of the overlying Grassy Creek Shale; it is also characteristic of the Camp Run Member of the New Albany Shale in Indiana and western Kentucky (Griffith, 1977), and portions of the Selmier Shale in southeastern Illinois.

Geophysical characteristics

The Sweetland Creek Shale exhibits geophysical characteristics typical of a predominantly gray to greenish-gray shale with minor interbedding of black shale (fig. 4). The Sweetland Creek Shale can nearly always be readily distinguished from the underlying limestone by geophysical discontinuities (especially gamma ray), but the contact

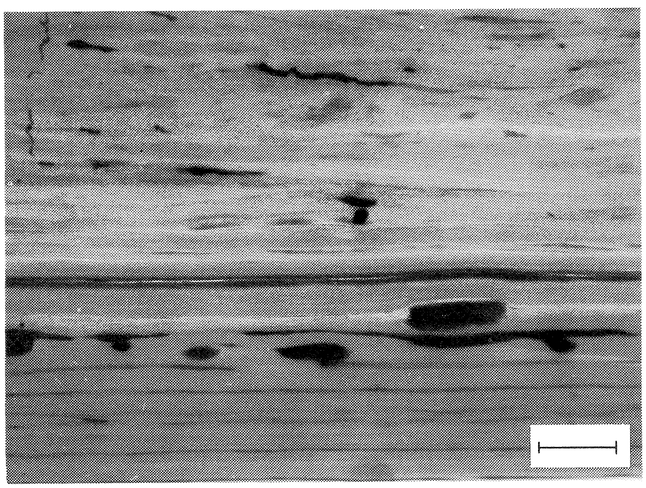


FIGURE 22. Interbedded bioturbated dark greenish-gray shale and thickly laminated olive-black shale. Sweetland Creek Shale; radiograph, Tri-Star Production #1D Lancaster core, 3085.6 ft (sample 2IL7C1), Effingham County, Illinois. Bar scale = 1 cm.

FIGURE 24. *Zoophycos* and *Teichichnus* penetrating downward into a black shale bed. Sweetland Creek Shale, Midland Electric Coal #1 Peters core, 661.5 ft (sample 8IL13L1), Sec. 11, T. 7 N. - R. 6 E., Peoria County, Illinois. Bar scale = 1 cm

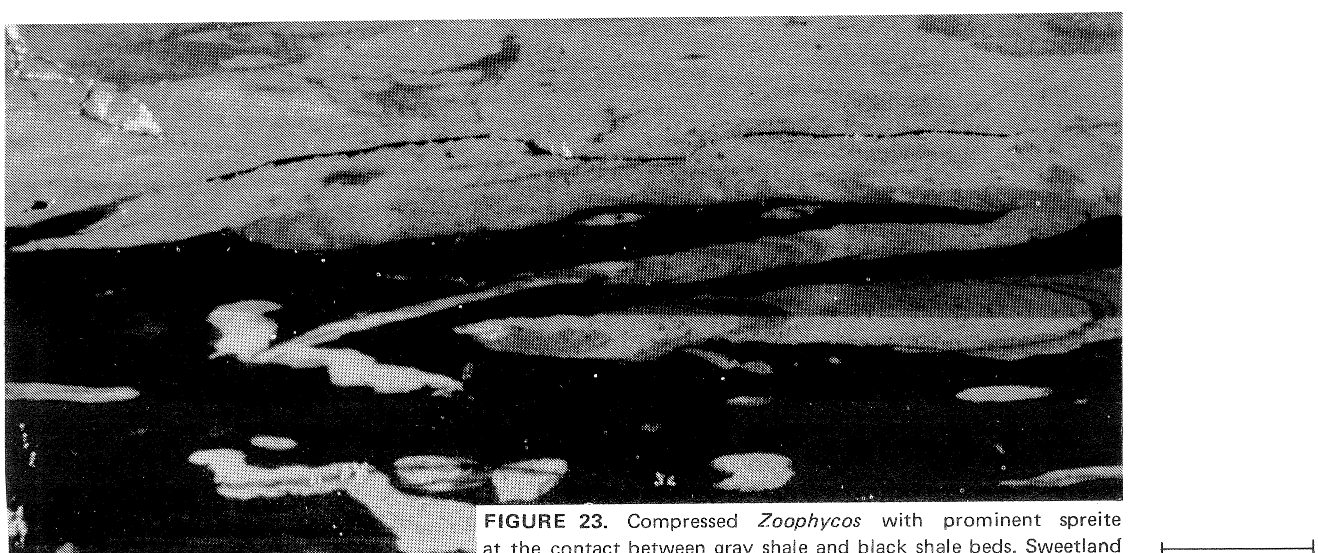
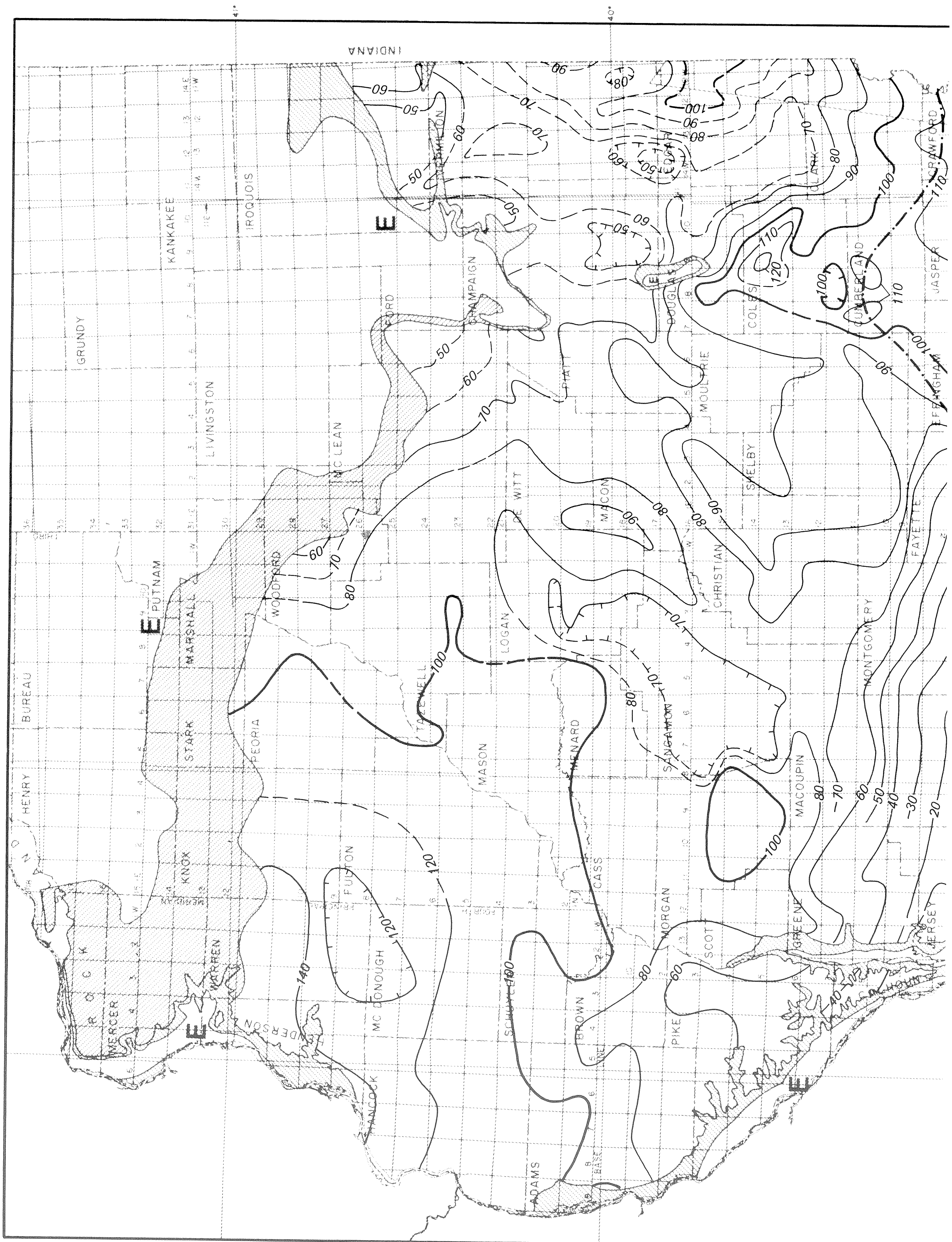


FIGURE 23. Compressed *Zoophycos* with prominent spreite at the contact between gray shale and black shale beds. Sweetland Creek Shale, Northern Illinois Gas #1 MAK core, 1111.4 ft (sample 6IL22L1), Tazewell County, Illinois. Bar scale = 1 cm.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CRAWFORD
CUMBERLAND
JASPER
EFFINGHAM
MOULTRIE
PIATT
MC LEAN
DE WITT
MACON
SHELBY
CHRISTIAN
FAYETTE
MONTGOMERY
PUTNAM
MARSHALL
WOODFORD
BUREAU
STARK
PEORIA
TAZEWELL
LOGAN
SANGAMON
MENARD
MASON
MACOUPIN
HENRY
KNOX
FULTON
CASS
MORGAN
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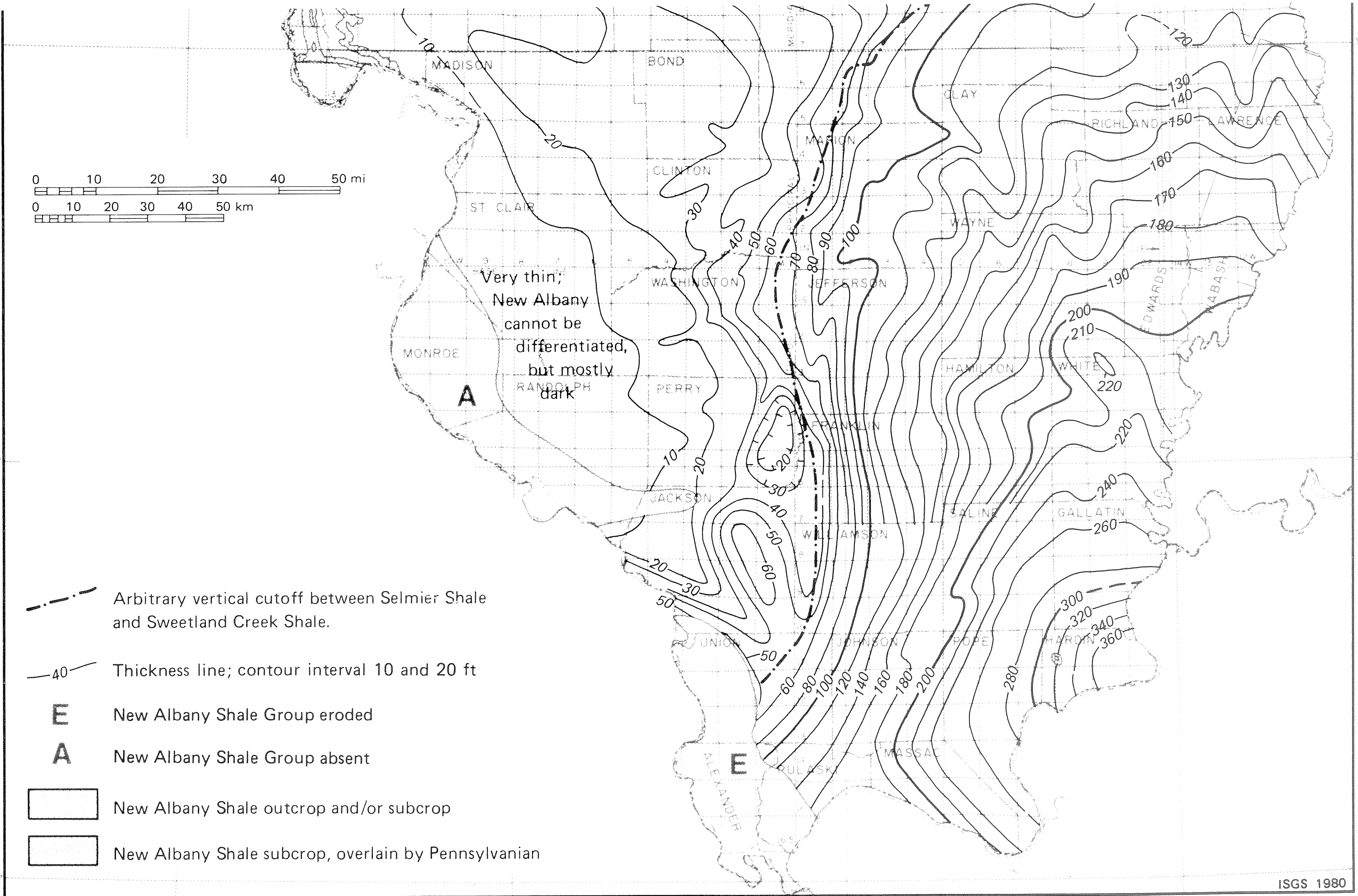


FIGURE 25. Thickness of the Grassy Creek-Sweetland Creek-Selmier Shales undifferentiated.

with the overlying Grassy Creek Shale is much more subtle than the sharp Selmier-Grassy Creek contact (3a horizon) in the southern depocenter.

Distribution and thickness

The Sweetland Creek Shale in the subsurface is distinguishable as a separate formation principally in central Illinois and parts of southwestern Illinois. Equivalent strata are present across much of western and north central Illinois, where they are transitional with the overlying Grassy Creek Shale and not consistently distinguishable from the Grassy Creek (using available subsurface data and methods). Unfortunately, the Sweetland Creek is also not readily distinguishable from the Grassy Creek in the subsurface of western Illinois adjacent to the Sweetland Creek type section in Muscatine County, Iowa. Subsurface data in the area are very sparse in both Iowa and Illinois. In the few New Albany Shale cores available from western Illinois the Sweetland Creek has been identified by its distinctive lithology (appendixes 4, 5, and 6).

Because of the difficulty in tracing geophysical horizons within the Sweetland Creek-Grassy Creek interval across western and central Illinois, the precise stratigraphic relationships of the various areas of Sweetland Creek Shale cannot be determined. For this reason we have not included a separate map of the Sweetland Creek, although it may be mappable in certain isolated areas. The total thickness of the Selmier-Sweetland Creek-Grassy Creek interval is shown in figure 25.

Stratigraphic relationships

The Sweetland Creek Shale of western and central Illinois interfingers with and grades laterally into the lower portion of the Grassy Creek Shale of southeastern Illinois. Gray shale tongues in the lower portion of the Grassy Creek become thicker toward the north and west, away from the southern depocenter (plate 1, A-F; I-M). The gray shale eventually becomes dominant over black shale within the interval. Consequently, the Sweetland Creek-Grassy Creek boundary is defined along a major vertical cutoff; south and east of this cutoff the Sweetland Creek is not separated or lithologically distinct from the Grassy Creek Shale (figs. 25 and 30).

Age and correlation

On the basis of extensive studies of the conodont faunas of the Sweetland Creek Shale in the type area, an early to middle late Devonian (*toI*) age has been assigned to the formation in that area (Klapper and Furnish, 1962; Collinson et al., 1962; Collinson et al., 1967). A *toI* age has also been suggested for the Selmier Member of Indiana (Collinson et al., 1967; Lineback, 1968, 1970) on the basis of conodont evidence. Collinson et al. (1967) suggest that the deep basin Sweetland Creek (Selmier in this report) of southeastern Illinois is age equivalent to both the type Sweetland Creek and the type Selmier.

By correlating geophysical marker horizons across the basin, North (1969) demonstrated that most of the Sweetland Creek Shale of northern and western Illinois is at a higher stratigraphic position and is therefore younger than is the deep basin Sweetland Creek (our Selmier). The present study concurs with North's interpretation, although a thin interval of Sweetland Creek Shale may be equivalent to the uppermost Selmier. The Sweetland Creek grades laterally into, and is therefore equivalent in age to, the lower part of the thick Grassy Creek Shale in southeastern Illinois. The term "Sweetland Creek," as applied in northern and western Illinois, probably includes strata younger than the type section which were apparently included in the Grassy Creek by Collinson et al. (1967). Because of a lack of data in the area, it is very difficult to correlate subsurface sections precisely to the Sweetland Creek type section.

On the basis of subsurface physical correlations, the Sweetland Creek of western Illinois correlates with perhaps the uppermost Selmier, all the Morgan Trail, and part or all the Camp Run Members of Indiana.

GRASSY CREEK SHALE

The Grassy Creek Shale (Keyes, 1898, 1912) is named for Grassy Creek, a stream in Pike County, Missouri. As originally defined, the Grassy Creek included all black, gray, and green shale above the Cedar Valley Limestone or older formations and beneath the Louisiana Limestone. Later, however, Keyes (1912) differentiated the upper gray shale as the Saverton Shale. Collinson et al. (1967) further restricted the Grassy Creek by assigning the lower gray and green shale to the Sweetland Creek Shale. In Illinois, the Grassy Creek was at first geographically restricted to the western portion of the state, later extended to the central and southwestern portions by Workman and Gillette (1956), and still later extended to eastern and southeastern portions by Collinson et al. (1967) and North (1969).

As currently defined, the Grassy Creek Shale is restricted to the dominantly black shale interval of the middle and upper part of the New Albany Shale Group.

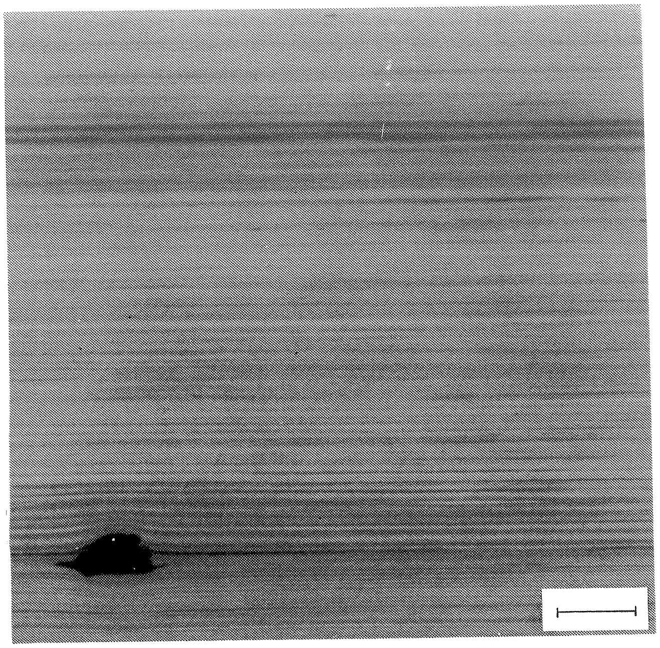


FIGURE 26. Very finely laminated black shale. Large black feature at lower left is a pyrite nodule. Grassy Creek Shale; radiograph, Orbit Gas #1 Clark core, 2181.2 ft (sample 1KY1L1), Christian County, Kentucky. Bar scale = 1 cm.

FIGURE 27. Finely laminated Grassy Creek Shale with dark, pyritic laminations. Radiograph, G. W. Millar #1 Sample core, 1723.4 ft (sample 1IL16L1), Sangamon County, Illinois. Bar scale = 1 cm.

Lithology

In southern Illinois and western Kentucky, the Grassy Creek Shale consists of brownish-black (5YR2/1) to grayish-black (N2), finely laminated, pyritic, carbonaceous shales. The organic carbon content of these shales is among the highest in the New Albany Group, generally ranging from about 4 to 15 weight percent. The Grassy Creek grades northward into less carbonaceous olive-black (5Y2/1) to olive-gray (5Y4/1) shales with thin interbeds of grayish olive-green (5GY3/2) to grayish-green (5G5/2) mudstone.

The mineralogy of the Grassy Creek is similar to the mineralogy of the New Albany Shale as a whole; the predominant clay components are illite, minor expandable mixed-structure clays, and chlorite. The illite and mixed-structure clays are present in approximately fixed proportions, whereas chlorite is relatively variable and is generally more abundant (up to 20 percent of the $<2\ \mu m$ fraction) in samples from northern and central Illinois. Quartz, feldspar, and coarse micas are the principal detrital silt components. Dolomite and a very small amount of calcite are present as cement between silt grains in thin laminae, as scattered, isolated grains in the clay matrix, and as fracture fillings. Pyrite and marcasite are abundant and occur along bedding planes as fine crystals, as scattered framboids, as small flattened nodules or lenses, and as scattered large nodules. A small amount of apatite, most of which probably occurs as conodonts, fish debris, and other phosphatic skeletal material, has been detected in many samples of Grassy Creek Shale.

The Grassy Creek is characteristically very finely laminated, with extraordinarily even, parallel, and closely-spaced laminae (figs. 26 and 27). They range from 20 μm to about 1mm in thickness and are composed of silt-sized quartz and feldspar, usually tightly cemented by carbonate and pyrite. Little or no interparticle porosity is visible in thin sections. Small nodules and irregular masses of pyrite are scattered along the laminae of some samples (fig. 28); in other samples only occasional large pyrite nodules are present (fig. 26). The deformation of silt laminae around pyrite nodules and the preservation of uncompressed *Tasmanites* with pyrite fillings indicate that pyritization was an early diagenetic event that occurred before significant lithification and compaction of the sediment. Variations in the form and distribution of pyrite probably reflect differences in the early diagenetic environments of these shales.

Some laminae are composed of concentrations of amorphous organic matter and *Tasmanites* associated with considerable pyrite. These laminations probably result from variations in the productivity of phytoplankton in the overlying water mass, although rhythmic biogenic laminae analogous to the coccolith-rich laminae in Black Sea sediments (Ross and Degens, 1974) or to the diatomaceous laminae in Gulf of California sediments (Calvert, 1964) have not been observed. The uniformity of both silt and organic laminae in the Grassy Creek Shale, the general absence of detrital grains larger than about 50 μm, and the absence of current-formed physical sedimentary structures all suggest deposition in very quiet water by pelagic sedimentation.

Fossils in the Grassy Creek Shale are predominantly pelagic organisms. *Tasmanites* is abundant in most samples, and conodonts, fish skeletal debris, and inarticulate brachiopods are present (but rare) throughout the shale. No evidence of infaunal burrowing organisms is found in the finely-laminated shale. Many of the thin interbeds of greenish-gray shale in central and western Illinois contain abundant, very small (mostly <1 mm) burrows, but the adjacent black shales are laminated and undisturbed.

Across much of the Illinois Basin there is a very thin greenish-gray shale at the top of the New Albany Shale, immediately beneath the Chouteau Limestone. This bed, generally too thin to be discriminated by geophysical logs, is believed to correlate with the Jacobs Chapel Bed of Indiana (Campbell, 1946; Rexroad, 1969; Lineback, 1968, 1970). Just beneath the Jacobs Chapel Bed is a discontinuous, thin (generally less than 5 feet), but distinctive and widespread black shale bed, which is mappable using gamma-ray logs (fig. 29) and appears correlative with the Henryville Bed of Indiana (Campbell, 1946; Lineback, 1968). These two beds and the Falling Run Bed of phosphatic nodules are present at the top of the New Albany at two unusual surface exposures of the shale in southeastern Illinois: at Horseshoe, a narrow-fault block slice along the Shawneetown Fault in Saline County; and at Hicks Dome, a cryptoexplosive structure in Hardin County that has uplifted the shale and other strata by nearly 4000 feet (appendix 9). The Jacobs Chapel-Henryville-Falling Run sequence is also present in the Jenkins #1 Simpson core in Wayne County (appendix 8), the only core of the New Albany Group in southeastern Illinois that includes the uppermost few feet of the shale. Because of the widespread traceability of these thin beds across the Illinois Basin, the Indiana names have been extended into Illinois. Across most of the southern depocenter these three beds are directly underlain by dominantly black shale and are therefore included with the Grassy Creek Shale. In some areas they are underlain by substantial thickness of gray shale and are then assigned to the Hannibal-Saverton Shale. Although in most areas of Indiana these beds are underlain by black shale and are included in the Clegg Creek Member, in a few areas they rest on gray shales and are included in the Ellsworth Shale Member.

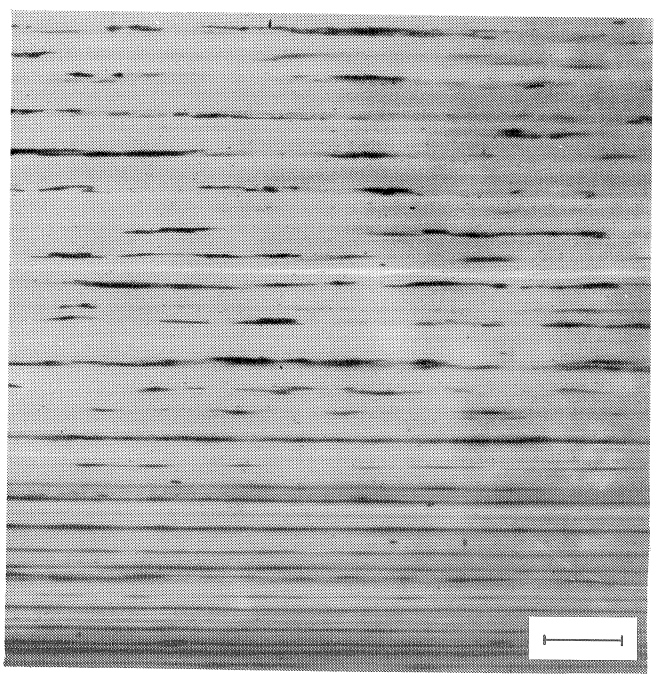


FIGURE 28. Finely laminated Grassy Creek Shale with numerous small pyrite nodules along bedding planes. Radiograph, Tri-State Prod. #1D Lancaster core, 3065.3 ft (sample 2IL5C1), Effingham County, Illinois. Bar scale = 1 cm.

Geophysical characteristics

The Grassy Creek Shale in the southern depocenter exhibits the high gamma-ray and resistivity values typical of organic-rich brownish-black to olive-black shales (fig. 3; table 2). Lower values represent beds of less organic-rich, generally lighter-colored shales. These latter beds become more prominent northward from the southern depocenter. The most consistently high gamma-ray and high-resistivity values in the Grassy Creek are in the upper portion. This organic-rich zone, bounded by the 3e and 3f horizons, constitutes an important marker bed recognizable across much of the Illinois Basin.

In much of central Illinois the resistivity of the Grassy Creek exhibits only a modest increase relative to the Sweetland Creek or Saverton Shales (fig. 4); in fact, the sharpest increase in resistivity may be several feet below the basal Saverton contact. The gamma-ray curve, however, is marked by an abrupt increase at the Grassy Creek contact.

Distribution and thickness

The thick, dominantly black shales which characterize the Grassy Creek Shale are found primarily in the southern depocenter. To the north and west, the black shale interfingers with gray shales to such an extent that the Grassy Creek loses its distinct separate identity (plate 1, A-F). In much of northern and western Illinois the Grassy Creek is therefore not readily distinguishable from the underlying Sweetland Creek Shale. In parts of southwestern Illinois the two formations also cannot be distinguished and the lithology is dominantly black shale. Here the Sweetland Creek may be too thin to recognize on logs.

The Grassy Creek Shale attains its maximum thickness, about 160 feet (50 m), in eastern Hardin County, Illinois and adjacent Kentucky (fig. 30). A second thick area, with maximum thicknesses more than 130 feet (40 m), is centered farther north in the areas of Wayne, Edwards, and Wabash Counties. In Warren and Henderson Counties in the western depocenter the undifferentiated Grassy Creek-Sweetland Creek attains its maximum thickness of about 140 feet (43 m) (fig. 25). Equivalent strata extend northwestward into Iowa as a broad tongue.

Stratigraphic relationships

Throughout most of Illinois the Grassy Creek Shale lies conformably on the Sweetland Creek Shale or the Selmier Shale. In areas where the Grassy Creek is not differentiated from the Sweetland Creek, the undifferentiated unit conformably overlies the Sylamore Sandstone.

