Stratigraphy of the New Albany Shale in Indiana

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By JERRY A. LINEBACK

DEPARTMENT OF NATURAL RESOURCES
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By JERRY A. LINEBACK[1]

Abstract

The New Albany Shale in Indiana is composed of dolomitic and siliceous brownish-black carbon-rich shale, greenish-gray mudstone and shale, and minor amounts of dolomite and quartzose rocks. Five lithologically distinct members are recognized, in descending order: (1) Clegg Creek Member—massive brownish-black silty and dolomitic pyritic shale; (2) Camp Run Member—interbedded brownish-black shale and greenish- to olive-gray mudstone and shale; (3) Morgan Trail Member—brownish-black shale containing many thin pyritic beds; (4) Selmier Member—greenish-gray dolomitic mudstone; and (5) Blocher Member—brownish-black calcareous to dolomitic pyritic shale.

The Blocher and