Across most of the basin, the Grassy Creek is conformably overlain by the Saverton Shale or the undifferentiated Hannibal-Saverton Shales. At the southwestern end of the central Illinois thin (fig. 6), the Saverton Shale is absent or very thin and unrecognizable. In these areas the Grassy Creek is overlain by the Louisiana Limestone or the Horton Creek Formation. Across much of the southern depocenter, the Hannibal-Saverton Shales are very thin or absent or cannot be separated from the Grassy Creek; in these areas the Grassy Creek is directly overlain by the Chouteau Limestone or, where the Chouteau is missing, by the Springville Shale.

All the formations in the Saverton-Louisiana-Horton Creek-Hannibal interval thin and grade laterally eastward into the black shales of the upper portion of the Grassy Creek in the southern depocenter. Although the Hannibal-Saverton interval is not distinct in samples or electric logs in much of this area, its probable equivalent can be recognized as a relatively low radioactivity unit in the upper part of the Grassy Creek (plates 1, A-F; 2, L-M).

The lower portion of the Grassy Creek Shale grades laterally into the Sweetland Creek Shale through an interval of intertonguing gray and black shales. In the southern depocenter, black shales predominate in this interval and it is assigned to the Grassy Creek; farther to the north and west, gray shale predominates in the interval, and is assigned to the Sweetland Creek Shale (plate 1, A-F; I-M).

Age and correlation

The type Grassy Creek Shale of northeastern Missouri and equivalent strata of western Illinois clearly represent a much smaller interval of geologic time than does the thick Grassy Creek in the southern depocenter. The base of the Grassy Creek in southeastern Illinois (the 3a horizon) is older than the base of the type Grassy Creek, which

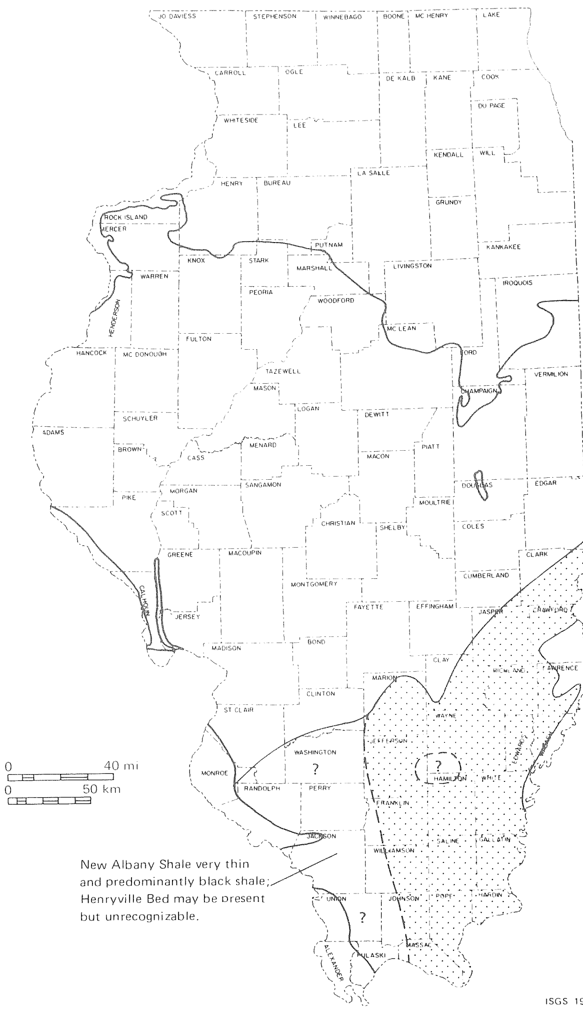
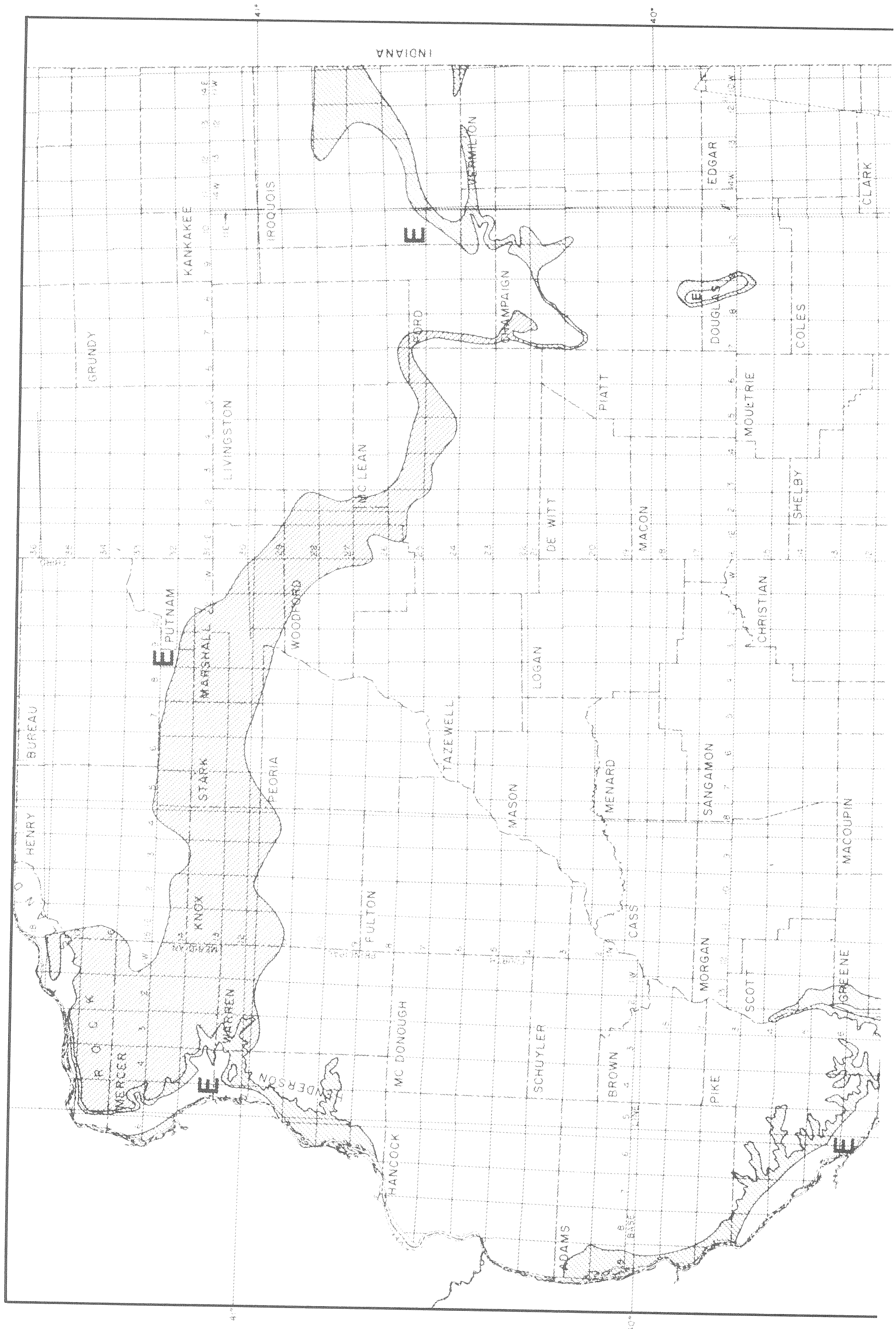


FIGURE 29. Occurrence of the Henryville Bed (stippled area) at the top of the New Albany Shale, based on gamma ray logs.

correlates approximately with the 3c or 3e horizon (plates 1, A-F; 2, G-H). Similarly, the top of the Grassy Creek black shales in the southern depocenter occurs at a higher geophysical horizon than does the top of the type Grassy Creek. Where the greenish-gray shales assignable to the Hannibal-Saverton are absent, the uppermost black shale of the Grassy Creek is probably Kinderhookian in age.

The Morgan Trail, Camp Run, and Clegg Creek Members of Indiana are probably physical and time equivalents to the Grassy Creek Shale of much of southeastern Illinois. Geophysical correlations in the present study suggest that the type Grassy Creek Shale of western Illinois is equivalent to only the lower part of the Clegg Creek Member and perhaps to the upper part of the Camp Run Member, whereas the upper portion of the Clegg Creek Member is time equivalent to the Saverton through Hannibal interval of Illinois (Lineback, 1970).

The megafauna of the Grassy Creek is very sparse, and the microfauna is not well known. Most of the



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IROQUOIS
KANKAKEE
CHAMPAIGN
DOUGLAS
COLES
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MOULTRIE
LIVINGSTON
MC LEAN
SHELBY
DE WITT
MACON
CHRISTIAN
PUTNAM
MARSHALL
WOODFORD
LOGAN
BUREAU
TAZEWELL
PEORIA
STARK
SANGAMON
MENARD
MASON
HENRY
MACOUPIN
KNOX
FULTON
CASS
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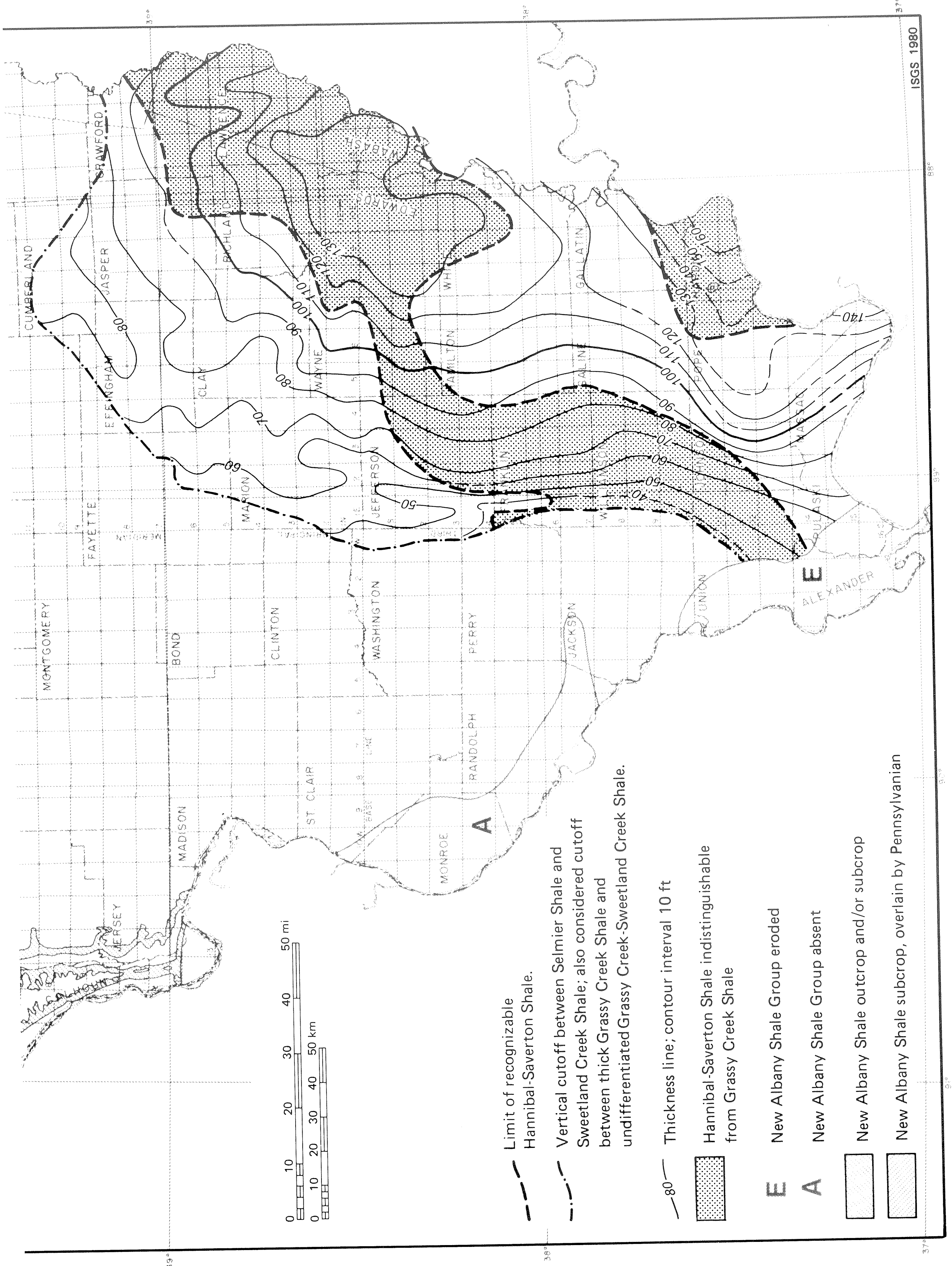


FIGURE 30. Thickness of the Grassy Creek Shale.

conodont faunas which Branson and Mehl (1934) attributed to the Grassy Creek were actually from the overlying Saverton Shale, which they did not differentiate from the Grassy Creek (Collinson et al., 1967). Abundant faunas from the underlying Sweetland Creek and overlying Saverton bracket the Grassy Creek in the type region as early late Devonian, representing the *to*II and *to*III zones (Collinson et al., 1962; Collinson et al., 1967). Biostratigraphic data from the Indiana outcrops place the Morgan Trail and Camp Run Members in the late Devonian *to*II and *to*III zones and suggest that the Clegg Creek Member extends through the *to*IV, *to*V, and *to*VI zones of the late Devonian, as well as through the *Cu* I and into the lowermost *Cu* II zones in the Kinderhookian (early Mississippian). The Devonian-Mississippian boundary lies only a few feet below the top of the Clegg Creek Member in Indiana (Huddle, 1934; Lineback, 1970).

Tracing of geophysical marker horizons suggests that the base of the Grassy Creek Shale in western Illinois correlates approximately with the base of the Clegg Creek Member of Indiana or perhaps with a horizon within the Camp Run Member.

SAVERTON SHALE

The Saverton Shale (Keyes, 1912) is named for the town of Saverton, Ralls County, Missouri. The Saverton is overlain across parts of western Illinois by the Louisiana Limestone or Horton Creek Formations. In most areas where these formations are absent, the Saverton is essentially indistinguishable from the overlying Hannibal Shale, and the two formations are mapped as a single unit.

Lithology

The Saverton Shale consists of interbedded greenish-gray (5G5/1), dark greenish-gray (5G4/1, 5GY4/1), and olive-black (5Y2/1) shales. The organic carbon content of these shales is low, ranging from 0.3 to 3 percent. Generally, the darkest and highest organic content shales are found at the base of the Saverton, where it grades downward through an interval of brownish-black (5YR2/1) shale into the underlying Grassy Creek Shale.

The clay composition of the Saverton is primarily illite, minor expandable mixed-structure clays, and chlorite. Chlorite is abundant in all samples of Saverton examined; kaolinite was not detected in any samples. The silt fraction of the Saverton is predominantly quartz and feldspar. Carbonate silt is only a minor constituent and is usually confined to a few laminae. Calcite is very rare, but dolomite is detected in variable quantities in almost all samples. The total silt content of the Saverton is generally low, and very often most of the coarse silt and fine sand-sized grains are concentrated within burrow fillings. These segregations are very similar to those resulting from size sorting in muds by vertically-oriented deposit feeders, as described by Rhoads (1974). The pyrite content of the Saverton is relatively low and most pyrite occurs within burrows.

The lower part of the Saverton Shale in the subsurface of Illinois consists of thinly interbedded greenish-gray and olive-black shales (figs. 31, 32). Generally, the interbedding is about 1-2 centimeters, becoming progressively thicker and less distinct upward through the shale section.

The greenish-gray beds are non-laminated, silty, and organic poor. The silt content, greatest near the base of the layer, grades upward into more clay-rich shale, resembling crude graded bedding. The basal contacts of the layers are typically very sharp and the uppper contacts grade into the next overlying olive-black bed. Numerous very small *Chondrites* burrows are present at the top of the light layer (fig. 33). The organisms that produced these burrows must have been very small, as the individual burrow tubes are less than one millimeter across. Nematodes, copepods, and ostracodes are organisms in this size range that are known to extensively burrow in modern muddy sediments (Moore, 1931; Cullen, 1973).

The olive-black beds are less silty, more organic-rich, and laminated. The laminae are discontinuous, even, parallel, and very thin, usually composed of alternating high and low concentrations of organic matter; silt laminae are rare. The olive-black beds are not burrowed except near their bases.

The greenish-gray/olive-black shale couplets in the Saverton are possibly the result of sudden, episodic sedimentation events. The sharp bases of the light-colored beds appear to be erosional and the crude graded bedding suggests deposition in a waning current regime (perhaps by low-velocity density currents). The gray sediments were probably derived from areas where organic matter was not accumulating and where burrowing organisms survived. The currents apparently transported the sediment and a few small burrowers to their final resting place, where the burrowers were able to survive only a short time and thus had a minimal sediment-mixing effect. Sedimentation then returned to "normal" for the area, and dark, organic-rich, laminated mud accumulated until the next sudden influx of sediment.

The upper portion of the Saverton Shale usually consists of massive, bioturbated, greenish-gray mudstones. These are low in organic carbon content (<1%) and are generally unfossiliferous, although brachiopod and crinoid fragments have been found in a few samples. The extensive bioturbation has resulted in a homogenous appearance or in a disinctive swirling texture (fig. 34). Individual burrow types are only rarely identifiable on either radiographs or core samples.

FIGURE 31. Interbedded bioturbated greenish-gray shale and poorly laminated black shale. Pyrite (black) is distributed along laminae in black shale beds and within burrows in gray shale beds. Saverton Shale; radiograph, Northern Illinois Gas #1 MAK core, 1063.2 ft (sample 6IL17C1), Tazewell County, Illinois. Bar scale = 1 cm.

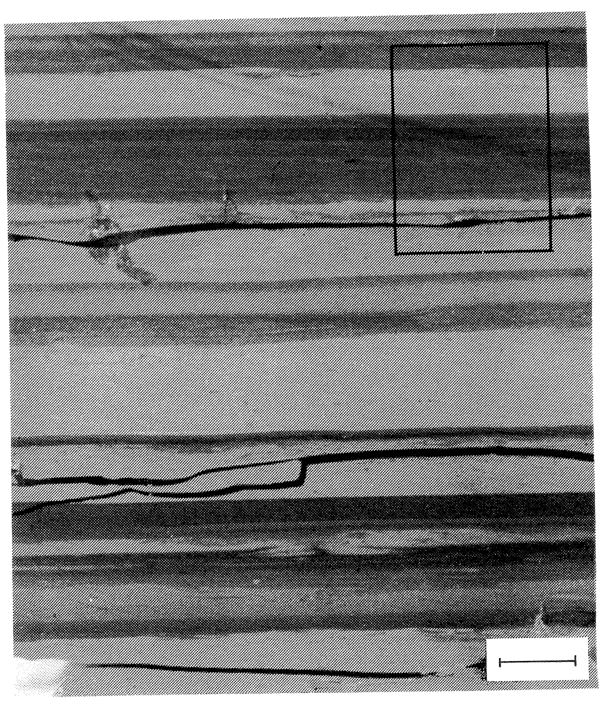


FIGURE 32. Thinly interbedded gray and olive black shale. Saverton Shale; core slab, Northern Illinois Gas #1 MAK core, 1063.2 ft (sample 6IL17C1), Tazewell County, Illinois. Bar scale = 1 cm.

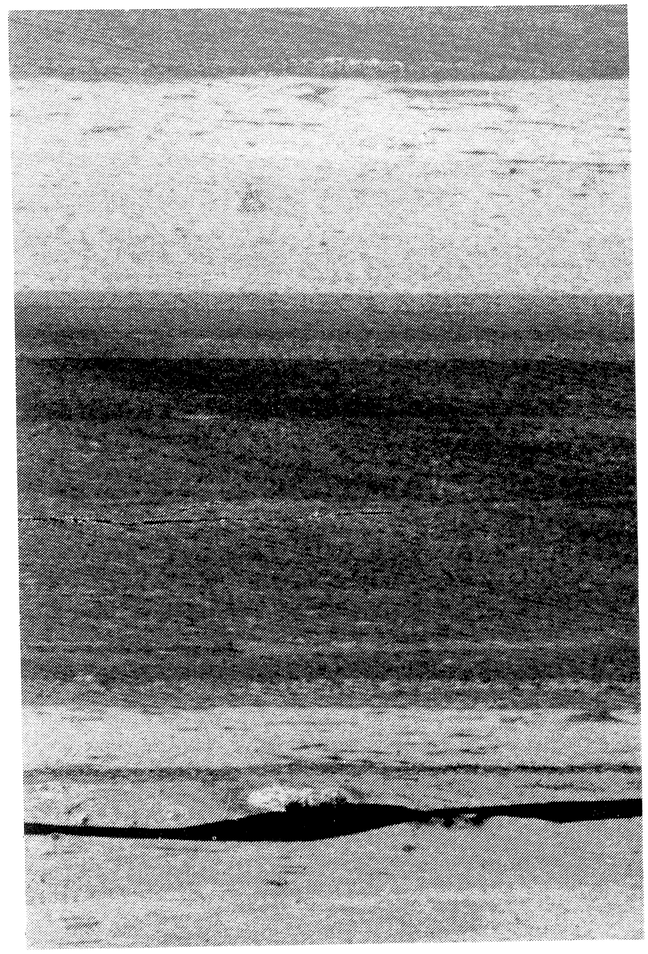


FIGURE 33. Close-up of area outlined on figure 32, showing small dark burrows in upper part of gray shale bands.

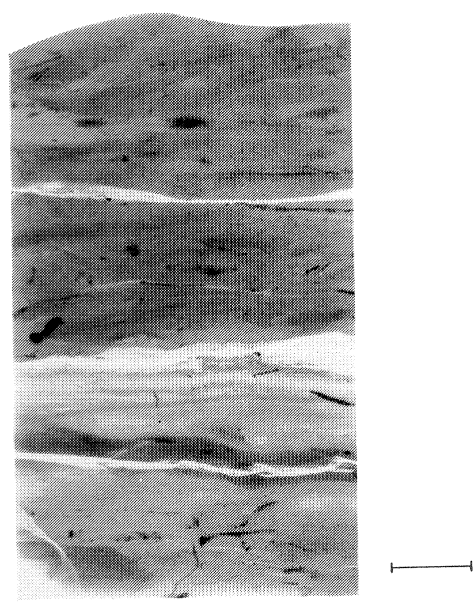
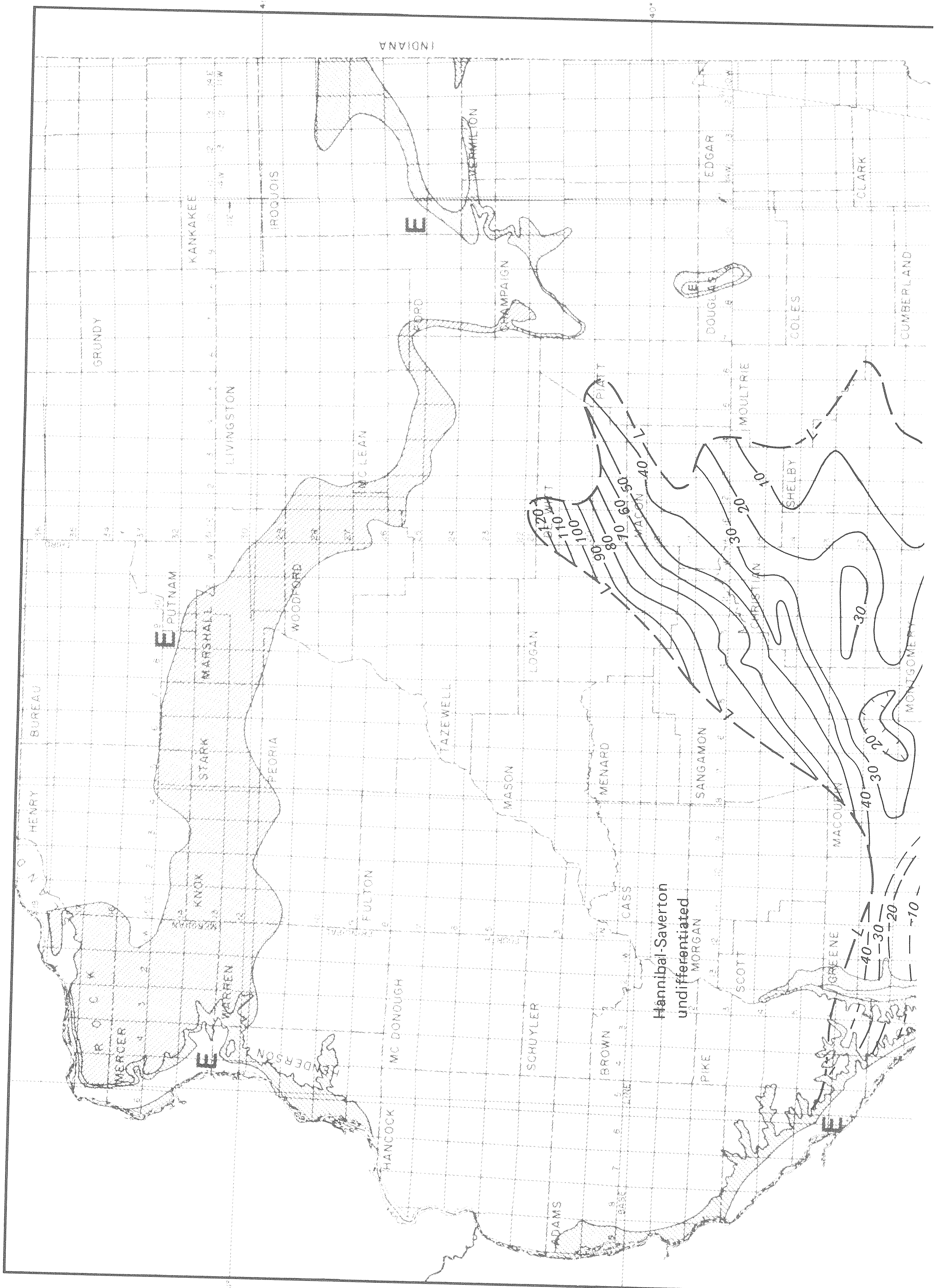


FIGURE 34. Very indistinctly bedded and bioturbated Saverton Shale. Radiograph, G. W. Millar #1 Sample core, 1656.2 ft (sample 1 IL9L2), Sangamon County, Illinois. Bar scale = 1 cm.


Hannibal-Saverton
undifferentiated
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CHRISTIAN
MONTGOMERY
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LOGAN
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WOODFORD
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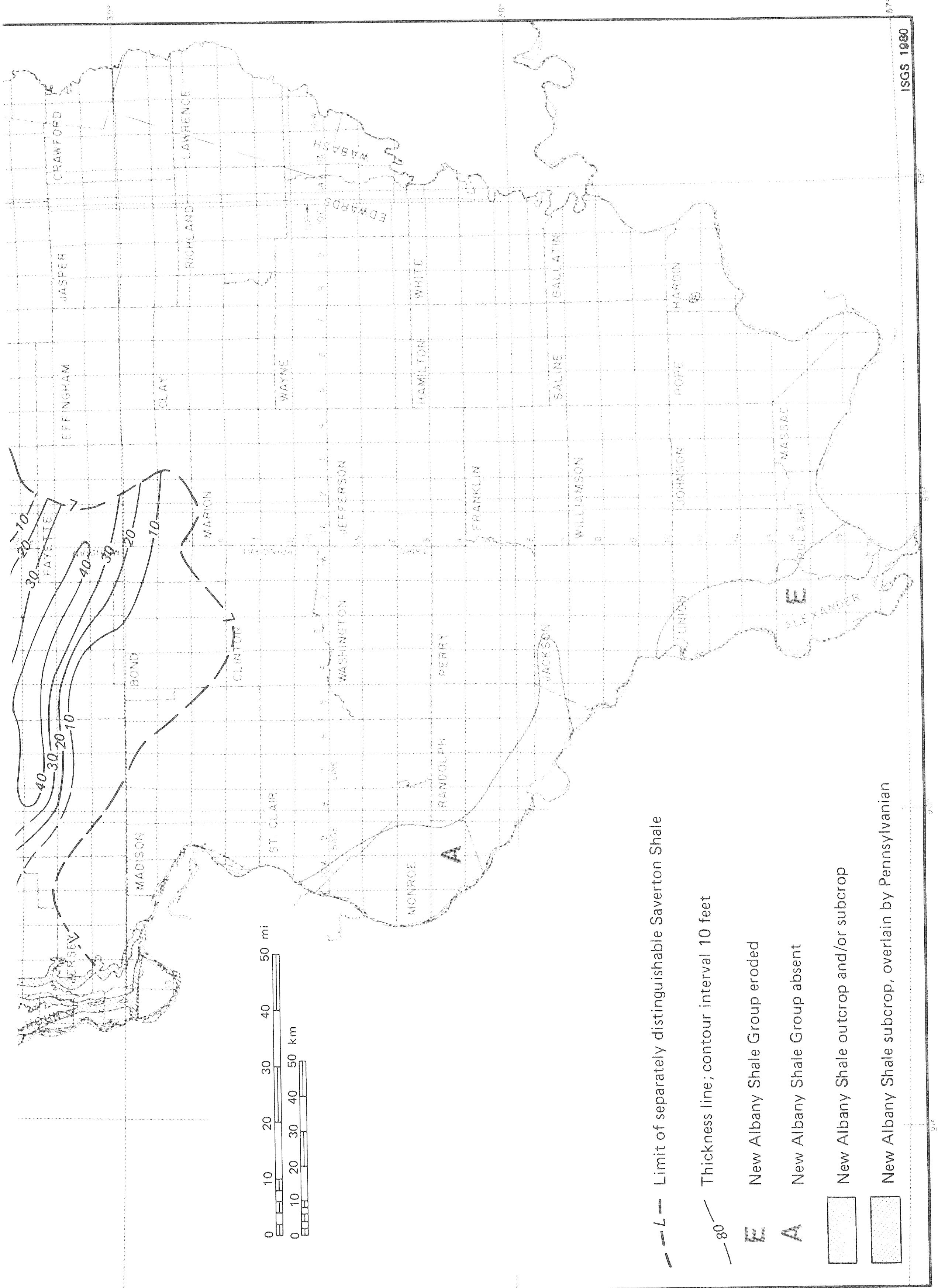
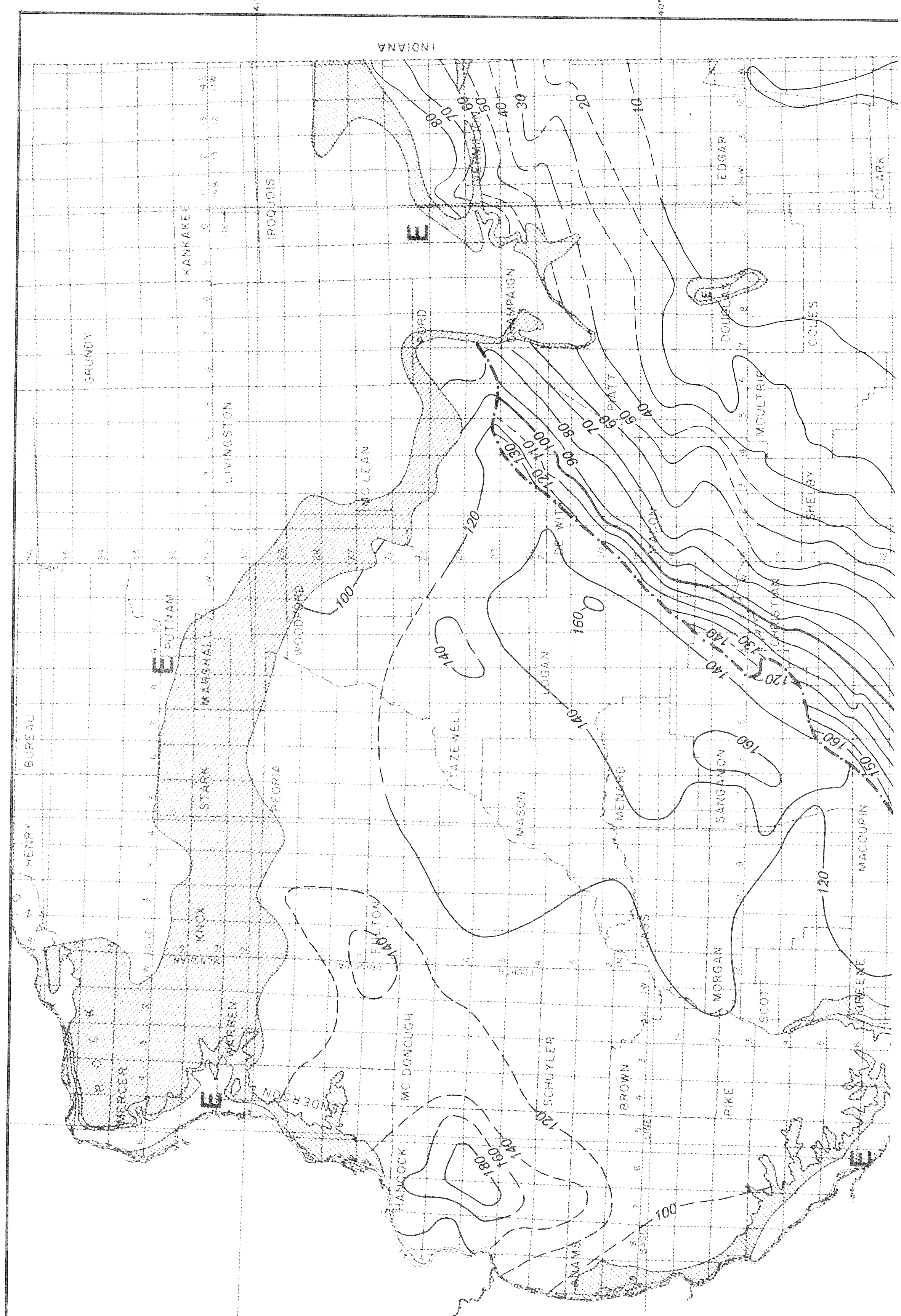


FIGURE 35. Thickness of the Saverton Shale.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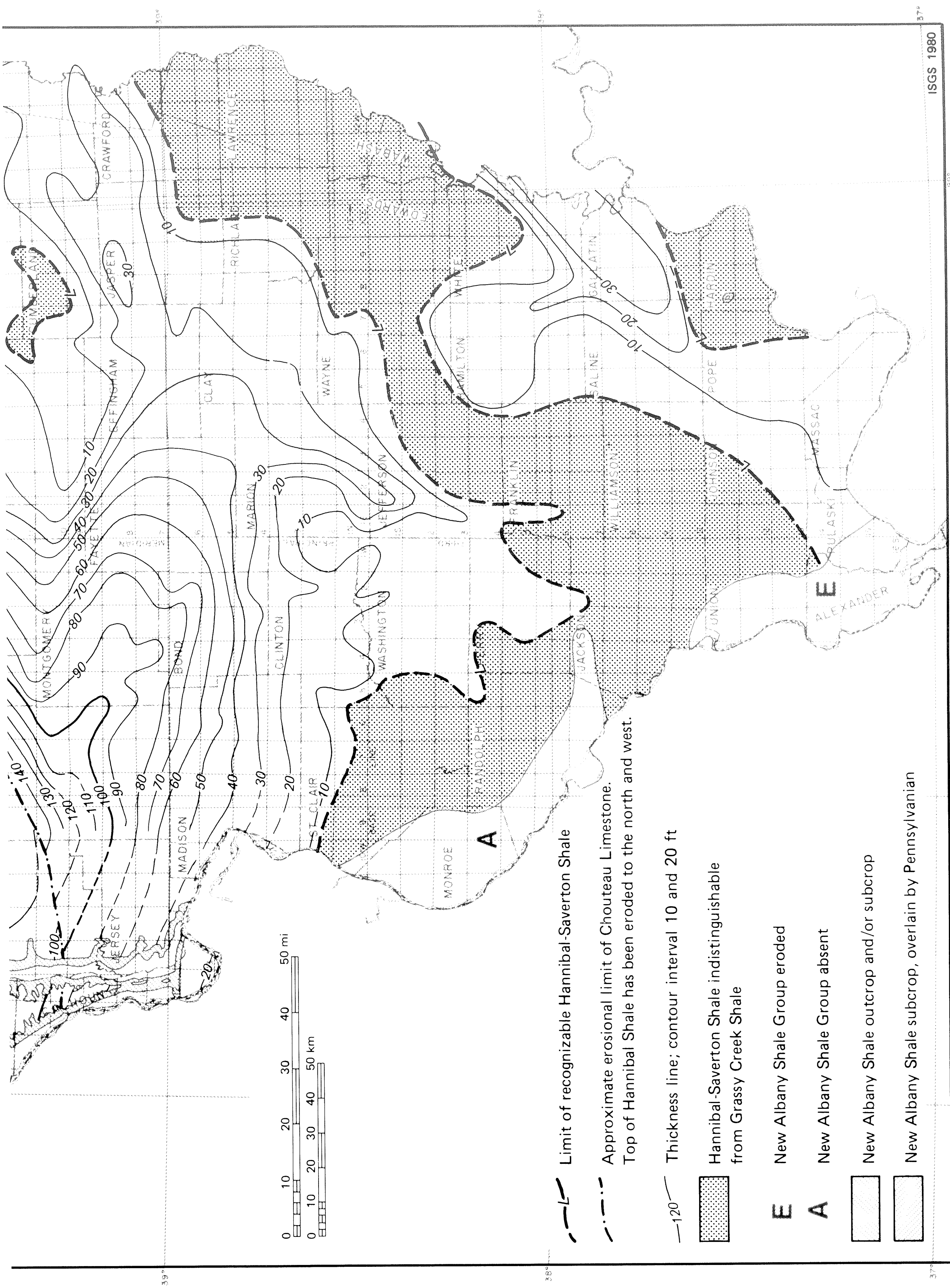


FIGURE 36. Thickness of the Hannibal Shale-Horton Creek Formation-Louisiana Limestone-Saverton Shale undifferentiated.

Geophysical characteristics

Geophysical characteristics typical of the Saverton Shale are illustrated in figure 4. Most noteworthy are the low-resistivity and moderate gamma-ray values typical of the gray to greenish-gray shales (table 2). Where the Lousiana Limestone or limestones of the Horton Creek overlie the Saverton, the top of the Saverton is marked by the sudden increase in resistivity and decrease in gamma-ray response characterisitc of limestones. The gamma ray log generally provides a sharper discrimination between the Saverton and underlying Grassy Creek than does the resisitivity log, although the distinction on the basis of resistivity is generally much more pronounced within the southern depocenter than in central Illinois.

Distribution and thickness

The Saverton Shale is recognized as a distinct, separate formation in central and western Illinois, but has not been mapped separately from the overlying Hannibal Shale where the intervening Louisiana Limestone and Horton Creek Formation are both missing.

The Saverton (as a separate entity) attains its maximum thickness of about 120 feet (37 m) near the northern part of its distribution (fig. 35). From there the formation generally thins to the south and east as the lower portion grades laterally into the Grassy Creek Shale (plate 1, A-F; I-M). In the southern portion of its distribution area, the Saverton thins southward to a feather edge and becomes indistinguishable on the northern edge of the Sparta Shelf (plate 2, J-K; L-M).

Stratigraphic relationships

Because it has so many facies relationships with underlying and overlying formations, the Saverton is perhaps the most difficult of all the New Albany units to correlate regionally. Both the upper and lower boundaries of the formation shift vertically across its area of distribution. The Saverton Shale conformably overlies the Grassy Creek Shale throughout its extent and grades laterally southward and eastward into the upper portion of the Grassy Creek (plate 1, A-F).

Where the Louisiana Limestone is present, it overlies and defines the top of the Saverton Shale; in some places it appears to rapidly grade laterally into the Saverton (plate 2, G-H). Where the Louisiana is absent, the only widely traceable horizon suitable for the top of the Saverton found in this study is the base of the upper limestone in the Horton Creek Formation (the Hamburg Oolite Bed). The silty shales and siltstones between the Louisiana Limestone and Hamburg Oolite Bed, normally assigned to the Horton Creek Formation, are thereby shifted into the Saverton Shale along a vertical cutoff at the limit of the Louisiana Limestone (plate 1, A-F). Where both the Louisiana and Hamburg Oolite are absent, we could not consistently differentiate the Saverton from the overlying Hannibal Shale, and the two were mapped as a single unit (fig. 36). Figure 37 portrays diagrammatically the relationships in this stratigraphically complex area. These definitions of mappable units are essentially the same as those of Workman and Gillette (1956) and Moore (1970).

Age and correlation

The Saverton Shale in the upper Mississippi Valley region has yielded abundant conodonts. On the basis of these faunas, the formation has been shown to range from zone *to*III through zone *to*VI (the uppermost Devonian) and has been inferred to be partly equivalent to the Louisiana Limestone (uppermost Devonian) (Collinson et al., 1967). Where the Louisiana is absent and the top of the Saverton extends to the base of the Hamburg Oolite Bed, still younger beds are probably included in the Saverton. As the Saverton grades laterally eastward into the Grassy Creek, the base of the Saverton becomes younger.

On the basis of biostratigraphic and geophysical evidence, the Saverton correlates to part of the upper portion of the Clegg Creek Member of Indiana (Collinson et al., 1967; Lineback, 1970). Other regional correlations have been shown by Collinson et al. (1967).

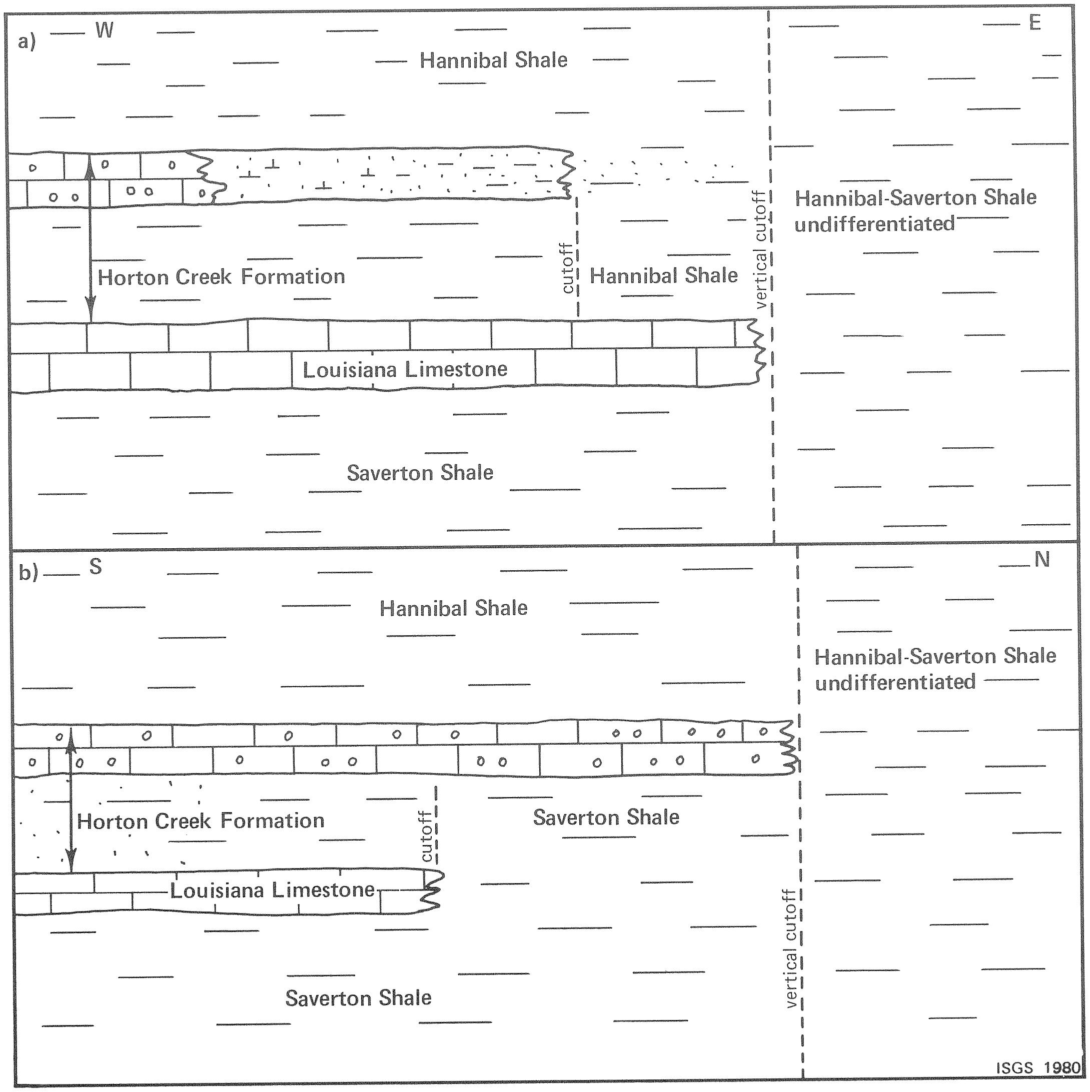


FIGURE 37. Diagrammatic stratigraphic cross sections through the Hannibal-Horton Creek-Louisiana-Saverton interval in the subsurface of western Illinois.

A. East-west cross section in the vicinity of Fayette County. The Louisiana Limestone extends farther east than the limestones and calcareous siltstone at the top of the Horton Creek Formation, which are grading eastward into shales. When the beds at the top of the Horton Creek can no longer be recognized, a vertical cutoff is used to drop the base of the Hannibal Shale to the top of the Louisiana Limestone, the next lower mappable horizon. The stratigraphic interval of the Horton Creek Formation is therefore assigned to the Hannibal Shale east of the cutoff.

B. North-south cross section in Macoupin and Montgomery Counties. In this area the upper limestone bed at the top of the Horton Creek (the Hamburg Oolite Bed) extends farther north than the Louisiana Limestone. When the Louisiana pinches out (or grades into shale) the top of the Saverton Shale is adjusted upward along a vertical cutoff to the base of the Hamburg Oolite Bed, the next higher mappable horizon. The stratigraphic interval of the lower part of the Horton Creek is therefore assigned to the Saverton Shale north of this cutoff. Because of the differing lateral extent of the two main carbonate beds within the New Albany Shale (the Louisiana Limestone and the Hamburg Oolite bed) the body of siltstones and shales between the two beds are in some areas assigned to the Horton Creek (where both beds are present), in some areas to the Saverton Shale (where only the upper bed is present), and in some areas to the Hannibal Shale (where only the lower bed is present). Where neither carbonate bed is present the Hannibal and Saverton Shales cannot be practically nor consistently separated and they are mapped together as an undifferentiated unit.

The Louisiana Limestone (Keyes, 1892) is named for the town of Louisiana, Pike County, Missouri, where it is well exposed in the bluffs along the Mississippi River. Although no specific type section has been designated, a prominent exposure on the south side of the town of Louisiana is generally accepted as the type section (Collinson and Atherton, 1975).

Lithology

The Louisiana Limestone is a light gray to tan, wavy-bedded, micritic limestone interbedded with thin shales and dolomites. In surface exposures the limestone is often very pure carbonate with little insoluble residue and is texturally very homogeneous, hence it is commonly termed "lithographic limestone." The dolomite interbeds are often laminated, however, and in many areas the limestone appears faintly mottled with burrows. Subsurface samples of the Louisiana are also very fine-grained micritic limestones; they are, however, often argillaceous and are always extensively bioturbated (fig. 38).

Invertebrate fossils are present but generally rare in the Louisiana. The fauna is dominated by very small brachiopods and dwarf crinoids. Rare bryozoans, ostracodes, sponges, rugose and tabulate corals, pelecypods, gastropods, cephalopods, trilobites, and conodonts have also been found (Williams, 1943).

Geophysical characteristics

The Louisiana Limestone is identified by its moderate to high resistivity, or by low gamma-ray value where gamma-ray logs are available (fig. 4). A thin zone of relatively high bulk density and sonic velocity persists beyond the geographic area where the Louisiana can definitely be identified (plate 1, D-F, Fayette County well #1748 and Marion County well #5712). This zone appears to mark the stratigraphic position of the Louisiana.

Distribution and thickness

In Illinois the Louisiana Limestone occurs in an east-west elongated tongue across the southwest central portion of the state (fig. 39). Outcrops occur in the Illinois and Mississippi River valleys. In this subsurface study, the Louisiana is recognized as a mappable formation where it can be distinguished on geophysical logs or in sample studies from the overlying Horton Creek Formation. In this study the Louisiana was mapped over a wider area than that mapped by Workman and Gillette (1956). Moore (1970) shows the Louisiana as even more extensive, especially northeastward into Christian and Shelby Counties. Although we do not necessarily disagree with Moore's interpretation, we feel that the Louisiana is not unequivocally distinguishable from the limestone in the Horton Creek Formation in this northeastern area.

Although the Louisiana is more than 70 feet (21 m) thick near Hannibal, Missouri, its maximum thickness (remaining after erosion) in Illinois is about 30 feet (9 m) in the area of the Pike-Calhoun County line. Throughout most of its extent eastward into Illinois, the Louisiana is less than 10 feet (3 m) thick (fig. 39). Evidence from physical correlations suggests that the thin Louisiana in the subsurface of Illinois is a limestone tongue equivalent only to the middle portion of the thick Louisiana along the Mississippi River.

Workman and Gillette (1956) and Moore (1970) mapped the Louisiana Limestone in the area of the Mississippi River floodplain in Pike County, Illinois. Devonian and younger rocks, however, have been eroded from most of this area (Willman et al., 1967) and the thicknesses mapped by previous workers are extrapolative.

Stratigraphic relationships

The Louisiana Limestone conformably overlies and laterally intergrades with the Saverton Shale. In certain small areas

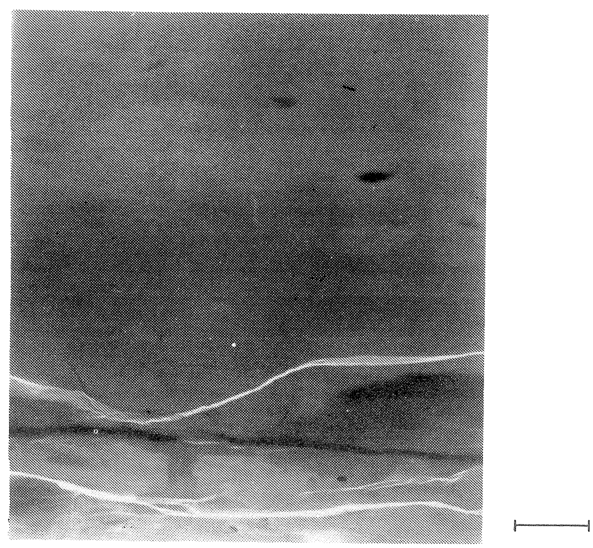


FIGURE 38. Bioturbated micritic limestone. Louisiana Limestone; radiograph, Benedum Trees #1 Van Zant core, 2773.0 ft (sample 7IL2L2), Fayette County, Illinois. Bar scale = 1 cm.

(notably Jersey County and vicinity) where the Saverton is absent or perhaps very thin and unrecognizable, the Louisiana directly overlies the Grassy Creek Shale.

Throughout much of its extent in western Illinois, the Louisiana is overlain by the Horton Creek Formation. Where the contact is exposed in western Illinois, it is typically a channeled and eroded surface. Studies of the conodont fauna suggest that the hiatus between Louisiana and Horton Creek deposition was brief; the unconformity is believed to be only locally significant along the flanks of the Lincoln Anticline (Collinson and Atherton, 1975). We have found no evidence in the subsurface of Illinois for a significant regional unconformity.

In its type area along the Mississippi River, the thick Louisiana Limestone is commonly overlain directly by the Hannibal Shale. Although some evidence has been cited for a disconformity between the two formations (Keonig et al., 1961; Sandberg et al., 1972), Collinson (1979, personal communication) suggests that there is no substantial faunal hiatus between the two formations.

In the present study, lines of physical evidence, including regional thickness relationships, stratigraphic position, and lithologic similarity, suggest that the upper part of the type Louisiana Limestone grades laterally into the Horton Creek Formation (Reinbold, 1979; manuscript in review).

Age and correlation

The Louisiana Limestone fauna was considered Mississippian by Williams (1943) on the basis of megafauna. Scott and Collinson (1961) subsequently studied the conodont fauna and concluded that the formation is of latest Devonian age. Collinson et al. (1967) believe the Louisiana correlates with *to*V and *to*VI zones of the European standard cephalopod zonation. In the subsurface of Illinois the thin tongue of Louisiana Limestone mapped in this study is probably correlative with only a portion of the type Louisiana Limestone.

The Louisiana is considered correlative in age with part of the Clegg Creek Member of the New Albany Shale in Indiana. Although a greenish-gray shale bed lying below the Falling Run Bed in Jackson County, Indiana, has yielded no conodonts, its brachiopod fauna is similar to that of the Louisiana (Lineback, 1970).

HORTON CREEK FORMATION

The name Horton Creek was proposed by Conkin and Conkin (1973) for the limestones, siltstones, sandstones, and shales previously included in the "Glen Park" Formation in Illinois. Conkin and Conkin designated the Horton Creek as the basal member of the Hannibal Shale in western Illinois. However, in order to remain consistent with the established stratigraphic nomenclature for the New Albany Shale Group in Illinois, the Illinois State Geological Survey elevates the Horton Creek to formation rank and leaves the Hannibal Shale as defined by Atherton et al. (1975). In this report, the term Horton Creek Formation is used essentially as it was first used by the Survey by Collinson et al. (1979). The Horton Creek Formation is the same as the "Glen Park" Formation described by Atherton et al. (1975).

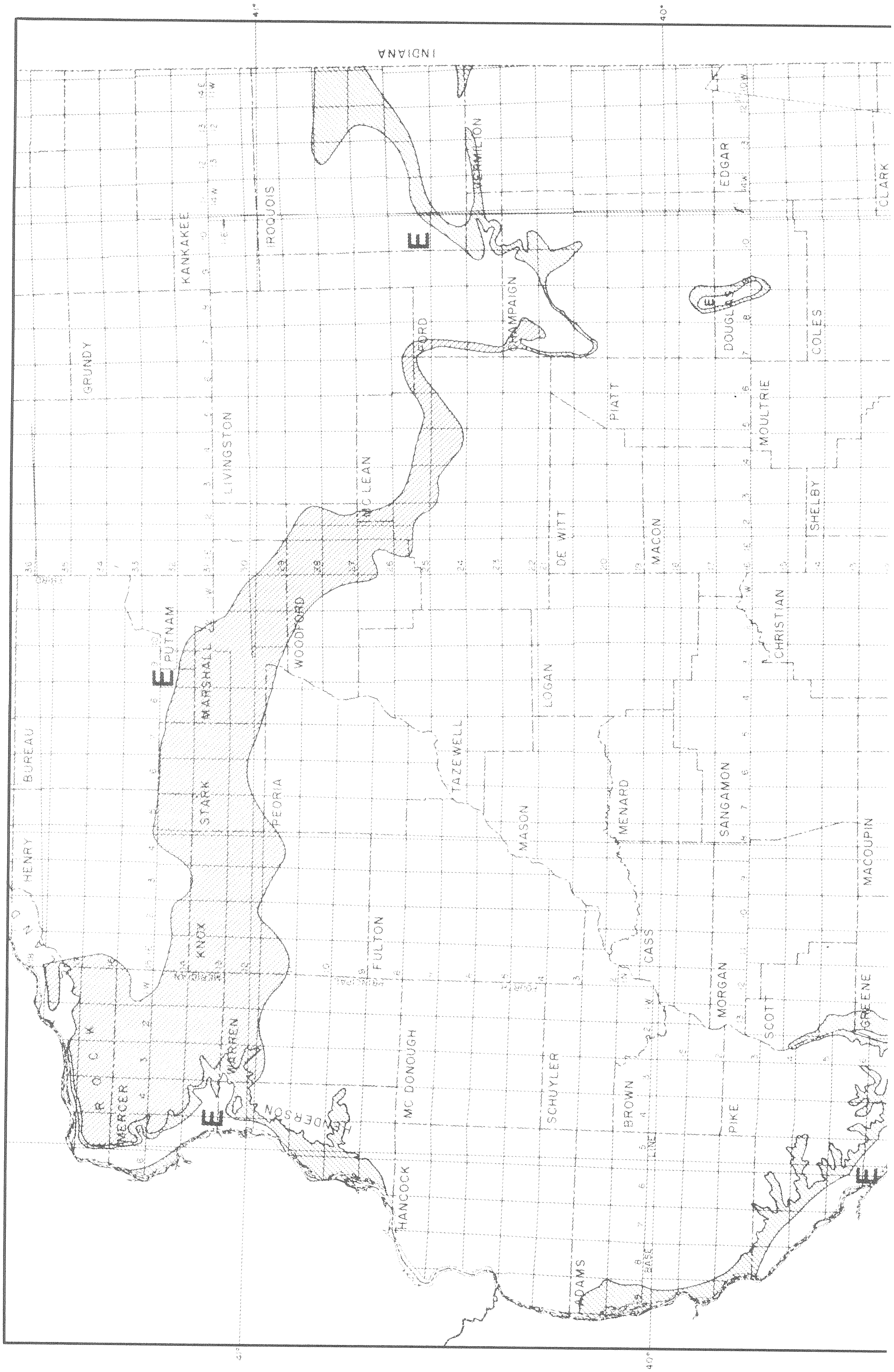
The type section designated for the Horton Creek Formation by Conkin and Conkin (1973) is in the south bank of Horton Creek, Sec. 6, T. 6 S., R. 5 W., Pike County, Illinois. The Horton Creek type section is poorly exposed and may not endure, but sections in nearby creeks may supplement the designated type section (Collinson, 1979, personal communication). The exposures in Gresham Hollow near Hamburg (Sec. 1, T. 10 S., R. 3 W.) are especially good (Workman and Gillette, 1956).

Stuart Weller (1914) applied the name Hamburg Oolite to exposures of oolitic limestone at Hamburg, Calhoun County, Illinois. In this report the name Hamburg Oolite Bed identifies the distinctive oolitic limestone near the top of the Horton Creek Formation. Weller considered the Hamburg Oolite to be younger than the Glen Park Formation of Missouri, but Moore (1928) redefined the Glen Park to include the Hamburg strata. Scott and Collinson (1961) reported that conodont studies showed the presumed Glen Park strata in Illinois to be substantially younger (lowermost Mississippian) than the type Glen Park in Jefferson County, Missouri (middle Upper Devonian). Collinson (1961) therefore referred to the Illinois strata as the "Glen Park" Formation, intending to introduce a new name for these strata at a later date. Although the name "Gresham Formation" has received some informal usage at the Illinois State Geological Survey, it was never formally proposed in any publication and "Glen Park" has remained in widespread general usage until the present time.

Lithology

The Horton Creek Formation is a lithologically complex unit consisting of siltstones, shales, sandy limestones, micritic limestones and dolomites, limestone conglomerates, and oolitic limestones.

The siltstones and shales in the Horton Creek are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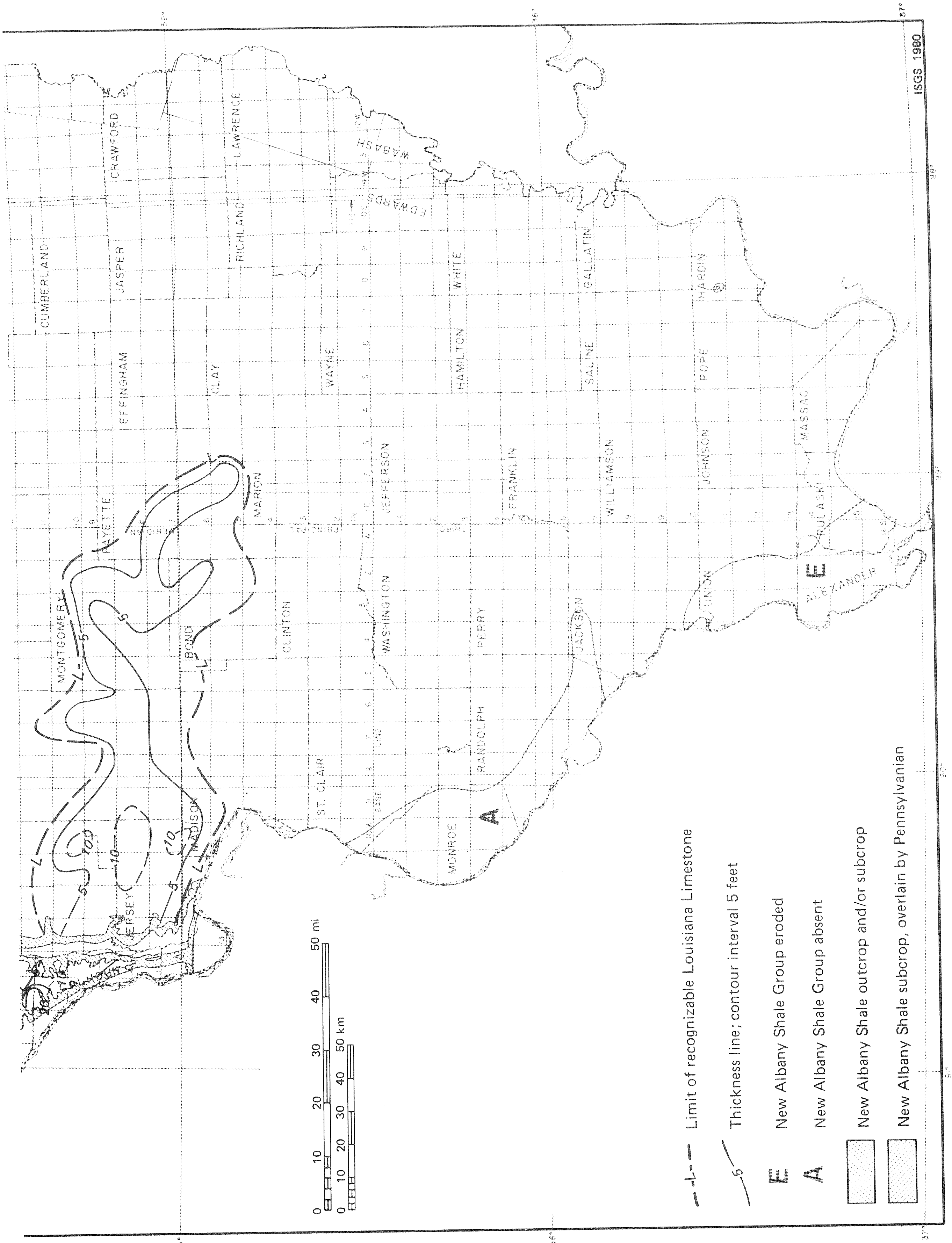


FIGURE 39. Thickness of the Louisiana Limestone.

similar to the Hannibal and upper Saverton Shales. They are greenish-gray (5GY5/1) to dark greenish-gray (5GY4/1), highly bioturbated, generally unfossiliferous, and commonly calcareous. In many areas the shales are very silty and thin beds of siltstone are common.

The most widespread carbonate lithology in the Horton Creek is gray to tan, argillaceous, sparsely fossiliferous micritc limestone and dolomite similar to the Louisiana Limestone (fig. 40). These carbonate mudstones and wackestones are present throughout the extent of the Horton Creek and constitute the sole carbonate lithology observed towards the southern and eastern limits of the formation.

Oolitic limestones are also common in the Horton Creek, especially in the upper part. The Hamburg Oolite Bed, a widespread and distinctive oolitic limestone generally near the top of the Horton Creek, is discontinuously present over a wide area of central Illinois and has been used to differentiate limestones in the Horton Creek from the Louisiana Limestone in the subsurface (Workman and Gillette, 1956; Moore, 1970). As mapped by Workman and Gillette (1956, fig. 9) on the basis of sample studies, the oolitic limestone is present mainly as a northeast trending belt across the northern portion of the formation's extent. This oolitic facies belt parallels and trends along the northern edge of the central thin (fig. 6). Exposures of oolitic limestones in the Horton Creek in extreme western Illinois and eastern Missouri are cross-bedded biocalcarenites containing abundant coarse-grained skeletal fragments of brachiopods, bryozoans, crinoids, gastropods, and bivalves. Rounded intraclasts of calcareous siltstone and silty micrite are common.

At Jimtown Hollow in Pike County, Illinois the Horton Creek contains an oolitic limestone conglomerate bed about 2 meters thick (Workman and Gillette, 1956; Collinson, 1961). This bed contains abundant clasts of lithographic micrite ranging from a few millimeters to several centimeters in diameter. The pebbles are well-rounded and poorly sorted, and are often warped or bent around their nearest neighbors (fig. 41). The pebbles are lithologically identical to the Louisiana Limestone, suggesting that they were derived from erosion of Louisiana exposures, and their deformation further suggests that they were only partially lithified when this bed was deposited. The pebbles form a grain-supported fabric and the intervening spaces are filled with sand-sized micrite clasts, oolites, and sparry calcite cement.

Geophysical characteristics

The geophysical properties of the Horton Creek Formation reflect the variability of its lithologic composition. The "complete" section of Horton Creek (fig. 4) consists of a lower siltstone and upper oolitic limestone unit. A negative SP deflection, and a substantial negative deflection in gamma-ray values typically encompass Louisiana Limestone. Electrical resistivity of the Horton Creek is generally low to moderate for siltstone portions and moderate to high for the upper limestone unit.

In areas where only one limestone (the Louisiana or the upper unit of the Horton Creek) is present, there may be confusion in distinguishing the two geophysically; even in sample studies or cores, the two limestones may appear very similar in lithology. The presence of oolites is generally accepted as characteristic of the limestones in the Horton Creek. In a few wells, however, sample studies suggest that the lower limestone bed (Louisiana) may also contain oolites.

Distribution and thickness

The Horton Creek Formation is distinguished as a separate formation in parts of central and west-central Illinois (fig. 42). The formation attains a maximum thickness of more than 60 feet (18 m) in the southeastern portion of its distribution area, where it consists mostly of siltstone. Beyond the area of limestones in the Horton Creek, the siltstone and shale cannot be separated from the Hannibal-Saverton Shale, and a vertical cutoff therefore marks the limit of the formation. Beyond the northern limit of the Louisiana Limestone (fig. 39) the siltstones and shales of the lower part of the Horton Creek cannot be separated from the Saverton Shale; as previously noted, they are therefore mapped as part of the Saverton, and the Horton Creek thickness is restricted essentially to the upper limestone unit (fig. 37).

Workman and Gillette (1956) mapped a relatively thick siltstone unit above the Hamburg Oolite Bed as part of their Glen Park Formation. This accounts for the thick arcuate bar-like body shown along the northwestern edge of the Glen Park occurrence in their thickness map. In the present study, concurring with Moore (1970) and Atherton et al. (1975), we consider this siltstone body to be part of the Hannibal Shale.

Stratigraphic relationships

Where the Horton Creek Formation crops out in western Illinois, it lies unconformably on the Louisiana Limestone, and as previously noted, this unconformity is believed to be of short duration and relatively local. Beyond the limit of the Louisiana the Horton Creek rests on the Saverton Shale or, in the vicinity of Madison and St. Clair Counties, on the Grassy Creek Shale.

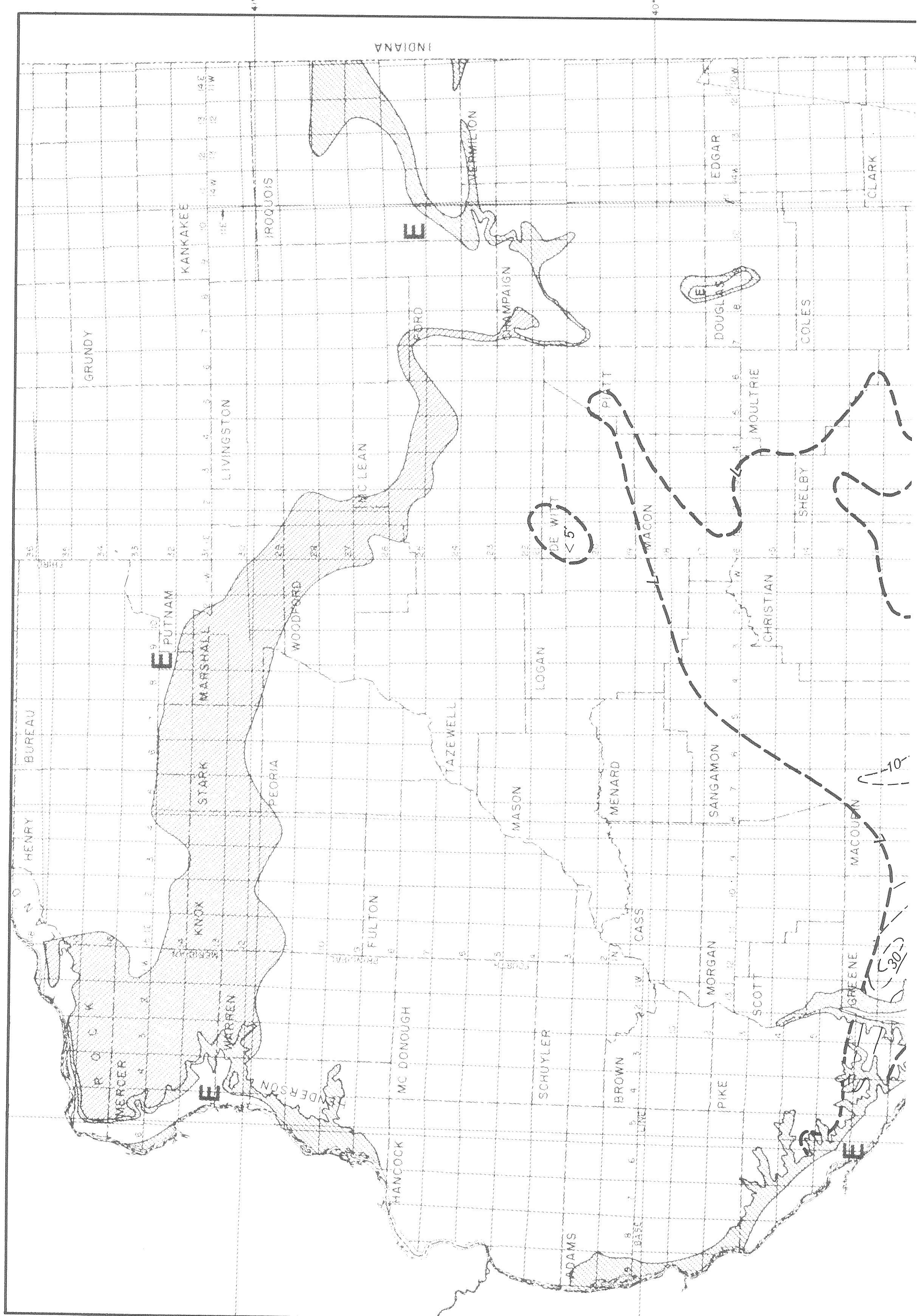
In the subsurface, the Horton Creek grades laterally eastward into the lower portion of the Hannibal Shale and ultimately becomes undifferentiable from the Hannibal (plate 2, J-K). In the northern portion of the Horton Creek occurrence, the mappable formation is restricted to only the upper limestone bed. Below the limestone are silty shales, assigned to the Saverton Shale, that are probably equivalent to the siltstone in the Horton Creek farther south where the intervening Louisiana Limestone separates them from the Saverton below (fig. 37). The limestone in the Horton Creek thins to the north and eventually pinches out in the Hannibal-Saverton interval. In the western Illinois outcrop area, the Horton Creek generally appears to grade laterally into the upper portions of the thick type Louisiana Limestone and Saverton Shale.

Age and correlation

Biostratigraphic (mainly conodont) studies of the Horton Creek outcrops summarized by Collinson et al. (1971) and Collinson et al. (1979) have suggested that the formation is entirely Mississippian and that the base coincides with the Devonian-Mississippian boundary. The age relationships in the subsurface of Illinois beyond the area of biostratigraphic control remain problematic. Physical stratigraphic evidence collected in this study suggests that part or all the shales and siltstones between the thin Louisiana Limestone and Hamburg Oolite Bed, assigned in this and previous studies to the Horton Creek ("Glen Park") Formation, are lateral

FIGURE 40. Bioturbated, argillaceous, fossilliferous, micritic limestone in the Horton Creek Formation. Light band near the top of the sample is a thin interbedded greenish-gray shale. Radiograph, G. W. Millar #1 Sample core, 1633.9 ft (sample 11L7L2), Sangamon County, Illinois. Bar scale = 1 cm.

FIGURE 41. Rounded micrite pebble conglomerate with abundant oolites between pebbles. Horton Creek Formation; polished slab, sample NAS-012, Jimtown Branch Section, Pike County, Illinois. Bar scale = 1 cm.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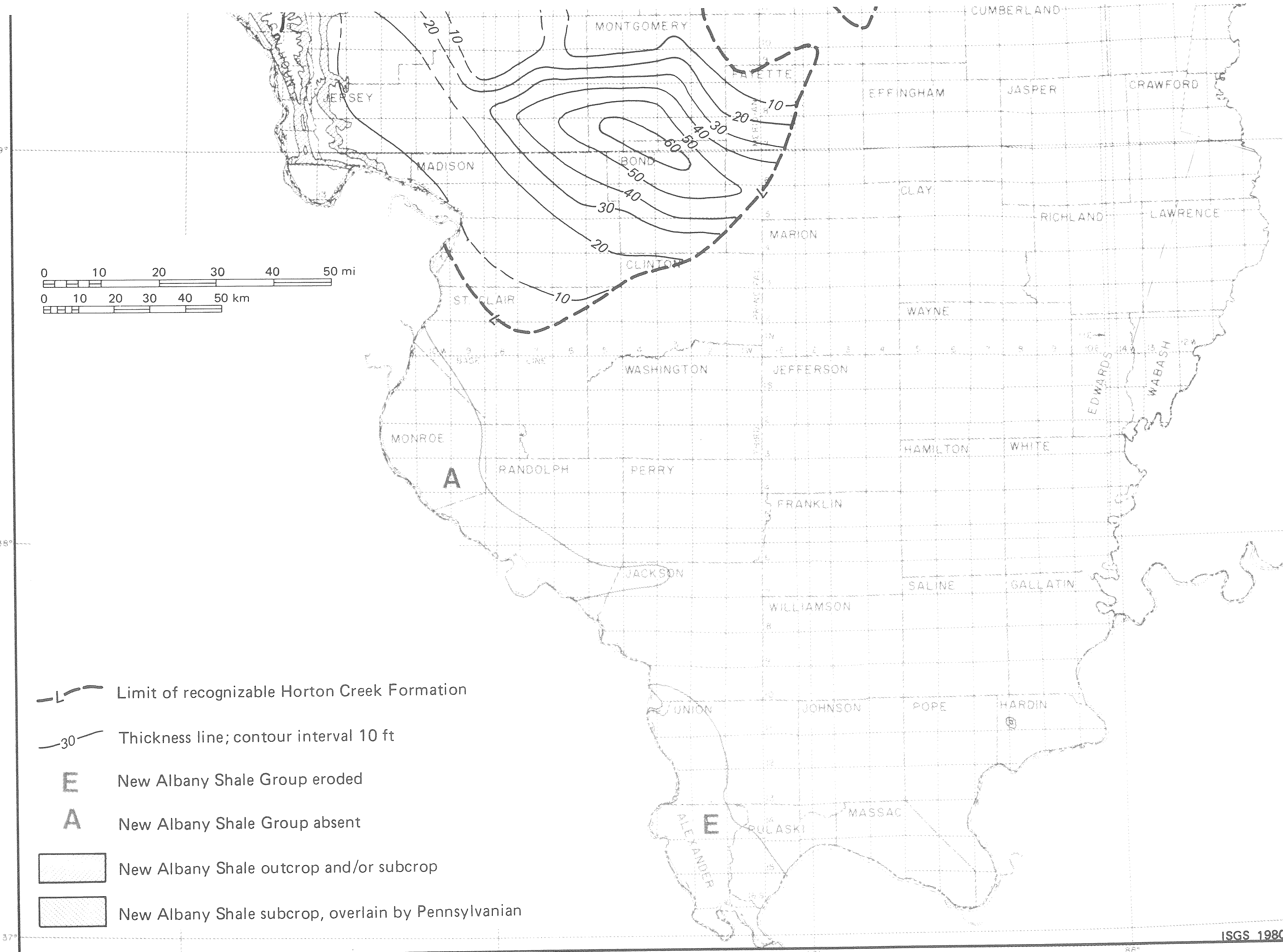


FIGURE 42. Thickness of the Horton Creek Formation.

facies equivalents of the upper part of the type Louisiana Limestone and the upper part of the Saverton Shale (both Devonian). Charles Sandberg (1979, personal communication) generally agrees with this interpretation, suggesting that conodont evidence supports a latest Devonian age assignment for the type Horton Creek and perhaps most of the other strata assigned to the Horton Creek. Gilbert Klapper (1979, personal communication), also citing conodont evidence, reaffirms an earliest Mississippian age assignment for the oolitic limestone bed immediately overlying the Louisiana Limestone at Starks Roadcut (plate 2, G-H) at Louisiana, Missouri. The bed is probably correlative to the Hamburg Oolite Bed in Illinois. It appears, therefore, that strata assigned to the Horton Creek may very well be Devonian or may straddle the Devonian-Mississippian boundary.

HANNIBAL SHALE

The Hannibal Shale (Keyes, 1892) is named for exposures in the Mississippi River bluffs at the city of Hannibal in Marion County, Missouri. Workman and Gillette (1956) classified the Hannibal as a group, and in western Illinois they subdivided it into the Glen Park Formation (Ulrich, 1904), Maple Mill Formation (Bain, 1895), and English River Formation (Bain, 1895). The Hannibal Shale was returned to formation status by Collinson (1961).

Lithology

The Hannibal Shale consists of dark greenish-gray (5GY4/1, 5G4/1), greenish-gray (5GY6/1, 5G6/1), grayish olive-green (5GY3/2), and dusky yellow-green (5GY5/2) mudstones and shales. Their organic carbon content is usually very low (<1%).

The clay composition of the Hannibal is predominantly illite and chlorite, with minor expandable mixed structure clays. Kaolinite has not been detected in any samples of the Hannibal or undifferentiated Hannibal-Saverton. The silt content of the Hannibal is variable but generally high. Most of the mudstones are moderately silty clay shales; however, argillaceous siltstone beds are locally prominent, especially in the upper portion of the formation. The silt fraction is predominantly quartz, potassium feldspars, dolomite, and coarse grained micas. Calcareous mudstones are found only near the limestones in the Horton Creek or Lousiana and probably grade laterally into the limestone. Pyrite is a minor component of these mudstones and is mainly present as burrow fillings.

The mudstones of the Hannibal Shale are highly bioturbated, with no lamination, bedding, or primary sedimentary structures (figs. 43, 44). The Hannibal was originally known as the "Vermicular sandstone and shales" because of the abundance of burrows. Although most trace fossils are too indistinct to be identified in core samples, *Planolites, Scalarituba missouriensis,* and *Zoophycos (Taonurus) caudagalli* are common on weathered outcrop samples.

A thin olive-black shale (the Nutwood Member) present in the Hannibal was mapped across a portion of western Illinois by Workman and Gillette (1956). They described the Nutwood as a dark brown to black, slightly silty, fissile shale with abundant *Tasmanites.* Because of a lack of suitable samples we have not examined the Nutwood in detail in this study.

Geophysical characteristics

Because the Hannibal Shale varies considerably in composition and thickness across Illinois, it is difficult to choose a specific reference set of geophysical logs typical of the formation. Figure 4 illustrates geophysical characteristics somewhat typical of the Hannibal in central Illinois, where

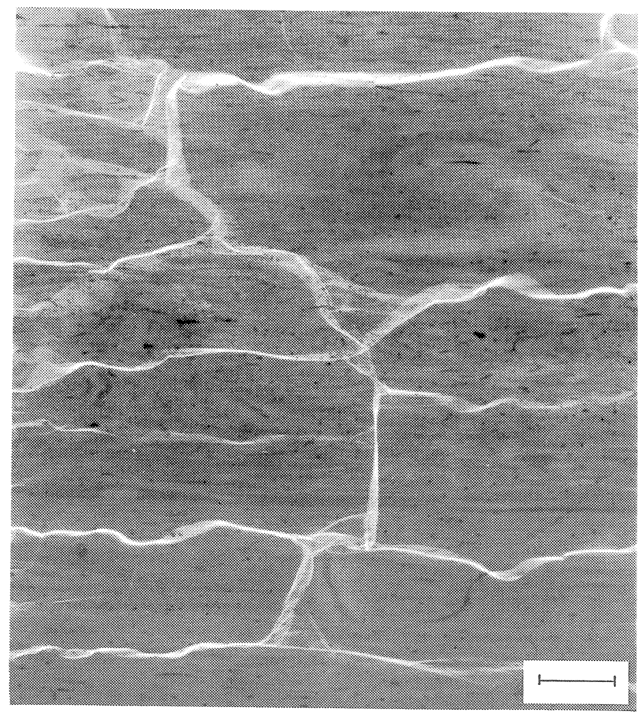


FIGURE 43. Bioturbated and very indistinctly bedded Hannibal-Saverton Shale (high in section, probably Hannibal equivalent). Many of the burrows are silty and lightly pyritized at the center (see lower portion of slab). Radiograph, Northern Illinois Gas #1 RAR core, 383.4 ft (sample 4IL7C1), Henderson County, Illinois. Bar scale = 1 cm.

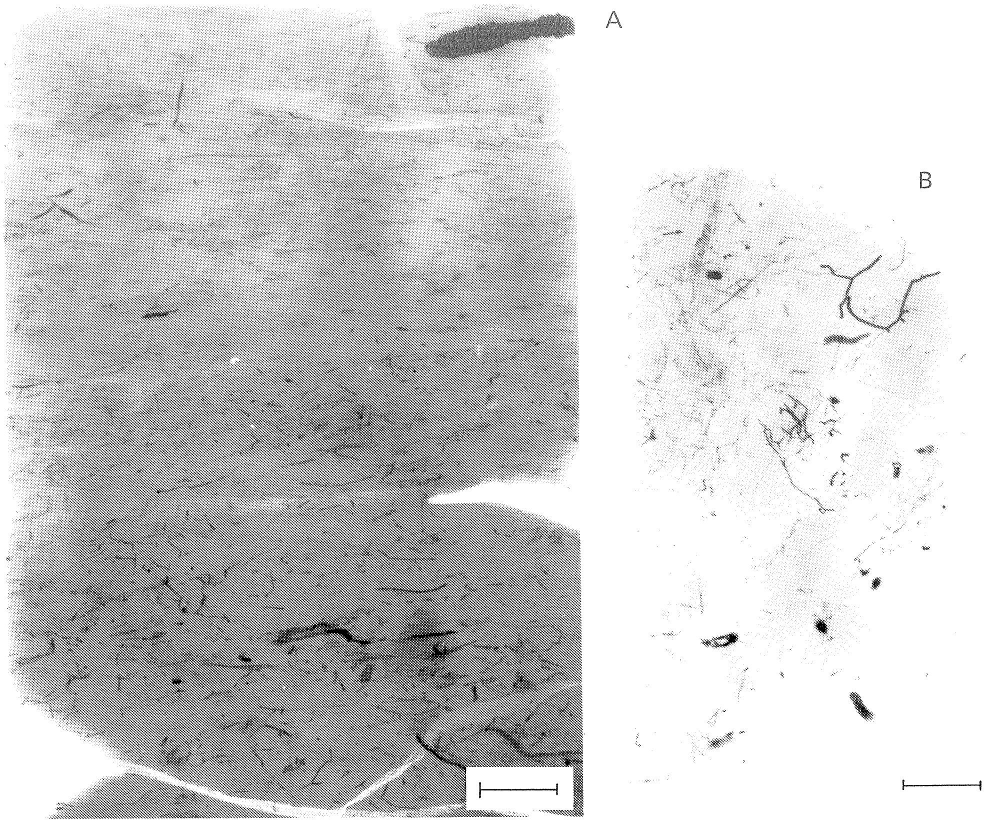


FIGURE 44. Highly bioturbated Hannibal-Saverton Shale with abundant small pyritic burrows. A. Vertically oriented slab, large pyrite filled burrow in upper right corner and abundant compressed microburrows. B. Horizontal slab (parallel to bedding) with several short, branching pyritic burrows. The average burrow diameter is about 0.1 mm. Radiograph, Northern Illinois Gas #1 MAK core, 962.2 ft (sample 6IL7C1), Tazewell County, Illinois. Bar scale = 1 cm.

it is predominantly greenish-gray mudstone with some silty and calcareous portions (table 2).

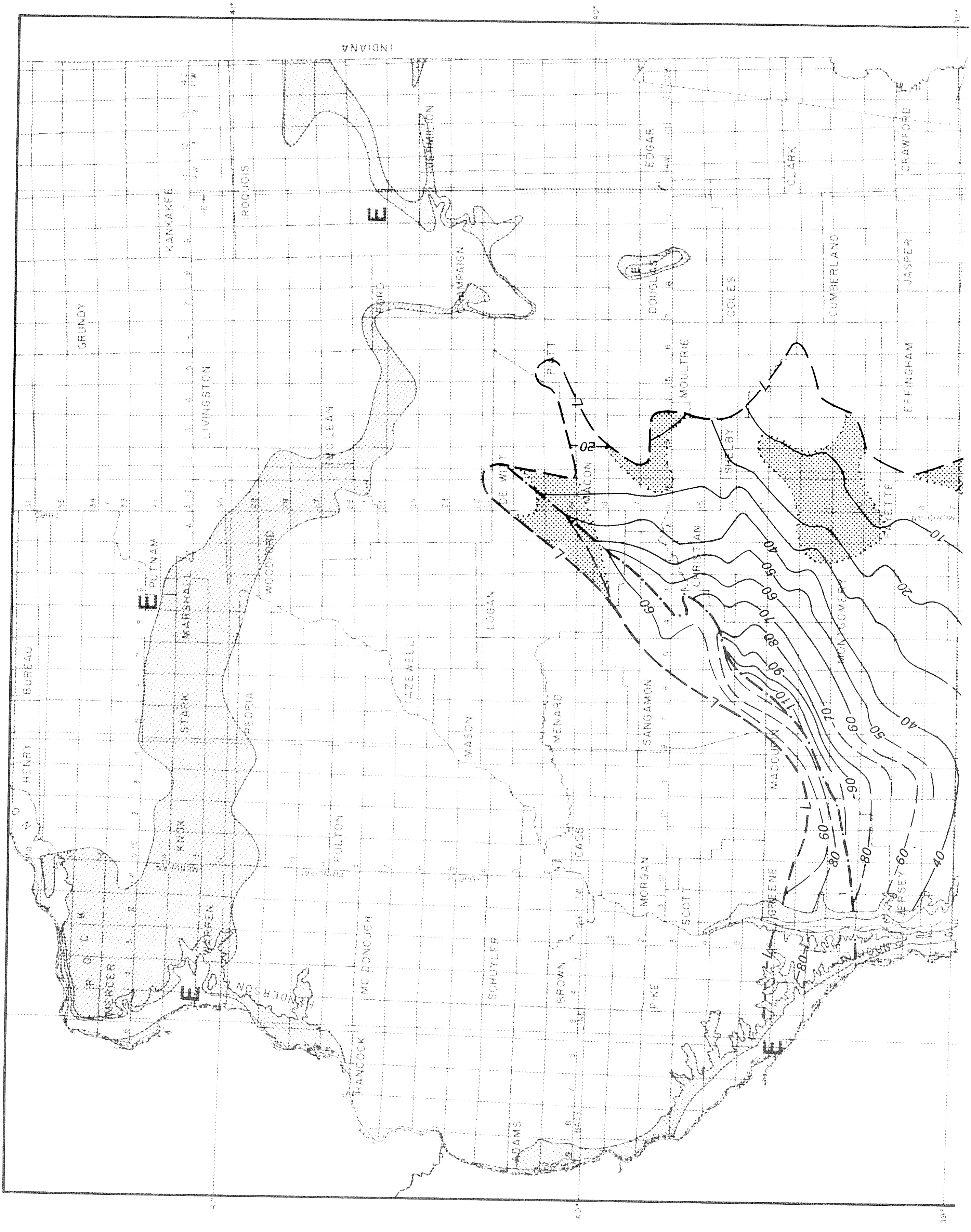
The Nutwood Member, an olive-black shale, exhibits characteristics somewhat subdued in comparison with other black shales in the New Albany. The resistivity is only modestly higher than that of the greenish-gray shale and the gamma-ray increase is also generally small-to-moderate. The Nutwood was not mapped as a separate unit in this study. Workman and Gillette (1956, fig. 11) mapped the thickness and extent of the Nutwood on the basis of subsurface sample studies.

In the southern depocenter, the Hannibal exhibits geophysical characteristics indicating that it is greenish-gray to olive-black shale. In some areas the Hannibal-Saverton Shale is indistinguishable from the underlying Grassy Creek Shale on the basis of electrical resistivity, density, or sonic velocity (figs. 3, 30); however, a variable but relatively low-value gamma-ray interval is commonly present beneath the Chouteau Limestone. This interval, approximately the top 35 feet (11 m) of New Albany in figure 3, appears to be essentially correlative with the Hannibal-Saverton Shale (plates 1, A-F; 2, L-M).

A thin black shale bed that we have correlated with the Henryville Bed of Indiana occurs near the top of the Hannibal-Saverton Shale across much of the southeastern Illinois depocenter (fig. 29; appendixes 8, 9). This thin bed has a very high gamma ray value, low density, and low sonic velocity; the electrical resistivity is also very high. Because this bed is difficult to separate from the overlying Chouteau Limestone on resistivity logs, the Chouteau's thickness may have been overestimated in some previous studies.

Distribution and thickness

The Hannibal Shale is mapped as a separate formation in parts of central and west-central Illinois. The Hannibal is thickest, more than 110 feet (34 m) in northeastern Macoupin County, immediately to the southeast of the limit of erosional truncation by the Burlington Limestone (fig. 45). North and west of this line the Hannibal thins rapidly but somewhat erratically as a result of the erosion. The Hannibal generally thins toward the southeast (presumably away from its source area); however, it thickens locally where the Horton Creek Formation is not separately distinguishable and is consequently combined with the Hannibal.


INDIANA
VERMILION
EDGAR
CLARK
CRAWFORD
IROQUOIS
KANKAKEE
CHAMPAIGN
DOUGLAS
COLES
CUMBERLAND
JASPER
GRUNDY
FORD
LIVINGSTON
PIATT
MOULTRIE
EFFINGHAM
MC LEAN
DE WITT
MACON
SHELBY
CHRISTIAN
PUTNAM
MARSHALL
WOODFORD
LOGAN
BUREAU
TAZEWELL
SANGAMON
MONTGOMERY
STARK
PEORIA
MASON
MENARD
HENRY
KNOX
FULTON
CASS
MORGAN
MACOUPIN
GREENE
SCOTT
JERSEY
MERCER
WARREN
HENDERSON
MC DONOUGH
SCHUYLER
BROWN
PIKE
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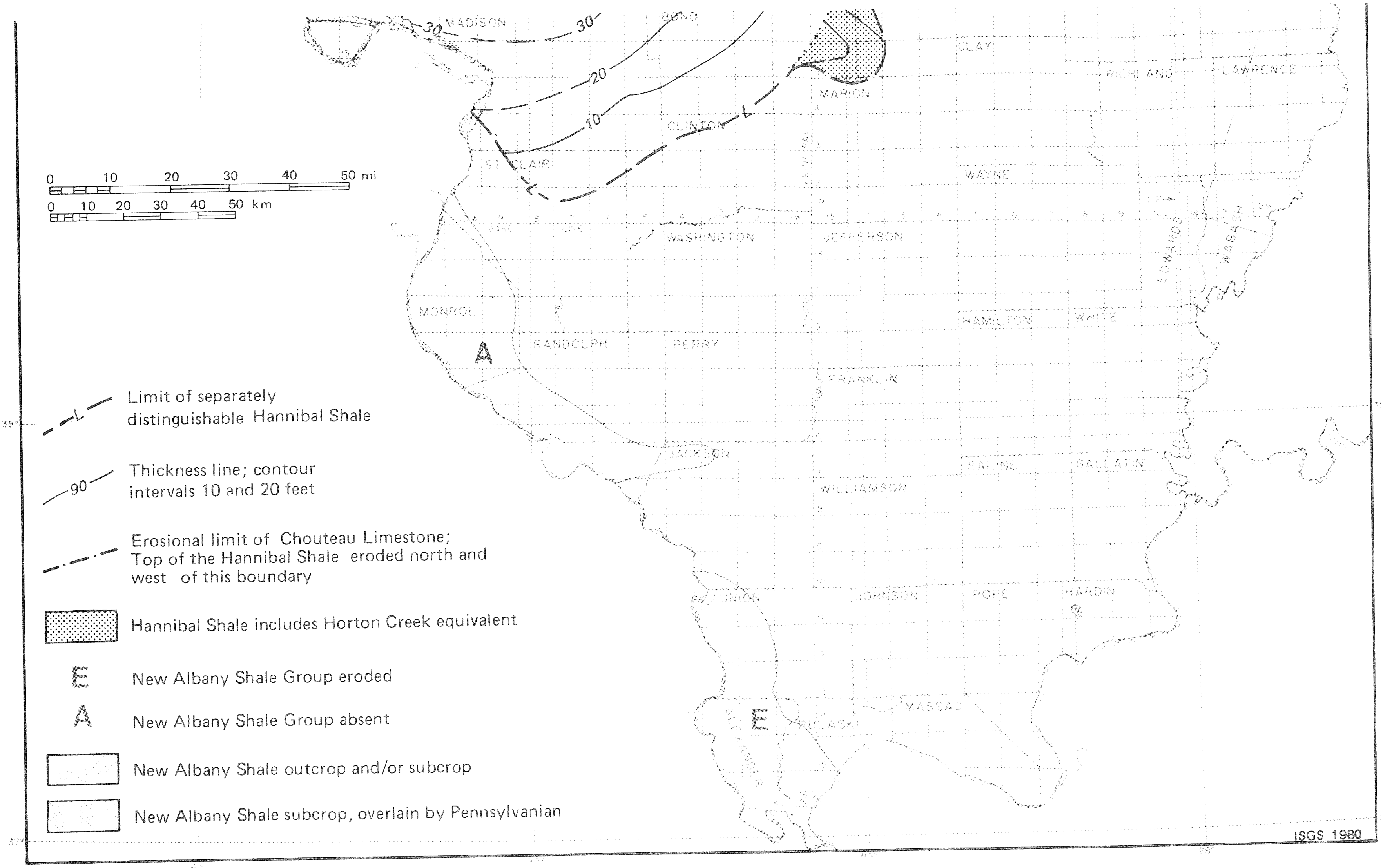

FIGURE 45. Thickness of the Hannibal Shale.

Across much of western and central Illinois, the Hannibal cannot be mapped separately from the underlying Saverton Shale where the intervening Louisiana Limestone and Horton Creek Formation are absent (fig. 36). The Hannibal Shale crops out in the areas of the Illinois and Mississippi River valleys.

Stratigraphic relationships

The Hannibal Shale was originally defined by Keyes (1892) as the shales overlying the Louisiana Limestone and underlying the Chouteau Limestone at Hannibal, Missouri; later the overlying limestone was identified as Burlington rather than Chouteau (Workman and Gillette, 1956). In the type section and in nearby areas, the basal Hannibal rests upon the Louisiana Limestone and may include strata equivalent to the Horton Creek Formation. Where the Horton Creek Formation is recognized, the Hannibal conformably overlies it. Where both the Lousiana and Horton Creek are absent, the Hannibal-Saverton sequence could not be practically subdivided in the study (fig. 37).

In some portions of southeastern Illinois and Indiana the Jacobs Chapel Bed, Henryville Bed, and Falling Run Nodule Bed occur at the top of the gray Hannibal-Saverton Shale (appendixes 8, 9). Although the Jacobs Chapel and Falling Run Beds cannot be identified without cores, the Henryville Bed can be traced on gamma ray logs in the subsurface; in some areas it overlies a substantial thickness of Hannibal-Saverton Shale. These thin beds are considered within the Hannibal-Saverton when they occur at the top of significant recognizable thickness of Hannibal-Saverton Shale; when they occur at the top of the dominantly black shales, they are considered part of the Grassy Creek Shale.

Age and correlation

Collinson et al. (1971), citing conodont studies, concluded that the base of the Mississippian occurs at or near the base of the Hannibal Shale in western Illinois; he arbitrarily designated the top of the Louisiana Limestone as the base of the Mississippian. In areas where the Hannibal and Saverton Shales are thin and cannot be separated from one another, the relative proportions of Devonian and Mississippian-aged strata are not accurately known.

The starved basin conditions which characterize early and middle Mississippian sedimentation in the Illinois Basin (Lineback, 1969) apparently began at, or shortly after, the close of the Devonian. The Falling Run Bed, Jacobs Chapel Bed, and Henryville Bed are widespread thin beds equivalent to most or all of the type Hannibal Shale (Lineback, 1970). Where the Henryville and Falling Run Beds occur near the top of the Hannibal-Saverton Shale, most of the greenish-gray shale is therefore probably Devonian (or Saverton equivalent). Where these thin beds rest directly on black Grassy Creek Shale (as at Hicks Dome and Horseshoe in extreme southeastern Illinois), the Hannibal equivalent is probably represented mainly by the Falling Run-Henryville-Jacobs Chapel succession, with possibly a few feet of the underlying black shale also age equivalent to the type Hannibal.

SUMMARY OF BASINWIDE STRATIGRAPHIC RELATIONSHIPS

The New Albany Shale Group of Illinois is essentially equivalent to the New Albany Shale (formation) of Indiana and Kentucky (fig. 46). In Illinois the New Albany is subdivided into formations, whereas equivalent units are given member status in Indiana and Kentucky. In the southern depocenter, the maximum age range of the New Albany is from upper Middle Devonian through Kinderhookian.

The Blocher Shale of Illinois is essentially equivalent to the Blocher Member of Indiana as restricted in this study. The base of the unit is older in the central portion of the southern depocenter than it is toward the periphery. The Blocher grades laterally into the upper portions of the underlying carbonate units, the Lingle and Alto Formations in Illinois, the North Vernon Limestone in Indiana, and the Sellersburg Limestone in Kentucky.

In most of western and central Illinois, the Sylamore Sandstone lies at the base of the New Albany Shale Group. The Sylamore unconformably overlies rocks which range in age from Ordovician through Middle Devonian (or perhaps earliest Upper Devonian). The Sylamore is a transgressive unit, but where it occurs it is usually the basal formation of the Upper Devonian.

The Selmier Shale of southeastern Illinois is equivalent to the Selmier Member of Indiana, as redefined in this report. The Selmier Shale is mostly older than the Sweetland Creek Shale of western and central Illinois, but the basal portion of the Sweetland Creek is probably equivalent to the uppermost Selmier. In some areas of central and eastern Illinois, strata equivalent to the upper Selmier, or even the entire Selmier, are not lithologically distinct from the overlying Sweetland Creek and are therefore included with the Sweetland Creek.

The Sweetland Creek of western Illinois is also equivalent to the Morgan Trail Member and much or all of the Camp Run Member of Indiana. In much of the southern depocenter, the Camp Run and Morgan Trail equivalents are included in the Grassy Creek Shale.

The type Grassy Creek Shale of eastern Missouri and western Illinois is equivalent to only a small portion of the thick Grassy Creek Shale of the southern depo-

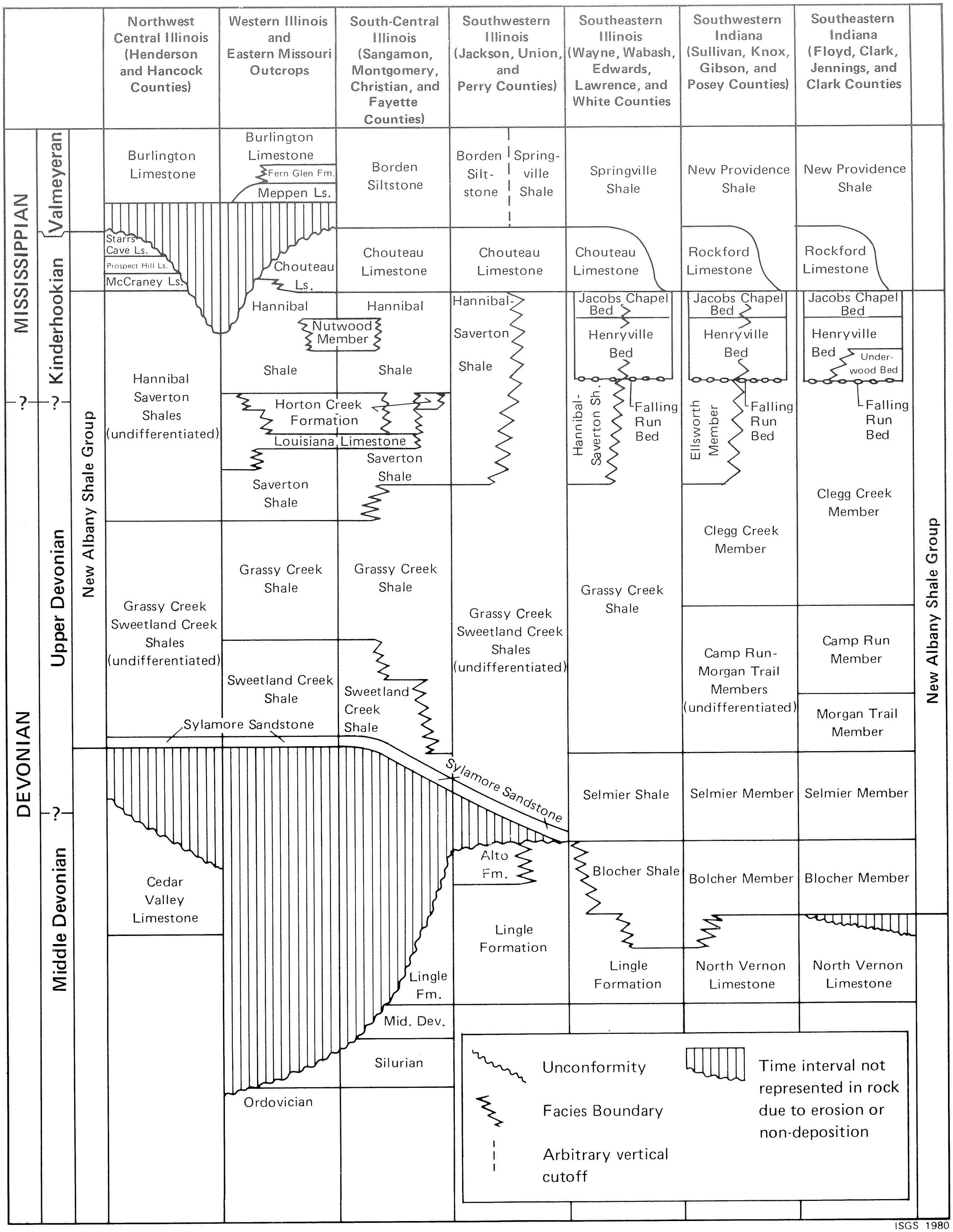

FIGURE 46. Physical correlation diagram of the New Albany Shale across the Illinois Basin (thicknesses not to scale).

center. The type Grassy Creek is equivalent to the lower portion of the Clegg Creek Member and perhaps the uppermost part of the Camp Run Member. In much of the depocenter, the Hannibal-Saverton equivalents are not readily distinguished from the Grassy Creek and are therefore included with the Grassy Creek. Thus defined, the Grassy Creek in these areas is equivalent to the entire Morgan Trail-Camp Run-Clegg Creek interval (Upper Devonian-Kinderhookian) of the Indiana outcrops.

The Hannibal-Saverton succession of western Illinois and the Mississippi Valley consists of laterally intergrading shale, siltstone, and limestone. The Louisiana Limestone and Horton Creek Formation, which lie between the Saverton and Hannibal, have no apparent lithologic equivalents in most of the southern and eastern parts of the basin. Where both the Louisiana and Horton Creek are absent, the Hannibal-Saverton Shale is undifferentiated. As already mentioned, the Hannibal-Saverton grades laterally into the Grassy Creek Shale in portions of the southern depocenter. The Hannibal-Saverton is equivalent to the upper portion of the Clegg Creek Member of Indiana. The Nutwood Member, a black shale within the Hannibal of western Illinois, may be roughly equivalent to the Henryville Bed. This high organic black shale bed within the upper portion of Clegg Creek of Indiana is recognized as a bed within the uppermost Grassy Creek or Hannibal-Saverton in southeastern Illinois.

In parts of extreme western Illinois, the Hannibal is overlain conformably by the McCraney Limestone of the North Hill Group. Over much of the basin, the New Albany is conformably overlain by the Chouteau Limestone or its Indiana equivalent, the Rockford Limestone. In some portions of the basin, the Chouteau (or Rockford) is absent, apparently as a result of depositional pinchout. In these areas the New Albany is directly overlain by the Springville Shale or equivalent Borden Siltstone (New Providence Shale in Indiana) with no compelling physical evidence for an unconformity. In parts of western and central Illinois, the New Albany has been truncated and is unconformably overlain by the Burlington Limestone or its facies equivalent, the Fern Glen Formation.

STRUCTURE ON BASE OF THE NEW ALBANY SHALE

The New Albany Shale Group structure map (plate 4) is a revised version of the Hunton Limestone Megagroup map published by Stevenson and Whiting (1967). The top of the Hunton Megagroup (Swann and Willman, 1961) is generally the same horizon as the base of the New Albany Shale and has been used previously by Weller (1936) and Bell (1943) in mapping the structure of Illinois. In a study of Devonian and Silurian rocks in central and western Illinois, Whiting and Stevenson (1965) presented a structure map contoured on the top of the Hunton Megagroup; this map was subsequently expanded into their 1967 map.

The northern limit of the mapped area (plate 4) is the northern edge of the top of the New Albany Shale. Although the Hunton Limestone extends some distance north of this line, over most of the area its top is a surface beveled by pre-Pennsylvanian and pre-Pleistocene erosion; therefore, it is unsuitable for structure mapping. The structure contours along the Indiana state line have been matched with a map prepared by the Indiana Geological Survey (Bassett and Hasenmueller, in preparation).

The eastern boundary of the mapped area is the Illinois-Indiana Border. The western boundary follows the Missisipi River, except for those places where the New Albany has been removed by erosion (E) or is absent due to non-deposition (A). In extreme southern Illinois, the map extends from a line formed by the Ste. Genevieve Fault and the eroded edge of the New Albany Shale Group to the Ohio River and eastward to the west edge of the Dixon Springs Graben. The southeasternmost portion of Illinois has not been mapped because of the complex faulting and the lack of drill holes penetrating the base of the New Albany Shale (only two exist). The location of these holes and the elevation on the base of the New Albany are shown on the map.

About 4300 data points were used on Stevenson and Whiting's original work map (1967), which was drawn to a scale of 1:250,000. In areas of dense drilling, the control was limited to one point per section. Plate 4 has a scale of 1:500,000, which precludes exact location of data points with symbols of suitable size; therefore, no data points are shown except the two in extreme southern Illinois.

In the area of Hamilton, White, Saline, and Gallatin Counties, the control points are too sparse to provide adequate data for structural interpretation. In these counties, the elevation of the base of the New Albany was estimated by combining maps of the structure of the middle "massive" member (Scottsburg Member) of the Menard Limestone (Siever, 1951; Swann, 1951) and a thickness map of the Menard to Hunton interval (unpublished map).

The sparsely drilled and complexly faulted area south of T. 10 S. in extreme southern Illinois was mapped by relying heavily on structure mapping on shallower horizons (Weller, 1940). The faults shown in this area are essentially the same as those shown on the geological map of Illinois (Willman et al., 1967), with modifications based on work by Ross (1963) and Kolata, Treworgy, and Masters (1981).

Major revisions of Stevenson and Whiting's 1967 map have been made in four areas. The first of these areas is in Lawrence and Crawford Counties, where anticlinal axes along the La Salle Anticlinal Belt were inadvertently shown

6 miles east of their actual location on Stevenson and Whiting's (1967) map. The second area is in the Silurian reef area of southwestern Illinois, which Bristol (1974) mapped in detail, including additional data acquired by drilling since 1967. The third area is in White and Gallatin Counties. Here, detailed mapping of the Wabash Valley Faults by Bristol and Treworgy (1979) resulted in the reinterpretation of the location and extent of several faults. A recent deep test on the Omaha Dome structure (T. 8 S., R. 8 E.) also revealed that the shallow structure is largely the result of igneous intrusions in Mississippian sediments; apparently no structural high exists on the Devonian. The fourth area is in western Franklin County, where the position of the steep flank of the DuQuoin Monocline was shown 4-5 miles east of its actual position on the 1967 edition of this map.

There are a few other minor changes based on scattered deep drilling done for the exploration of oil and gas for gas storage sites (e.g., one at Brubaker Field in Sec. 31, T. 3 N., R. 3 E., Marion County). Most of these changes are not worth noting, since only slight modifications of the 1967 map were required.

DEPOSITIONAL ENVIRONMENT OF NEW ALBANY SHALE GROUP

In this study, bioturbation patterns, the occurrence of invertebrate fossils, and regional stratigraphic relationships have been used to interpret the paleobathymetry, paleogeography, and depositional environments of the New Albany sea. Although many lithologic properties of the New Albany Shale vary only within relatively narrow limits, the bulk fabric of the rock varies considerably and was determined primarily by the activity of burrowing benthic organisms. Bioturbation has destroyed primary sedimentary structures, created a distinctive swirling texture in the sediment, reduced the amount and changed the composition of organic matter preserved, and may have affected the bulk physical properties of the shale. The distribution of lithofacies in the New Albany Shale across Illinois is most consistent with deposition of the shale in a deep water stratified anoxic basin centered in southeastern Illinois and adjacent western Kentucky.

In this stratified basin, three factors were apparently most important in controlling the distribution of benthic organisms and lithofacies: oxygenation of the bottom environment; wave energy; and basin topography (Cluff, 1980).

Bottom oxygenation

Stratification of the water column was the most important environmental restriction in the New Albany sea. Oxygen is stratified with depth in enclosed or semi-enclosed basins if the rate of vertical mixing and replenishment of bottom waters is less than the rate at which oxygen is consumed by the decay of organic matter falling through the water column. Three major zones can be defined on the basis of oxygen content and the characteristics of benthic fauna which are able to inhabit the water (fig. 47), as outlined by Rhoads and Morse (1971) and Byers (1977).

1. *Aerobic zone.* Wind, surface waves, and currents oxygenate the surface waters of the oceans by diffusion of atmospheric oxygen and, via mixing, carry the oxygen to moderate depths. The dissolved oxygen content is essentially at saturation and everywhere exceeds 1.0 ml/L, which is not restrictive to any group of marine invertebrates. The uppermost few tens of meters of virtually all modern seas have been oxygenated in this manner, and in most areas of the world ocean, the uppermost 500 meters is well oxygenated. Byers (1977) concluded that 50 meters is a reasonable *minimum* depth for the base of the aerobic zone. Sediments deposited in aerobic environments are characterized by their fossil content and prevalence of bioturbation in many areas.

2. *Dysaerobic zone.* This is a transitional zone characterized by rapid decrease in oxygen content with depth as it is consumed by organic decay processes. Rhoads and Morse (1971) defined this zone as containing between 0.1 and 1.0 ml of dissolved oxygen/L of seawater. The position of the dysaerobic zone coincides with the pycnocline in density stratified basins such as the Black Sea, or with the thermocline in more open marine settings. The precise

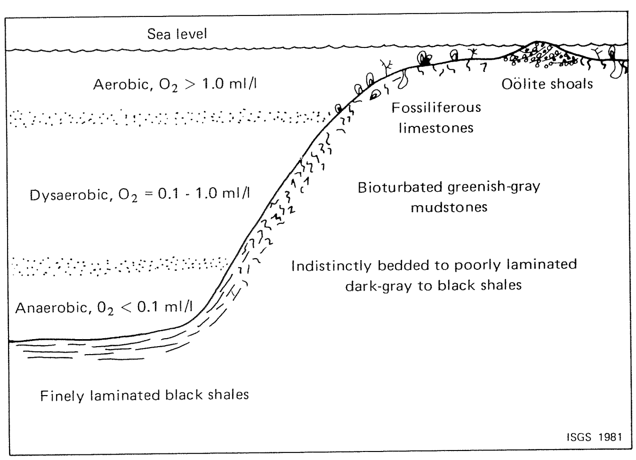

FIGURE 47. Idealized stratified anoxic basin, modified after Rhoads and Morse, 1971. Figure is not to scale and the basin slope and thickness of aerobic-dysaerobic zones are highly exaggerated. In modern enclosed basins, such as the Black Sea, the aerobic and dysaerobic zones occupy only a thin near surface layer and the vast bulk of the water column is anaerobic.

depth of this transition varies from basin to basin and depends on many factors, including latitude, size of the basin, and sill depth. Byers (1977) noted that the dysaerobic zone in Holocene seas is commonly about 100 meters thick and may lie at any depth below about 50 meters. The dysaerobic zone can be recognized in sedimentary rocks because the characteristic low-oxygen conditions are restrictive to many, but not all, marine invertebrates. Calcified taxa have high metabolic requirements for oxygen and are generally unable to survive in this zone. The only abundant invertebrates in this zone are soft-bodied (or lightly calcified) burrowing detritus feeders and micro-organisms (mostly bacteria). In the rock record this zone would therefore be bioturbated, but unfossiliferous.

3. *Anaerobic zone.* In the deepest, very poorly mixed areas of stratified basins, the influx of decaying organic matter settling through the water column exceeds the rate of replenishment of oxygen by mixing with surface waters. The dissolved oxygen content of these waters is less than 0.1 ml/L, and no multi-cellular organisms can live in this zone. Only micro-organisms, principally sulfate-reducing bacteria, survive under these conditions. In the rock record, sediments deposited in anaerobic environments would be characterized by their lack of bioturbation, preservation of abundant organic matter, and absence of in situ benthic fossils.

In large anoxic basins such as the Black Sea or in deep-silled basins along continental margins as found off the coast of southern California, fully anaerobic conditions are not established in water depths less than about 150 meters (Byers, 1977), and may develop at much greater depths.

Wave energy

Although the water is well oxygenated in very shallow, highly-agitated, nearshore environments, burrowing organisms are unable to survive the constant reworking of the substrate. Primary sedimentary structures are often preserved in these areas and fragmented skeletal remains of organisms are abundant. In the New Albany sea, cross-bedded oolitic limestones, well-washed biocalcarenites (grainstones and packstones), and carbonate mud pebble conglomerates were the distinctive lithologies deposited in these high energy environments. In offshore, slightly deeper areas

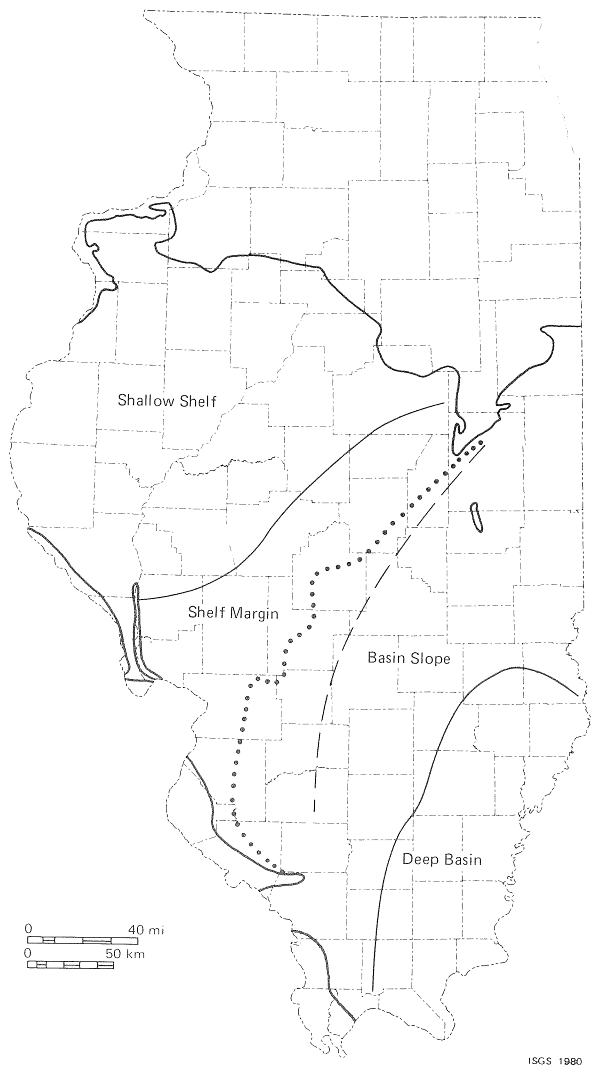

FIGURE 48. Paleogeography of the New Albany sea in Illinois. No sharp shelf margin-basin slope break has been identified, but facies relationships indicate that it was probably a zone north and west of the heavy dashed line. The position of the New Albany shelf margin area closely parallels the edge of the Mississippian Burlington-Keokuk crinoidal bank margin (dotted line), indicating that the basin paleogeography that controlled Valmeyeran sedimentation in the Illinois Basin (Lineback, 1966) was well established by the late Devonian.

Table 4. Relation of Schäfer biofacies to energy and oxygenation levels.

Energy		Biofacies	Oxygenation	
(increasing wave energy) ↑	very high	lethal heterostrate	aerobic	(decreasing oxygen) ↓
	high	vital heterostrate	aerobic	
	low	vital isostrate	aerobic to dysaerobic	
	low	lethal isostrate	anaerobic	

Table 5. Depositional environment of major lithofacies in the New Albany Shale.

	Benthic invertebrate body fossils	Bioturbation	High energy sed. structures	Bottom oxygenation	Schäfer biofacies
LITHOFACIES					
Limestones and dolomites	X	X	x	Aerobic	Mostly vital isostrate; some lethal heterostrate
Bioturbated mudstones	x	X	O	Dysaerobic	Vital isostrate
Indistinctly bedded shales	O	X	O	Dysaerobic	Vital isostrate
Thickly laminated shales	O	x	O	Mostly anaerobic	Lethal isostrate
Finely laminated shales	O	O	O	Anaerobic	Lethal isostrate

X = common x = rare O = absent

where wave agitation was not a significant environmental restriction, burrowing organisms were abundant. The intense activity of the burrowers destroyed primary sedimentary structures and tended to homogenize the sediment, as is typical in the carbonate wackestones and the greenish-gray shales in the New Albany.

Schäfer (1972) developed a classification of marine biofacies relating the preservation of benthic invertebrate assemblages to energy of the environment (as recorded by physical reworking of the substrate) and bottom oxygenation (table 4). Benthic organisms are excluded from the lethal heterostrate biofacies because of very high agitation and constant reworking of the bottom sediments; whereas organisms are excluded from the lethal isostrate environment by the lack of oxygen in bottom waters. The vital heterostrate and vital isostrate biofacies are environments in which benthic organisms live; the remains of these organisms are incorporated in the sediment with varying degrees of physical reworking.

The major lithofacies in the New Albany Shale and their distribution have been discussed in previous sections. Table 5 summarizes some of the characteristics of these lithofacies and the oxygenation conditions and biofacies they represent, and figure 47 illustrates the general distribution of these facies in an idealized anoxic basin. Only the oolitic limestones and limestone conglomerates in the Horton Creek Formation record high energy conditions (lethal heterostrate biofacies). The sparsely fossiliferous micritic limestones in the Horton Creek and the Louisiana Limestone probably represent aerobic, but less energetic (vital isostrate), conditions of deposition. The mudstones and shales in the New Albany record low energy (isostrate) environments with a continuous gradation of oxygenation conditions from aerobic to anaerobic (fig. 47).

Paleogeography of the New Albany sea

The distribution of lithofacies in the New Albany Shale across Illinois and the pattern of two depositional centers separated by an area of thin deposition (fig. 6) is interpreted to represent a shelf-slope-basin transition. Figure 48 is a generalized paleogeographic reconstruction for the New Albany sea based on the observed facies distribution, their interpreted environments, and thickness patterns.

The Blocher, middle Selmier Shale, and Grassy Creek Shale are predominantly laminated black shales deposited in anaerobic environments. Black shales attain their maximum thickness and development in the southern depocenter, and thin progressively in all directions away from there (figs. 49, 50). Toward the northwest these anaerobic shales grade into predominantly bioturbated gray shales deposited in dysaerobic environments. This facies pattern suggests that the southeastern Illinois depocenter was a deep-water (>150 m), anaerobic basin region during most of the New Albany deposition.

The predominance of dysaerobic gray shales, including most of the Sweetland Creek, Saverton, and Hannibal Shales (fig. 51), in the western depocenter suggests that this region was a stable area under moderate water depths (probably greater than 50 meters) for most of New Albany time. It is therefore interpreted as a broad shelf region (fig. 48). The northeast trending central thin separating these two regions is characterized by intertonguing of gray and black shales (fig. 51) and is interpreted as the basin slope.

The shelf margin between the shallow shelf area of western Illinois and the basin slope in central Illinois was apparently not a sharp break, as several distinctive lithologic transitions and thickness changes occur across a northeast-southwest trending belt more than 30 miles wide (fig. 48). In this shelf margin zone are found most of the carbonate beds in the New Albany, including the oolitic limestone belt in the Horton Creek Formation (figs. 51, 52). Thin carbonate beds also extend southeastward and down the basin slope for considerable distances; however, these slope beds are very argillaceous wackestones and are distinctly basinal in character. The Hannibal-Saverton Shale thins very rapidly across the shelf margin (figs. 36, 51), as does the Grassy Creek-Sweetland Creek undifferentiated interval (fig. 25) and the total New Albany thickness (plate 3). The overlying Chouteau Limestone thins and pinches out, possibly grading laterally into Hannibal Shale,

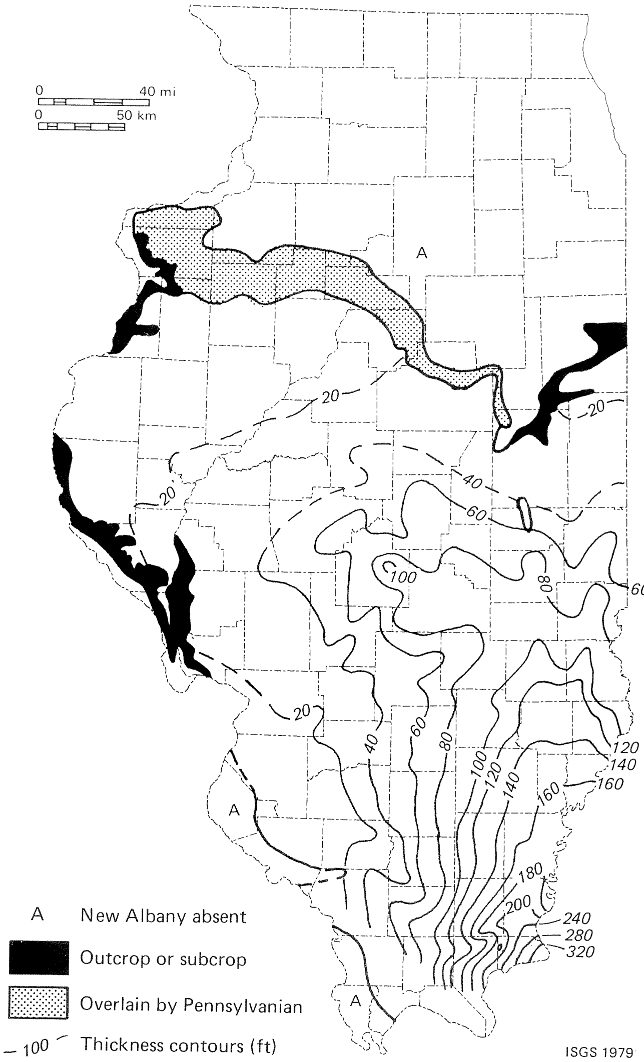

FIGURE 49. Cumulative thickness of radioactive shale within the New Albany Shale Group in Illinois. Radioactive shale is here defined as that shale which has a gamma ray log value >60 API units above a normal (organic-poor) shale base line. Radioactive shale, thus defined, closely corresponds to the laminated black shale lithofacies as determined by core studies.

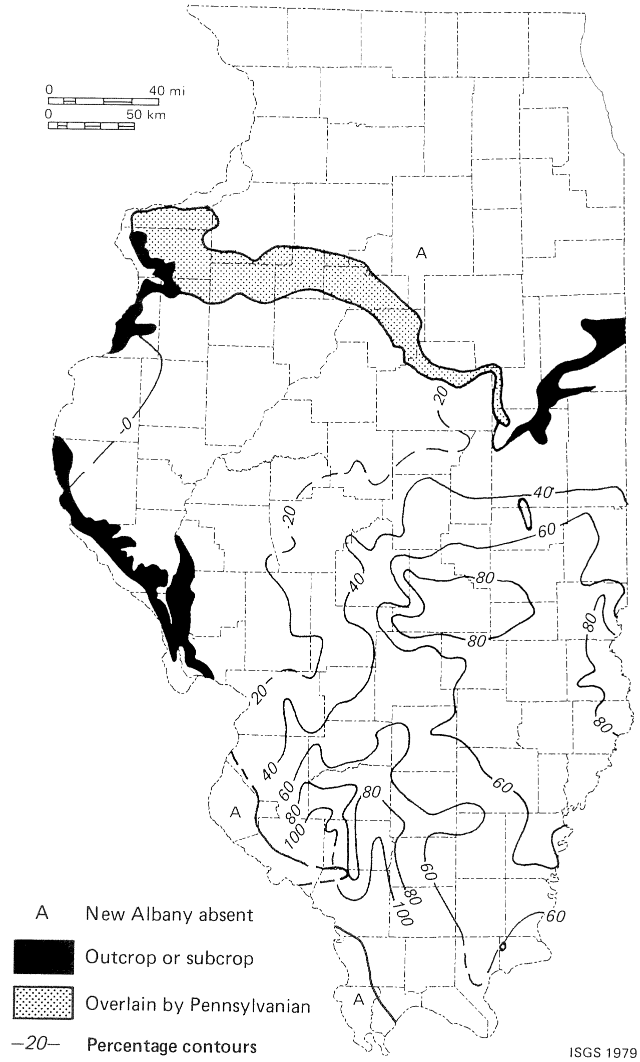

FIGURE 50. Cumulative percentage of radioactive shale within the New Albany Shale Group in Illinois.

near the northwest limit of the shelf margin (fig. 52). These relationships suggest that the New Albany shelf margin was probably a gentle ramp rather than a sharp, steep break such as existed during deposition of the Burlington-Keokuk crinoidal bank (Lineback, 1966). The close correspondence between the position of the New Albany shelf margin area and the Burlington-Keokuk bank edge (fig. 48) clearly indicates that the Valmeyeran paleogeography of the Illinois Basin was well established by late Devonian time.

Fluctuations in oxygenation and depositional environments

As previously noted, some portions of the New Albany Shale are characterized by widespread lateral intertonguing and gradation of lithofacies while other portions are characterized by thin interbedding of lithologies; this indicates that depositional conditions were not static, but rather fluctuated, on both local and regional scales. Tongues of laminated black shale extend out of the southern depocenter and far across western and central Illinois, the most notable of these being thin Grassy Creek Shale in those regions (plates 1, A-F; 2, B-I). Tongues of bioturbated greenish-gray shale also extend down off the western Illinois shelf region into the basin, for example, the gray shales in the Sweetland Creek and Selmier Shales (plate 1, A-F). These broad relationships are illustrated in figure 51, a generalized NW-SE cross section across the New Albany basin running approximately parallel to, and through, many of the same drill holes shown in plate 1, A-F.

The regional interfingering of gray and black shales across Illinois is interpreted as the result of major vertical fluctuations in the position of the anaerobic-dysaerobic boundary. When the anaerobic/dysaerobic boundary rose in the water column, black shale deposition transgressed across areas where gray shales had been deposited. Similarly, when the anaerobic/dysaerobic boundary fell in the water column, the area of black shale deposition was restricted and gray shales extended down into deeper areas of the basin. Even during the maximum transgression of anaerobic conditions across the shelf area of western Illinois, however, less than 20 feet of black shale was deposited in this region. During most of the New Albany deposition the fluctuations in oxygenation conditions were restricted to the deep basin

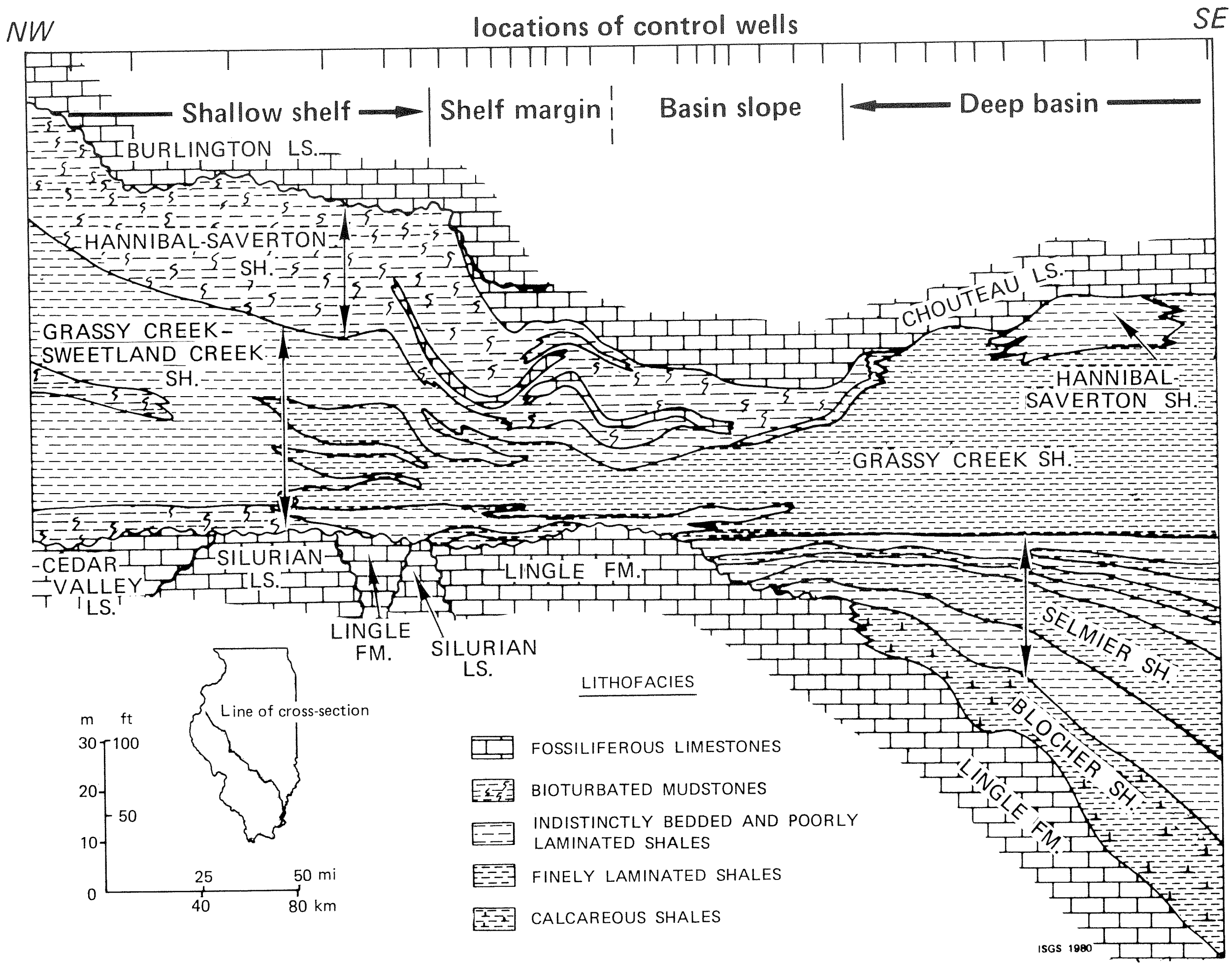

FIGURE 51. Generalized NW-SE stratigraphic cross-section through the New Albany Shale Group in Illinois (modified from Reinbold, 1978). The basin slope region is characterized by alternating black and olive-black shales which onlap the basal unconformity (Selmier Shale) and by a rapidly thinning greenish-gray shale tongue at the top of the shale (Hannibal-Saverton). The shelf margin area is characterized by extensive interfingering and lateral gradation between gray and black shale (Grassy Creek-Sweetland Creek Shales) and by several thin limestone stringers (Louisiana Limestone; Horton Creek Formation). The shelf-slope break appears to be a transitional zone, rather than a sharp shelf edge.

area, and most of the prominent facies changes occur on the basin slope and shelf margin.

Assuming moderate to low depositional slopes for the basin, vertical fluctuations in the position of the aerobic-anaerobic interface by tens of meters could result in basin-wide lateral facies shifts. Indeed, many of the sharp geophysical horizons which can be traced across the basin probably reflect sudden (in terms of geologic time) vertical movements in the oxygenation boundaries. Anoxic conditions can develop over large areas in enclosed basins very rapidly, as shown by the development of anoxic water over about 50 percent of the area of the Black Sea in just 400 years and the rise in the average depth of the O_2-H_2S interface by nearly 2,000 meters in the last 7,000 years (fig. 53) (Deuser, 1974). Such changes would produce a virtually isochronous horizon in the sedimentary record.

The small-scale interbedding of bioturbated gray shales and laminated black shales in the Sweetland Creek and Saverton Shales also reflects minor fluctuations in oxygenation. Vertical movements of oxygenation boundaries of a few meters or less would affect relatively small areas on the sea floor, and small fluctuations are likely to be typical of transition periods from well-established anaerobic conditions to dysaerobic conditions (and vice-versa). Some of the greenish-gray shale beds in the lower part of the Camp Run Member of the New Albany Shale in Indiana and central Kentucky, for example, can be traced for short distances, but bed-by-bed correlations along the outcrop belt are not possible (Lineback, 1970; Griffith, 1977). Small variations in sea floor topography may have also been important in these areas.

Turbidity currents or other episodic events could also have briefly oxygenated the bottom in areas where anaerobic conditions normally prevailed. Sholkovitz and Soutar (1975) reported that turbidity currents periodically oxygenate the bottom water in the Santa Barbara Basin off southern

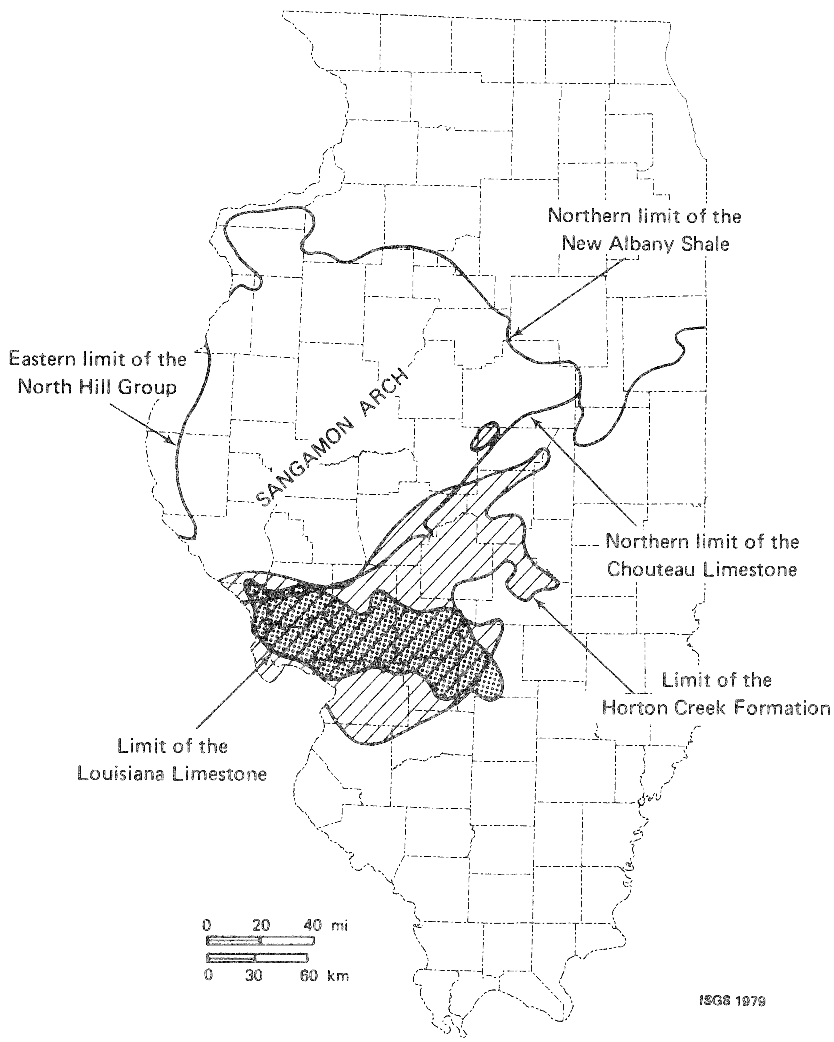

FIGURE 52. Extent of carbonates within and directly overlying the New Albany Shale.

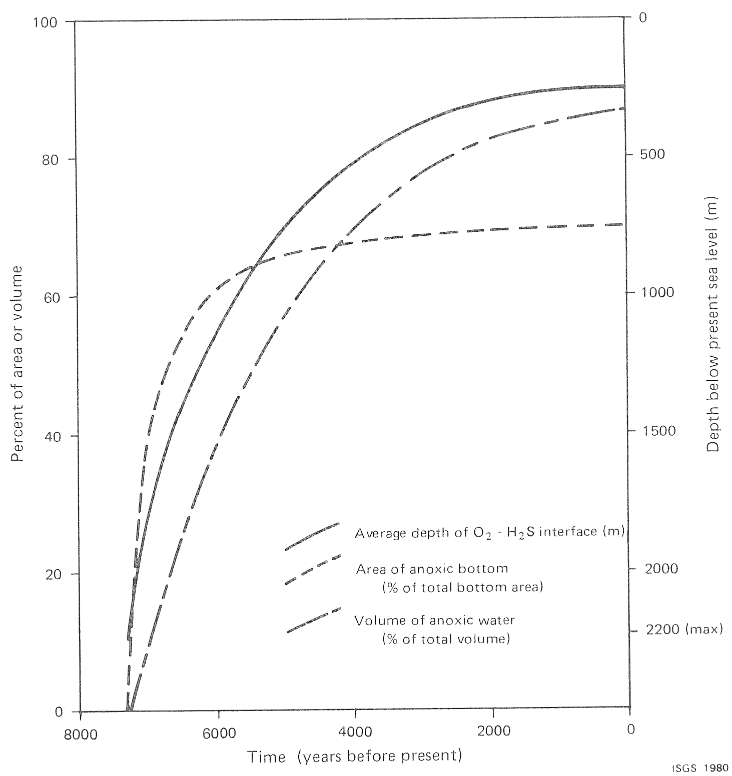

FIGURE 53. Rapid evolution of anoxic conditions in the Black Sea during the last 7300 years (after Deuser, 1974).

California. Physical evidence for episodic deposition of some greenish-gray shale beds in the Saverton Shale has been discussed previously.

The mechanism responsible for major oxygenation fluctuations is unknown. Eustatic sea level changes are one obvious possibility. There is little supporting evidence for major sea level variations, however, as other sediment characteristics (such as detrital mineralogy or grain size) do not co-vary with oxygenation changes. There is also little evidence for significant shoreline shifts or numerous unconformities along the basin margins. In fact, we believe that oxygenation conditions may have varied completely independently of sea level.

Global climatic variation could have been another possible control of oxygenation conditions in the New Albany sea and is a particularly appealing theory, considering the widespread distribution of Upper Devonian black shales across North America. Fischer and Arthur (1977) observed that the deep ocean basins of the world are oxygenated by the sinking of dense, cold, polar surface water during the freezing of sea ice. During periods of temperate world climate (as has been inferred for the late Devonian; Berry and Wilde, 1978) ocean bottom waters may cease to be replenished and would therefore become depleted in oxygen within a relatively short period of time. The mid-water oxygen minimum zone correspondingly expands, and, because periods of warm global climate usually accompany periods of maximum transgression of epieric seas, Fischer and Arthur (1977) reasoned that the oxygen-minimum zone would likely transgress across the continental shelves and into cratonic basins. Their model fits the world wide distribution of middle Cretaceous black shales in both deep ocean basins (sampled by the Deep Sea Drilling Project) and on the cratons (Arthur and Schlanger, 1979), and has been suggested as a possible model for Paleozoic black shale deposition.

If the major fluctuations in oxygenation observed in the New Albany Shale reflect global climatic events, and not basin-localized tectonic events, then the major anoxic periods of New Albany deposition could probably be correlated to similar anoxic events in other basins. Because the Illinois Basin was a relatively stable, slowly subsiding basin throughout the Devonian and early Mississippian, the record of events in the New Albany Shale may therefore ultimately serve as a base line for deciphering the history of tectonically more complex sequences, including the Devonian shales of the Appalachian Basin.

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APPENDIX 1. Orbit Gas #1 Ray Clark, Christian County, Kentucky

Location: 650 feet from north line; 90 feet from east line; Sec. 12, Kentucky Grid Section 12-G-25, Christian County, Kentucky
Elevation: 548 feet (167.0 m) above m.s.l. (kelly bushing)
Description: J. A. Lineback, Sept. 1976

Depth	Description
	New Albany Shale Group
	GRASSY CREEK SHALE
2175 to 2178 ft (662.9 to 663.9 m)	not cored
2178 to 2178.5 ft (663.9 to 664.0 m)	Shale, brownish black (5YR2/1), thinly laminated; phosphatic nodule at base, pyritic
2178.5 to 2184.4 ft (664.0 to 665.8 m)	Shale, brownish black (5YR2/1), laminae thicker and more prominent than in unit above; pyrite nodules and pyritic laminae
2184.4 to 2185.4 ft (665.8 to 666.1 m)	Shale, brownish black, much broken in coring
2185.4 to 2188.2 ft (666.1 to 667.0 m)	Shale, brownish black (5YR2/1), widely-spaced, prominent laminae of pyrite or pyritic laminae, pyrite nodules
2188.2 to 2192.0 ft (667.0 to 668.1 m)	Shale, brownish black (5YR2/1), many prominent laminae of pyritic dolomite up to 2 cm thick; thin laminae between the thicker ones
2192.0 to 2214 ft (668.1 to 675 m)	Core broken and lost in hole
2214 to 2216 ft (675 to 675.4 m)	Drilled during reaming of hole
2216.0 to 2226.0 ft (675.4 to 678.5 m)	Shale, brownish black to black (5YR2/1 to N1), thinly laminated with a few prom-iment beds of silt or dolomite with pyrite
2226.0 to 2226.1 ft (678.5 to 678.6 m)	Shale, olive gray (5YR4/1)
2226.1 to 2230.3 ft (678.6 to 679.8 m)	Shale, brownish black (5YR2/1), thinly laminated, with only a very few prominent pyritic laminae
2230.3 to 2230.6 ft (679.8 to 679.9 m)	Shale, olive-gray with some brownish-black layers
2230.6 to 2231.7 ft (679.9 to 680.2 m)	Shale, brownish black (5YR2/1), with laminae and some thin layers of olive-gray shale; a few pyritic laminae
2231.7 to 2232.6 ft (680.2 to 680.5 m)	Shale, olive-gray (5YR4/1), with laminae of brownish-black shale
2232.6 to 2234.3 ft (680.5 to 681.0 m)	Shale, brownish black (5YR2/1), thinly laminated, very few prominent, thin, pyritic laminae and pyrite nodules
2234.3 to 2236.0 ft (681.0 to 681.5 m)	Shale, olive-gray (5YR4/1), with thin laminae of brownish-black shale becoming more abundant toward base
2236.0 to 2238.6 ft (681.5 to 682.3 m)	Shale, olive-gray (5YR4/1), a few black laminae
2238.6 to 2247.7 ft (682.3 to 685.1 m)	Shale, brownish black (5YR2/1), thinly laminated; a few prominent laminae or thin beds of pyritic sand or dolomite; a few thin beds of olive-gray shale
	SELMIER SHALE
2247.7 to 2249.9 ft (685.1 to 685.8 m)	Shale, alternating beds of brownish-black and olive-gray shale, laminated.
2249.9 to 2257.8 ft (685.8 to 688.2 m)	Shale, olive-gray (5YR4/1), a few brownish-black laminae, a brownish-black bed at 2253.4 feet (686.8 m), and a bed of argillaceous dolomite at 2256.6 feet (687.8m); sharp base

2257.8 to 2268.4 ft (688.2 to 691.7 m)	Shale, brownish black (5YR2/1), thinly laminated, several prominent laminae of sand or sandy dolomite
2268.4 to 2269.3 ft (691.4 to 691.7 m)	Dolomitic sandstone in laminated layers, some cross bedded; contains thin black-shale bed
2269.3 to 2275.5 ft (691.7 to 693.6 m)	Shale, brownish black (5YR2/1), thin laminations of dolomite; a few prominent laminations
2275.5 to 2276.3 ft (693.6 to 693.8 m)	Shale, brownish black (5YR2/1), thinly laminated
2276.3 to 2276.5 ft (693.8 to 693.9 m)	Dolomite, laminated
2276.5 to 2301.5 ft (693.9 to 701.5 m)	Shale, brownish black (5YR2/1), thinly laminated; several beds of dolomite up to 2 cm thick; a few pyritic beds and nodules; dolomite becomes more calcitic toward base of unit; vertical fractures
	BLOCHER SHALE
2301.5 to 2320.6 ft (701.5 to 707.3 m)	Shale, brownish black (5YR2/1), calcareous (reacts to acid whereas shale above does not, sharp contact at top); thinly laminated; beds of limestone (granular, fine grained, less than 2 cm thick) scattered throughout; a 10-cm bed of calcareous sandstone at 2303.2 ft (702.0 m); a 0.5-cm bed of phosphatic sandstone at 2310.1 ft (704.1 m); a 6-cm thick bed of dark gray (N3), silty, limestone at 2317.3 ft (706.3 m); and a 3-cm thick bed of dark gray, possibly phosphatic, fossiliferous limestone at base of unit
	Hunton Limestone Megagroup
	SELLERSBURG LIMESTONE
2320.6 to 2321.9 ft (707.3 to 707.7m)	Limestone, dark gray, coarse grained, crystalline, fossiliferous
2321.9 to 2322.2 ft (707.7 to 707.8 m)	Shale, dark gray, calcareous and limestone, shaly
2322.2 to 2330.9 ft (707.8 to 719.45 m)	Limestone, dark gray, crystalline, fossiliferous
2330.9 to 2331.0 ft (710.45 to 710.5 m)	Limestone, very dark gray, chert nodules

APPENDIX 2. Millar #1 G. W. Sample, Sangamon County, Illinois

Location: SW¼ SW¼ NE¼, Sec. 11, T. 15 N., R. 3 W., Sangamon County, Illinois
Elevation: 595.8 feet (181.6 m) above m.s.l.
Description: J. A. Lineback, Nov. 1976

Depth	Description
	CHOUTEAU LIMESTONE
1567 to 1569.4 ft (477.6 to 478.4 m)	Limestone, brownish gray (5YR5/1), wavy bedded, finely crystalline, fossiliferous. Glauconite and greenish tinges below 1569
	New Albany Shale Group
	HANNIBAL SHALE
1569.4 to 1590.5 ft (478.4 to 484.8 m)	Shale, greenish gray (5G5/2 to 5GY5/1), some beds of darker olive-gray (5GY4/1 or 5Y3/2), core mostly broken to small, rounded pieces
1590.5 to 1591.1 ft (484.8 to 485 m)	Shale, sandy, burrows
1591.1 to 1591.9 ft (485 to 485.2 m)	Shale, greenish gray (5GY5/1)
1591.9 to 1592 ft (485.2 to 485.24 m)	Limestone, light brownish gray, thin bedded
1592 to 1594.5 ft (485.2 to 486 m)	Shale, greenish gray, silty
1594.5 to 1596.8 ft (486 to 486.7 m)	Shale, dark olive-gray (5Y3/1); breaks into rounded pieces, becomes slightly lighter olive gray (5Y4/1) downward
1596.8 to 1601.5 ft (486.7 to 488.1 m)	Shale, olive-gray (5Y5/1), irregular bedding
1601.5 to 1636 ft (488.1 to 498.7 m)	Shale, mostly medium gray (5Y5/1), with beds of darker gray (5Y4/1 or 5Y3/1), burrows and thin laminations of the lighter or darker shale; irregular bedding, breaks into rounded irregular pieces, somewhat silty, some greenish gray (5Y5/1), some of the core broken
	HORTON CREEK FORMATION
1636 to 1638.9 ft (498.7 to 499.5 m)	Limestone, finely crystalline, irregular wavy beds, medium gray; nodular bedding in middle with blobs of limestone in an argillaceous matrix; sparsely fossiliferous, with few brachiopods
	SAVERTON SHALE
1638.9 to 1656.9 ft (499.5 to 505 m)	Shale, greenish gray to dark greenish gray (5GY4/1), breaks to small rounded fragments; upper part crushed, lower part more intact; pyrite nodules in places
1656.9 to 1657 ft (505 to 505.05 m)	Shale, dark brownish gray (5YR3/1), nonfissile; burrows
	GRASSY CREEK SHALE
1657 to 1657.5 ft (505.05 to 505.2 m)	Shale, olive-gray (5Y5/1)
1657.5 to 1696.5 ft (505.2 to 517.1 m)	Shale, dark brownish gray (5YR3/1) with thin beds of brownish gray (5YR4/1 and 5YR5/1), more fissile than overlying shale and becoming more fissile downward; pyrite, burrows and spores, some brownish black (5YR2/1) near base
	SWEETLAND CREEK SHALE
1696.5 to 1763.6 ft (517.1 to 537.5 m)	Shale, brownish black (5YR2/1 to 3/1), some thin laminations of greenish gray, a few thin laminations of dolomite and/or calcite; spores, some thinly laminated; unit is fissile
1763.6 to 1777 ft (537.5 to 541.6 m)	Shale, lighter in color than above, olive-gray to brownish gray (5Y3/2 to 5YR4/1), generally fissile, thinly laminated; pyrite nodules
	Hunton Limestone Megagroup
	LINGLE LIMESTONE
1777 to – ft (541.6 m to –)	Limestone, dark greenish brown, argillaceous

APPENDIX 3. Tristar Production #1D Lancaster, Effingham County, Illinois

Location: SE¼ SW¼ NW¼, Sec. 31, T. 9 N., R. 4 E., Effingham County, Illinois
Elevation: 612.1 feet (186.6 m) above m.s.l. (ground level)
Description: J. A. Lineback and J. T. Wickham, Feb. 1977

Depth	Description
	CHOUTEAU LIMESTONE
3006 to 3009.9 ft (916.2 to 917.4 m)	Limestone, light olive-gray (5Y5/2), wavy; nodular bedding with greenish-gray, calcareous shale partings; crinoidal; grades to shale at base with a few limestone nodules in a greenish shale matrix in lower 0.1 foot (0.03 m)
	New Albany Shale Group
	HANNIBAL-SAVERTON SHALES (undifferentiated)
3009.9 to 3010.3 ft (917.4 to 917.5 m)	Shale, dark greenish gray (5G4/1), grading downward to more gray shale; fossiliferous bed near top with brachiopods
	GRASSY CREEK SHALE
3010.3 to 3011.2 ft (917.5 to 917.8 m)	Shale, dark gray (N2), gradational at top, with thin beds of light and dark shale
3011.2 to 3023.5 ft (917.8 to 921.6 m)	Shale, dark brownish black to dark gray (5YR2/1 to N2), a few fossils (*Lingula*); tracks and trails on bedding planes, little or no obvious bedding; laminae very thin or lacking, generally massive in appearance
3023.5 to 3027 ft* (921.6 to 922.6 m)*	Broken and disturbed core, brownish-black shale
3027 to 3038 ft (922.6 to 926.0 m)	Core lost
3038 to 3052 ft (926.0 to 930.2 m)	Shale, brownish black (5YR2/1), a few pyritic nodules and a few very thin laminae; fine laminae of presumed carbonate, becoming more abundant in lower part; thin siltstone bed at 3042.5 ft (927.4 m); core broken in lower 2.5 ft (0.8 m)
3052 to 3069 ft* (930.2 to 935.4 m)*	Shale, brownish black (5YR2/1), finely laminated with a few prominent laminae and pyrite nodules; some apparent vertical fractures
3069 to 3070.8 ft (935.4 to 936.0 m)	Shale, medium dark gray (N2-N3), pyrite nodules, trace fossils (trails); a few greenish-gray shale laminae at base
	SWEETLAND CREEK SHALE
3070.8 to 3073.2 ft (936.0 to 936.7 m)	Shale, olive-gray (5Y4/1), laminae and thin beds of black shale; trace fossils; pyrite nodules
3073.2 to 3079.9 ft (936.7 to 938.8 m)	Shale, black (N2), thin beds and laminae of olive-gray and greenish-gray shale; burrow structures; pyrite lenses
3079.9 to 3081.0 ft (938.8 to 939.1 m)	Shale, greenish gray (5Y4/1), black laminae and thin beds
3081.0 to 3088.2 ft (939.1 to 941.3 m)	Shale, greenish gray (5Y4/1), black laminae and thin beds
3088.2 to 3094.0 ft (941.3 to 943.1 m)	Shale, olive-black (5Y2/1), some greenish-gray shale laminae and thin beds; core highly fractured below 3088.6 ft
3094.0 to 3100.2 ft (943.1 to 944.9 m)	Shale, black (N2), some greenish-gray laminae and streaks; pyrite nodules
	SYLAMORE SANDSTONE
3100.2 to 3100.3 ft (944.9 m)	Pyrite and siltstone bed
	Hunton Limestone Megagroup
	LINGLE LIMESTONE
3100.3 to 3104.5 ft (944.9 to 946.3 m)	Limestone, dark gray, coarsely crystalline, convolute shale partings in upper part; petroliferous smell; fractures along shale partings
3104.5 to 3105 ft (946.3 to 946.4 m)	Limestone, fossiliferous; coarse-grained fossil hash, bryozoans, crinoid fragments

* Approximate

APPENDIX 4. Northern Illinois Gas #1 RAR, Henderson County, Illinois

Location: SW¼ SW¼ NE¼, Sec. 32, T. 8 N., R. 4 W., Henderson County, Illinois
Elevation: 772 feet (235.3 m) above m.s.l. (ground elevation)
Description: J. A. Lineback and M. L. Reinbold, July, 1977

Depth	Description
	New Albany Shale Group
	HANNIBAL-SAVERTON SHALES (undifferentiated)
319 to 353.5 ft (97.2 to 107.7 m)	Shale, dark greenish gray (5G4/1 to 5/1), a few small pyrite nodules; scattered thin laminae of carbonate and olive-brown shale; otherwise, bedding faint
353.5 to 374.0 ft (107.7 to 114.0 m)	Shale, dark greenish gray (5G4/1 to 5/1), a little darker than above; carbonate laminae and olive-gray stringers more abundant than above
374.0 to 396.0 ft (114.0 to 120.7 m)	Shale, dark greenish gray with olive stringers common, increasing downward; gradational with unit below; thin carbonate laminae and pyritic stringers present
396.0 to 442.0 ft (120.7 to 134.7 m)	Shale, olive-gray (5Y4/1) to olive-black (5Y2/1), in beds about 1 cm thick interbedded with dark greenish-gray shale; thin (<1 cm) carbonate beds and laminae; a few brownish black stringers
442.0 to 458.0 ft (134.7 to 139.6 m)	Shale, brownish black (5YR2/1), with some olive-black (5Y2/1) interbeds; in beds 1 to 10 cm thick interbedded with dark greenish-gray shale (5G4/1) beds 1 to 3 cm thick; a few thin carbonate beds with a few pyrite stringers
	GRASSY CREEK SHALE
458.0 to 459.5 ft (139.6 to 140.1 m)	Shale, brownish black (5YR2/1), thinly laminated; pyritic; sharp base
459.5 to 484.0 ft (140.1 to 147.5 m)	Shale, olive-black (5Y2/1), uniform; faint, thin laminae; scattered pyrite; soft greenish-gray shale beds from 478.5 to 478.7 ft (145.8 to 145.9 m) and 482.9 to 483.0 ft (147.19 to 147.21 m)
	SWEETLAND CREEK SHALE
484.0 to 487.4 ft (147.5 to 148.6 m)	Shale, olive-brown (5Y3/1), thin beds
487.4 to 504.2 ft (148.6 to 153.7 m)	Shale, olive-gray (5Y3/1 to 4/1), with soft, thin, dark greenish-gray shale beds; grades downward into greenish-gray shale with olive-gray stringers
504.2 to 508.1 ft (153.7 to 154.9 m)	Shale, olive-black (5Y3/1), beds to 2 to 25 cm thick interbedded with dark greenish-gray shale beds 5 to 25 cm thick
508.1 to 509.0 ft (154.9 to 155.1 m)	Shale, dark greenish gray
509.0 to 512.2 ft (155.1 to 156.1 m)	Shale, olive-gray (5Y3/1 to 4/1); thinly laminated
512.2 to 512.6 ft (156.1 to 156.2 m)	Shale, dark greenish gray (5G4/1)
512.6 to 514.0 ft (156.2 to 156.7 m)	Shale, olive-black (5Y2/1), thinly laminated
514.0 to 514.8 ft (156.7 to 156.9 m)	Shale, dark greenish gray (5G4/1)
514.8 to 515.4 ft (156.9 to 157.1 m)	Shale, olive-black (5Y2/1), thin sand bed at 515.0 ft (157.0 m)
515.4 to 518.0 ft (157.1 to 157.9 m)	Shale, soft; dark greenish gray (5G4/1), some faint olive-brown streaks throughout; burrows
518.0 to 528.0 ft (157.9 to 160.9 m)	Shale, greenish black (5G2/1), olive-black streaks throughout; burrows

528.0 to 532.2 ft (160.9 to 162.2	Shale, dark greenish gray (5G4/1), with some faint olive-brown streaks; burrows; soft
532.2 to 550.4 ft (162.2 to 167.8 m)	Shale, olive-black (5Y2/1), thinly laminated; scattered pyrite and dolomitic laminae; some lighter colored olive laminae up to 1 cm thick in lower part
550.4 to 551.1 ft (167.8 to 170.0 m)	Shale, dark greenish gray; some olive laminae
551.1 to 582.4 ft (170.0 to 177.5 m)	Shale, olive-black (5Y2/1), thinly laminated; scattered greenish-gray laminae up to 1 cm; dark green shale beds with olive streaks between 559.9 and 560.1 ft (170.66 and 170.71 m), 573.4 and 573.5 ft (174.77 and 174.80 m); 575.0 and 575.5 ft (175.26 and 175.41 m), and 579.5 and 580.2 ft (176.63 and 176.84 m); thin carbonate laminae with pyrite between 581.7 and 582.0 ft (177.30 and 177.39 m)
582.4 to 599.2 ft (177.5 to 182.6 m)	Shale, olive-gray (5Y3/2) when wet, and light greenish gray when dry; dolomitic, hard, rather massive, and devoid of bedding except for 5-cm thick olive-black beds at 582.6 ft (177.58 m) and 582.8 ft (177.64 m); phosphatic bed 1 cm thick at 583.3 ft (177.79 m); calcite-filled vugs; a few fossil fragments; layer of pyritized *Atrypa* at 598.1 ft (182.30 m)
599.2 to 600.7 ft (182.6 to 183.1 m)	Shale, olive-black at base, laminated, dolomitic; grades upward to greenish-gray shale; abundant burrows; sharp base
600.7 to 601.0 ft (183.1 to 183.2 m)	Shale, greenish gray, dolomitic
601.0 to 603.7 ft (183.2 to 184.0 m)	Shale, gray, dolomitic, sandy, especially at base; faint bedding
	Hunton Limestone Megagroup
	CEDAR VALLEY LIMESTONE
603.7 to 608.4 ft (184.0 to 185.4 m)	Limestone, fossiliferous, argillaceous, light gray; irregular nodular beds; calcite-filled vugs
608.4 to 612.6 ft (185.4 to 186.7 m)	Limestone, dark gray; nodular bedding
612.6 to 613.0 ft (186.7 to 186.8 m)	Shale, dark gray, calcareous, laminated
613.0 to 619.1 ft (186.8 to 188.7 m)	Limestone, light gray, argillaceous, fossiliferous; nodular bedding

APPENDIX 5. Northern Illinois Gas #1 MAK, Tazewell County, Illinois

Location: NE¼ NE¼ NW¼, Sec. 8, T. 23 N., R. 2 W., Tazewell County, Illinois
Elevation: 641 feet (195.4 m) above m.s.l. (ground elevation)
Description: J. T. Wickham, Aug. 1977

Depth	Description
	BURLINGTON LIMESTONE
898 to 925.1 ft (273.7 to 282.0 m)	Limestone, light gray, coarse, fossiliferous; contains crinoid fragments and brachiopod shells; very thin laminae (2-3 mm) of greenish-gray fine-grained material; some pyrite nodules
	New Albany Shale Group
	HANNIBAL-SAVERTON SHALE (undifferentiated)
925.1 to 929.6 ft (282.0 to 283.3 m)	Shale, grayish green (10GY5/2), scattered gray, thin, calcareous laminae; thin non-calcareous, silty laminae in irregularly-bedded layers
929.6 to 938.1 ft (283.3 to 285.9 m)	Shale, dark greenish gray (5G4/1), some thin light gray, irregular, calcareous laminae; very few thin black-shale laminae; some noncalcareous, silty laminae; laminae irregularly bedded and discontinuous; burrows; pyrite nodules
938.1 to 938.2 ft (285.9 to 286.0 m)	Shale, dark greenish gray (5G4/1), contains layer of pyrite-replaced brachiopod shells
938.2 to 950.6 ft (286.0 to 289.7 m)	Shale, dark greenish gray (5G4/1), banded in places with greenish gray; faint black shale laminae; irregular non-calcareous silty inclusions
950.6 to 957.1 ft (289.7 to 291.7 m)	Shale, dark greenish gray (5G4/1), no color banding; uniform in appearance; silty stringers with pyrite nodules; brachiopod shells visible in fractures
957.1 to 960.1 ft (291.7 to 292.6 m)	Shale, dark greenish gray (5G4/1), with faint color banding of lighter greenish-gray layers; banding is along thin and discontinuous laminae
960.1 to 966.2 ft (292.6 to 294.5 m)	Shale, dark greenish gray (5GY4/1), very finely color banded with bioturbated black-shale laminae; dark gray, fine-grained nodules; pyrite nodules
966.2 to 973.3 ft (294.5 to 296.7 m)	Shale, dark greenish gray (5GY4/1), with prominent black shale beds; light gray, silty layers with pyrite stringers and nodules; burrows filled with brownish-green material
973.3 to 978.0 ft (296.7 to 298.1 m)	Shale, dark greenish gray (5GY4/1 to 5GY3/1), with faint color banding; thin black shale laminae; thin, light gray, silty laminae
978.0 to 992.3 ft (298.1 to 302.5 m)	Shale, dark greenish gray (5GY4/1 to 5GY3/1), with faint color banding; very few black shale laminae; light gray, silty laminae prominent; burrows
992.3 to 1014.0 ft (302.5 to 309.1 m)	Shale, dark greenish gray (5GY3/1) with distinct color banding of greenish-gray, greenish-black and black shale laminae; light gray non-calcareous, silty laminae; many laminae very thin (<3 mm) and disturbed by bioturbation
1014.0 to 1017.9 ft (309.1 to 310.3 m)	Shale, greenish black (5GY2/1) with some lighter shale interbeds; grades downward into shale with more numerous greenish-gray layers
1017.9 to 1054.0 ft (310.3 to 321.3 m)	Shale, greenish black (5GY2/1) with distinct color banding of light and dark greenish gray; black shale laminae; light gray, silty laminae; trace fossils; pyrite stringers
1054.0 to 1055.0 ft (321.3 to 321.6 m)	Shale, greenish gray interbedded with darker layers
1055.0 to 1083.0 ft (321.6 to 330.1 m)	Shale, grayish black (N2), with distinct interbedding of dark greenish-gray shales; bedding still in fine (<4 mm) laiminae; some light gray, silty laminae; scattered pyrite nodules concentrated at 1075

	GRASSY CREEK SHALE
1083.0 to 1103.0 ft (330.1 to 336.2 m)	Shale, grayish black (N2) thinly laminated; calcareous laminae with pyrite nodules centered along laminae; light brown spores visible on fracture surfaces
1103.0 to 1111.5 ft (336.2 to 338.8 m)	Shale, grayish black (N2), very thinly laminated with greenish-gray shale; thin (1-2 mm), calcareous, silty laminae; pyrite abundant in black shale and very abundant along calcareous, silty laminae
	SWEETLAND CREEK SHALE
1111.5 to 1124.0 ft (338.8 to 342.6 m)	Shale, grayish black (N2), very thinly laminated with greenish gray shale and light gray, calcareous, silty material; much bioturbation in greenish gray shales; contact from black shale down into greenish gray shale is sharp; contact from greenish gray to black shale is highly bioturbated
1124.0 to 1126.5 ft (342.6 to 343.4 m)	Shale, brownish olive gray (5Y4/1), laminated with dark greenish-gray and greenish-gray shales; some dark shale and light gray silty laminae
1126.5 to 1132.8 ft (343.4 to 345.3 m)	Shale, brownish olive gray (5Y4/1), uniform appearance
1132.8 to 1138.0 ft (345.3 to 346.9 m)	Shale, olive gray (5Y3/2), uniform appearance; zone of bioturbated greenish-gray shale from 1136.3 to 1136.5; gradational change to browner shale
1138.0 to 1145.8 ft (346.9 to 349.2 m)	Shale, brownish olive-gray (5Y4/1), uniform appearance; thinly laminated; contains spores; scattered greenish-gray and black-shale laminae; *Lingula*; bioturbated zone from 1141.2 to 1141.5
1145.8 to 1146.1 ft (349.2 to 349.3 m)	Shale, interlaminated black and greenish gray; prominent silty laminae, some calcareous
	Hunton Limestone Megagroup
	CEDAR VALLEY LIMESTONE
1146.1 to 1149.2 ft (349.3 to 350.3 m)	Limestone, light brownish gray; irregular bedding; calcite filled vugs; fossiliferous; many silt lenses
1149.2 to 1155.5 ft (350.3 to 352.2 m)	Shale, greenish gray, hard; calcite nodules; uniform appearance; does not break along bedding
1155.5 to 1158 ft (352.2 to 353.0 m)	Limestone, light brownish gray; vuggy; irregular bedding; stylolites

APPENDIX 6. Midland Electric Coal #1 Peters, Peoria County, Illinois

Location: SW¼ SW¼ NE¼, Sec. 11, T. 7 N., R. 6 E., Peoria County, Illinois
Elevation: 622 feet (189.6 m) above m.s.l. (kelly bushing)
Description: R. M. Cluff, March 1979

Depth	Description
	BURLINGTON LIMESTONE
– to 516.0 ft (– to 157.3 m)	Limestone, very light gray (N8), coarse biocalcarenite with fragmented crinoid and brachiopod debris; bottom contact irregular, stylolitic, sandy
	New Albany Shale Group
	HANNIBAL SHALE
516.0 to 531.0 ft (157.3 to 161.8 m)	Shale, greenish gray (5G6/1), highly bioturbated with silty or sandy burrow fillings; occasional very thin quartz sand laminae
531.0 to 537.0 ft (161.8 to 163.7 m)	Shale, as above, with interbedded burrowed silt beds 0.1 to 0.2 ft thick
537.0 to 545.0 ft (163.7 to 166.1 m)	Shale, dark greenish gray (5G4/1), bioturbated, with numerous small dark *Chondrites* burrows; scattered thin quartz silt laminae
545.0 to 560.5 ft (166.1 to 170.8 m)	Shale, dark greenish gray (5G3/1), and greenish gray (5G5/1); indistinctly bedded, with weak color banding; scattered burrow-disrupted silt lenses, numerous small burrows
	SAVERTON SHALE (approximate top)
560.5 to 583.0 ft (170.8 to 177.7 m)	Shale, dark greenish gray (5G4/1) with greenish black (5G2/1) interbeds, distinct color banding; weakly bioturbated; scattered thin pyritic silt laminae
583.0 to 592.0 ft (177.7 to 180.4 m)	Shale, greenish black (5G2/1), with dark greenish-gray (5G4/1) interbeds; weakly bioturbated; distinct color banding with sharp contacts or only very slightly burrowed contacts
592.0 to 601.0 ft (180.4 to 183.2 m)	Shale, as above, except with numerous dark *Chondrites* burrow networks; few silt laminae
601.0 to 612.5 ft (183.2 to 186.7 m)	Shale, greenish black (5G2/1), with dark greenish gray (5G4/1 to 5GY4/1) interbeds; weakly bioturbated; numerous thin pyritic quartz silt laminae; strongly contorted bedding from 607.75 to 608.5
612.5 to 632.8 ft (186.7 to 192.9 m)	core missing
632.8 to 648.8 ft (192.9 to 197.8 m)	Shale, olive-black (5Y2/1) with dark greenish-gray (5G4/1 to 5GY4/1) interbeds, sharp contacts; very small (<1 mm) burrows at tops of light colored beds; scattered thin silt laminae; scattered pyrite nodules
	GRASSY CREEK SHALE
648.8 to 661.5 ft (197.8 to 201.6 m)	Shale, olive-black (5Y2/1), pyritic; abundant *Tasmanites*; not visibly laminated but core has broken along numerous flat bedding planes; three very thin greenish-gray shale beds near top
	SWEETLAND CREEK SHALE
661.5 to 674.5 ft (201.6 to 205.6 m)	Shale, dark greenish gray (5GY5/1) with indistinct, interbedded, greenish black (5G2/1); highly-bioturbated, large *Zoophycos* and *Chondrites* burrows; scattered pyritic silt laminae
674.5 to 691.0 ft (205.6 to 210.6 m)	Shale, as above except interbedded with prominent beds of light greenish-gray shale (5G5/1); large burrows extend from base of light colored beds into underlying dark shale
691.0 to 699.1 ft (210.6 to 213.1 m)	Shale, dark olive-gray (5Y3/1), pyritic; abundant *Tasmanites*; not visibly laminated but broken along numerous closely spaced flat bedding planes

699.1 to 709.5 ft (213.1 to 216.3 m)	Shale, as above except interbedded with thin beds of dark greenish-gray (5GY4/1), burrowed shale; large *Zoophycos* burrows at 702 ft, 702.5 ft
709.5 to 715.8 ft (216.3 to 218.2 m)	Shale, olive-gray (5Y4/1); highly bioturbated; numerous large *Zoophycos* burrows
715.8 to 734.8 ft (218.2 to 224.0 m)	Shale, as above, except interbedded with greenish gray (5G5/1) bioturbated shale; large burrows extend from base of light beds into underlying dark shale
734.8 to 739.3 ft (224.0 to 225.3 m)	Shale, olive-gray (5Y4/1), with greenish-gray (5GY6/1) burrow mottling; scattered thin, calcareous, silt laminae disrupted by burrows; several prominent greenish-gray shale beds with large burrows at base
739.3 to 744.0 ft (225.3 to 226.8 m)	Shale, olive-gray (5Y5/1), highly bioturbated, with burrows becoming less distinct toward the base; pyritic, silty, thin pyritic sand at base (~3 mm thick)
	Hunton Limestone Megagroup
	CEDAR VALLEY LIMESTONE
744.0 to – ft (226.8 m to –)	Dolomite, olive-gray (5Y5/1), very fine grained, pyritic, bioturbated; coarse spar-filled vugs; scattered crinoid fragments

APPENDIX 7. Rector and Stone #1 Missouri Portland Cement, Hardin County, Illinois

Location: NE¼ NE¼ NE¼, Sec. 36, T. 11 S., R. 7 E., Hardin County, Illinois
Elevation: 578 feet (176 m) above m.s.l. (ground level)
Description: R. M. Cluff, J. A. Lineback, and M. L. Reinbold, Dec. 1978

Depth	Description
	New Albany Shale Group
	GRASSY CREEK SHALE
0 to 35 ft (0 to 10.7 m)	(No core) Drill cuttings: predominantly shale, brownish black (5YR2/1), siliceous, thinly laminated, weathered
35 to 52 ft (10.7 to 15.9 m)	Shale, brownish black (5YR2/1); massive to even and thinly laminated; highly fractured and mineralized
52 to 68 ft (15.9 to 20.7 m)	(No core) Drill cuttings; shale, brownish black (5YR2/1), hard; thinly laminated
68.0 to 79.0 ft (20.7 to 24.1 m)	Shale, olive-black (5Y2/1), to brownish black (5YR2/1), pyritic, hard, laminated, extensively fractured and mineralized; thin, dark olive-gray shale bed at 68.4 ft, with *Zoophycos* burrows
79.0 to 85.8 ft (24.1 to 26.2 m)	Shale, black (N1) to grayish black (N2), indistinctly laminated, pyritic, hard, calcareous and dolomitic laminae in lower part, brecciated and fractured with slight fluorspar mineralization. Thin greenish-black bed with indistinct burrows at 84.1 ft
	SELMIER SHALE
85.8 to 90.4 ft (26.2 to 27.6 m)	Shale, brownish black (5YR2/1) with some faint beds of olive-black (5Y2/1), a few dolomitic laminae, fractured; grades downward into shale, olive-gray (5Y4/1), thin laminae of darker shale, minor bioturbation, fractured, pyritic
90.4 to 92.0 ft (28.1 to 30.3 m)	Shale, olive-black (5Y2/1) to olive-gray (5Y4/1); discontinuous, parallel, thin dolomitic laminae; bioturbated, pyritic, hard, fractured
99.5 to 103.2 ft (30.3 to 31.5 m)	Shale, banded olive-gray (5Y4/1) and olive-black (5Y2/1); discontinuous, even, medium to very thin laminae; slightly bioturbated with small flattened burrows, highly fractured and mineralized
103.2 to 105.5 ft (31.5 to 32.2 m)	Shale, brownish black (5YR2/1); discontinuous, even, very thin to medium pyritic laminae; interbedded with shale, olive-gray (5Y4/1), burrowed, small flattened *Chondrites*
105.5 to 112.1 ft (32.2 to 34.2 m)	Shale, olive-gray (5Y4/1) with olive-black (5Y2/1) bands; highly bioturbated, indistinctly bedded; pyritic laminae; fault or explosion breccia with large clasts of gray and black shale at 108.2 ft
112.1 to 116.0 ft (34.2 to 35.4 m)	Shale, olive-black (5Y2/1) to brownish black (5YR2/1); widely spaced, discontinuous, even, very thin laminations, occasional burrows; grades into olive-gray (5Y4/1) shale at base, massive to indistinctly bedded, bioturbated, fractured
116.0 to 136.0 ft (35.4 to 41.5 m)	Shale, olive-black (5Y2/1) to brownish black (5YR2/1), a few compressed burrows; discontinuous, even, medium to thin laminae; pyritic, hard; thinly interbedded with shale; medium olive-gray (5Y5/1), massive to indistinctly bedded, highly bioturbated
136.0 to 142.0 ft (41.5 to 43.3 m)	Shale, interbedded brownish black (5YR2/1) and olive-black (5Y2/1) in bands 1-3 cm thick, slightly bioturbated, a few thin laminae, numerous mineralized fractures, some silt beds, dark olive-gray (5Y3/1) bed near base
142.0 to 147.0 ft (43.3 to 44.8 m)	Shale, interbedded dark olive-gray (5Y3/1) and olive-gray (5Y4/1) in bands 5 mm thick, grades into predominantly olive-gray shale, indistinctly bedded, burrowed
147.0 to 150.5 ft (44.8 to 45.9 m)	Shale, olive-black (5Y2/1), pyritic, massive
150.5 to 166.0 ft (45.9 to 50.6 m)	Shale, interbedded brownish black (5YR2/1) and dark olive-gray (5Y3/1) in bands 0.5 ft thick; discontinuous, even, very thin to medium laminae; gray shale slightly burrowed and indistinctly bedded; numerous mineralized fractures and brecciated zones

166.0 to 191.4 ft (50.6 to 58.4 m)	Shale, olive-black (5Y2/1) to brownish black (5YR2/1); indistinct, even, thin laminae, a few thick and very indistinct silt laminae; mineralized and pyritic fractures, scattered pyrite nodules; much of core broken and reduced to rubble
191.4 to 215.9 ft (58.4 to 65.8 m)	Shale, brownish black (5YR2/1) to olive-black (5Y2/1); indistinct, even, very thin to thin laminae, several pyrite and silt laminae; fractured, periodotite dikes and thin breccias
215.9 to 230.4 ft (65.8 to 70.3 m)	Shale, olive-black (5Y2/1) to brownish black (5YR2/1), massive to indistinctly bedded, pyritic, some high angle fractures; a few even, thin laminae; interbedded with dark olive-gray (5Y3/1) shale, massive, pyritic
230.4 to 243.0 ft (70.3 to 74.1 m)	Shale, olive-black (5Y2/1), indistinctly laminated shale grading into massive shale, numerous mineralized fractures
243.0 to 253.0 ft (74.1 to 77.2 m)	Shale, brownish black (5YR2/1) to grayish black (N2), even, very thin to medium laminae, pyritic, some thickening and thinning of laminae, mineralized fractures and breccias
253.0 to 261.1 ft (77.2 to 79.6 m)	Shale, olive-black (5Y2/1) to black (N1) at base, even, very thin laminae, several pyrite laminae, mineralized fractures; coring stopped at 261.1 ft

APPENDIX 8. Gordon T. Jenkins #1 Simpson, Wayne County, Illinois

Location: SW¼ SE¼ SW¼, Sec. 17, T. 3 S., R. 8 E., Wayne County, Illinois (API Number 1219129436)
Elevation: 387 feet (118.0 m) above m.s.l. (kelly bushing)
Description: J. A. Lineback and R. M. Cluff, Oct. 1979

Depth	Description
	SPRINGVILLE SHALE
5010.0 to 5031.3 ft (1527.0 to 1533.5 m)	Shale, olive-black (5Y2/1) to olive-gray (5Y3/1), massive with few irregularly spaced partings, conchoidal breakage, noncalcareous, major vertical fracture throughout
	Kinderhookian Series
	CHOUTEAU LIMESTONE
5031.3 to 5041.4 ft (1533.5 to 1536.6 m)	Limestone, olive-gray (5Y4/1) with greenish black (5G2/1) shaly partings, nodular bedded, abundant crinoid fragments, sharp base, gradational upper contact with Springville shale
	New Albany Shale Group
	HANNIBAL-SAVERTON SHALES
5041.4 to 5041.5 ft (1536.6 to 1536.6 m)	Shale, light olive-gray (5Y6/1), noncalcareous, bioturbated with small *Zoophycos* burrows (Jacobs Chapel Bed)
5041.5 to 5042.7 ft (1536.6 to 1537.0 m)	Shale, brownish black (5YR2/1), noncalcareous, very thin even parallel laminations in lower part, small burrows penetrate top from overlying gray-shale (Henryville Bed)
5042.7 to 5042.8 ft (1537.0 to 1537.0 m)	Shale, dark brownish gray (5YR3/1), with large phosphatic nodules (Falling Run Bed)
5042.8 to 5043.2 ft (1537.0 to 1537.2 m)	Shale, brownish black (5YR2/1) as above
5043.2 to 5043.3 ft	Shale, brownish black (5YR2/1) as above
5043.3 to 5051.2 ft (1537.2 to 1539.6 m)	Shale, olive-gray (5Y4/1) grading downward into olive-black (5Y2/1), massive, calcareous in upper part, brachiopods scattered throughout and most abundant in lower portion; scoured basal contact with concentration of brachiopod shells
	GRASSY CREEK SHALE
5051.2 to 5074.0 ft (1539.6 to 1546.6 m)	Shale, brownish black (5YR2/1), noncalcareous, irregularly spaced thin pyritic laminae, some layers of slightly lighter colored shale; several mineralized fractures between 5066 and 5070 ft
5074.0 to 5097.0 ft (1546.6 to 1553.6 m)	Shale, brownish black (5YR2/1), very thin dolomitic and calcareous laminations, pyritic, few fractures; silty(?) pyritic layer 0.2 ft thick at 5077.1 ft; core badly broken and fractured below 5087 ft; footages near base are approximate; fractures closely spaced and mineralized below 5095 ft
5097.0 to 5136.0 ft (1553.6 to 1566.1 m)	Shale, brownish black (5YR2/1), pyritic, few irregularly spaced very thin dolomitic laminations, noncalcareous, scattered short high-angle fractures; bottom one foot highly broken
5136.0 to 5149.5 ft (1566.1 to 1569.6 m)	Shale, brownish black (5YR2/1), slightly pyritic, very thin faint dolomitic laminae, two thin beds of dark olive-gray shale (5Y4/1), long near-vertical fracture in lower part
5149.5 to 5162.0 ft (1569.6 to 1573.4 m)	Shale, brownish black (5YR2/1) to olive-black (5Y2/1), with many very thin beds of olive-gray shale (5Y4/1) with burrows extending down from bases into black shale; pyritic and thin dolomitic laminae common; bottom three to four feet highly shattered and fractured
5162.0 to 5178.0 ft (1573.4 to 1578.3 m)	Shale, brownish black (5YR2/1), pyritic, few thin dark olive-gray to olive-black beds; bottom four feet highly broken and fractured
5178.0 to 5184.5 ft (1578.3 to 1580.2 m)	Shale, brownish black (5YR2/1) with thin interbeds of olive-gray (5Y4/1) shale, discontinuous, even, very thin laminae, gray shales slightly bioturbated, several irregular dolomitic siltstone lenses; discontinuous vertical fractures throughout

	SELMIER SHALE
5184.5 to 5199.0 ft (1580.2 to 1584.7 m)	Shale, olive-gray (5Y4/1) to dark olive-gray (5Y3/1), indistinctly bedded and moderately bioturbated; interbedded with thin olive-black (5Y2/1) shales; black shales have sharp bases and bioturbated tops, *Zoophycos* and *Chondrites* burrows most common; discontinuous even and lenticular dolomitic laminae common in less burrowed zones; several brachiopods at 5195.7 ft; major vertical fracture from 5190-5205 ft
5199.0 to 5218.5 ft (1584.7 to 1590.6 m)	Shale, brownish black (5YR2/1) to olive-black (5Y2/1), widely spaced and irregular discontinuous-even thick dolomite laminations, very few thin beds of lighter colored shale; several zones of closely spaced even-parallel pyritic laminae
5218.5 to 5220.9 ft (1590.6 to 1591.3 m)	Shale, brownish black (5YR2/1) interbedded with olive-gray (5Y4/1), widely spaced even very thin laminae, pyritic; small pyritic burrows in gray shales
5220.9 to 5224.5 ft (1591.3 to 1592.4 m)	Shale, brownish black (5YR2/1) to olive-black (5Y2/1), pyritic with numerous nodules and thick laminations
5224.5 to 5229.8 ft (1592.4 to 1594.0 m)	Shale, olive-gray (5Y4/1 to 5Y3/1), indistinctly bedded to massive, moderately bioturbated, few widely spaced thin pyrite laminations, many small pyrite nodules, indistinct beds of slightly darker shale
5229.8 to 5236.9 ft (1594.0 to 1596.2 m)	Shale, olive-black (5Y2/1 to 5Y3/1), few thin even-parallel dolomitic and pyritic laminae, numerous irregular pyrite nodules
5236.8 to 5246.3 ft (1596.2 to 1599.1 m)	Shale, brownish black (5YR2/1), even-parallel and discontinous even very thin laminations, pyritic with scattered nodules, noncalcareous
	BLOCHER SHALE
5246.3 to 5275.1 ft (1599.1 to 1607.8 m)	Shale, brownish black (5YR2/1), even-parallel very thin pyritic laminations, highly calcareous, very sharp upper contact; several calcisiltite beds up to 5 cm thick and slightly lenticular or cross-bedded (@ 5250.1 ft, 5253.0 ft, 5259.8 ft, 5261.5 ft, 5265.9 ft, and 5273.7 ft); shale is slightly more massive in lower part and is speckled with microfossils (?); major vertical fractures from 5246-5252 ft and 5261-5275.5 ft
	Hunton Limestone Megagroup
	LINGLE LIMESTONE
5275.1 to 5275.5 ft (1607.8 to 1608.0 m)	Limestone, medium dark gray (N4), very argillaceous, pyritic, abundant coarse crionoidal fragments, sharp top and gradational base
5275.5 to 5285.3 ft (1608.0 to 1611.0 m)	Limestone, medium light gray (N6), fossiliferous packstone with abundant coarse crinoidal fragments; fossil fragments becoming coarser downward, many irregular discontinuous argillaceous streaks in upper two feet, less argillaceous towards base; few very thin dark shale streaks (stylolitic residues?); large rugose corals at 5284.0 ft; no fractures

APPENDIX 9. Outcrop Section of the top of the New Albany Shale Group on Hicks Branch

Location: just south of center, Sec. 25, T. 11 S., R. 7 E., Hardin County, Illinois
Description: R. M. Cluff, Nov. 30, 1978

Description	Thickness: ft (m)
FT. PAYNE FORMATION	
Chert, dark yellowish orange (10YR6/6), deeply weathered, thin bedded	10+ (3+)
SPRINGVILLE SHALE	
Shale, pale yellowish brown (10YR6/2), siliceous, platy to fissile, burrowed (?) mostly covered	10.0 (3.0)
Shale, greenish black (5G2/1), highly glauconitic, bioturbated	0.7 (0.2)
Shale, pale green (10G7/2), to greenish gray (5G6/1), soft, fissile, slightly glauconitic	3.0 (0.9)
CHOUTEAU LIMESTONE	
Limestone, dark yellowish orange (10YR6/6), dolomitic; crinoidal wackestone, greenish stained burrows, thin shaly break between the two wavy- to nodular-bedded units	1.0 (0.3)
New Albany Shale Group	
GRASSY CREEK SHALE	
JACOBS CHAPEL BED	
Shale, greenish gray, deeply weathered to orange residue in creek bed	~2.5 (~0.8)
HENRYVILLE BED	
Shale, brownish black (5YR2/1) to grayish black (N2), fissile, thinly laminated, fractured; weathers to slightly greenish surface coloration	1.0 (0.3)
FALLING RUN NODULE BED	
Shale, as above with abundant phosphatic nodules	0.5 (0.2)
Shale, dark gray (N3), soft, fissile, few scattered phosphatic nodules	0.5 (0.2)
Shale, brownish black (5YR2/1), fissile, thinly laminated, pyritic, highly fractured, dense	10+ (3+)

APPENDIX 10. Type section of the Blocher and Morgan Trail Members

Type section of the Blocher and Morgan Trail Members (Lineback, 1968, 1970), revisited and revised 1979. Location: road cut along Indiana Highway 56, beginning in the stream bed at SE¼ SW¼ SW¼, Sec. 9, thence along the north line of the NW¼, Sec. 16, T. 3 N., R. 8 E., Jefferson and Scott Counties, Indiana. Blocher 7½' Quadrangle

	Thickness ft (m)
New Albany Shale: 47.8 ft (14.55 m) exposed	
CAMP RUN MEMBER: 7.5 ft (2.25 m) exposed	
14. Shale, brownish black (5YR2/1), fissile to platy	3.5 (1.05)
13. Shale, dark greenish gray (5GY4/1), flaky to blocky	0.5 (0.15)
12. Shale, brownish black (5YR2/1), fissile	0.8 (0.25)
11. Shale, dark greenish gray (5GY4/1), flaky to blocky	0.9 (0.25)
10. Shale, brownish gray (5YR4/1), fissile	1.4 (0.45)
9. Shale, dark greenish gray (5GY4/1), flaky	0.4 (0.19)
MORGAN TRAIL MEMBER: 29.5 ft (9.00 m)	
8. Shale, brownish black (5YR2/1), fissile to platy, carbon-rich; has several hard pyritic beds less than 0.05 ft (1.5 cm) thick in lower part; weathers gray, brown, and yellow	29.5 (9.00)
SELMIER MEMBER: 8.6 ft (2.65 m)	
7. Shale, greenish gray (5GY6/1), blocky; very weathered and poorly exposed	3.0 (0.90)
6. Dolomitic quartzose rock, brownish gray (5YR4/1); weathered	0.1 (0.05)
5. Shale, brownish black (5YR2/1), fissile to platy, dolomitic	5.5 (1.70)
BLOCHER MEMBER: 2.2 ft (0.65 m)	
4. Shale, brownish black (5YR2/1), platy to fissile, calcareous, hard; brachiopods and pteropods near top; weathers gray	2.0 (0.60)
3. Weathered ferruginous layer. Altitude 600 ft (183 m)	0.2 (0.05)
North Vernon Limestone: 1.1 ft (0.30 m) exposed	
2. Limestone, medium bluish gray (5B5/1), coarsely crystalline, fossiliferous; weathers gray	0.4 (0.10)
1. Limestone, light gray (N7), coarsely crystalline, fossiliferous; weathers brownish gray	0.7 (0.20)

APPENDIX 11. Type section of the Selmier Member

Type section of the Selmier Member (Lineback, 1968, 1970), revisited and revised 1979. Location: Measured in north wall of the Berry Materials Co. quarry in the NW¼ SW¼ SE¼, Sec. 27, T. 7 N., R. 8 E., and in the south wall, NE¼ NW¼, Sec. 34, T. 7 N., R. 8 E., North Vernon, Jennings County, Indiana. Butlerville 7½′ Quadrangle. The revised lower part of the section was measured in the north wall as exposed in 1979; the remainder of the Selmier is described from the original section in the south wall.

	Thickness ft (m)
New Albany Shale: 45.0 ft (13.8 m) exposed	
MORGAN TRAIL MEMBER: 13.0 ft (4.0 m) exposed	
24. Shale, brownish black (5YR2/1), fissile; weathers dark gray, brown, and yellow; pyritic beds as much as 0.1 ft (3 cm) thick are harder than the rest of the shale and form polygonal blocks on talus slope	13.0 (4.0)
SELMIER MEMBER: 27.1 ft (8.25 m)	
23. Shale, greenish gray (5GY6/1), blocky; weathers greenish gray to gray, very sharp contact with overlying black shale	2.1 (0.65)
22. Dolomite, weathered, brown; ferruginous	0.1 (0.05)
21. Shale, greenish gray (5GY6/1), blocky; weathers greenish gray to gray	3.3 (1.00)
20. Dolomite in lenticular beds, greenish gray (5GY6/1), micritic, pyritic	0.2 (0.05)
19. Shale, greenish gray (5GY6/1), blocky; weathers greenish gray to gray	6.0 (1.85)
18. Concretions, dolomitic, septarian, as much as 2 ft (0.6 m) in diameter and 0.5 ft (0.15 m) thick, dark greenish gray (5GY4/1), micritic; weathers brown; veins of pink dolomite	0.5 (0.15)
17. Shale, greenish gray (5GY6/1), blocky; weathers greenish gray to gray	1.0 (0.30)
16. Shale, olive-gray (5Y4/1), platy; weathers light gray	2.5 (0.75)
15. Shale, olive-gray (5Y3/1), fissile; harder than unit 16	0.5 (0.15)
14. Shale, olive-gray (5Y4/1), blocky	0.8 (0.25)
13. Shale, olive-gray (5Y3/1), platy	0.3 (0.10)
12. Shale, olive-gray (5Y4/1), blocky to platy, soft; contacts gradational	1.6 (0.50)
11. Shale, brownish gray (5YR3/1), fissile to platy; weathers medium gray; contains spores	1.0 (0.30)
10. Dolomitic quartzose rock. light brownish-gray (5YR6/1), pyritic; burrows; weathers light brown	0.4 (0.10)
9. Shale, olive-gray (5Y4/1), flaky, soft	1.3 (0.40)
8. Dolomitic quartzose rock; lenticular; weathers brown; burrows on upper surface; pyritic	0.4 (0.10)
7. Shale, brownish black (5YR2/1), fissile, hard; conchoidal fracture; dolomitic; lenticular beds of dolomite up to 0.1 ft (5 cm) thick; weathers gray	5.1 (1.55)
BLOCHER MEMBER: 4.9 ft (1.50 m)	
6. Shale, brownish-black (5YR2/1), fissile to platy, calcareous; hard; faintly laminated; conchoidal fracture; contains discontinuous lenses of micritic limestone, dark brown (5YR2/2), up to 0.8 ft (25 cm) thick about 3 feet (1 m) above base; several thin (1 cm) beds of calcareous sandstone in lower part; pteropods and brachiopods on some bedding planes; weathers light gray; lower 2 cm very pyritic	4.9 (1.50)
North Vernon Limestone: 1.4 ft (0.40 m) measured	
2. Limestone, dark gray (N4), finely crystalline, fossiliferous; phosphatic fossil layers; faint wavy beds	0.7 (0.20)
1. Limestone, light-gray (N7), crystalline, fossiliferous; irregular wavy beds	0.7+ (0.2+)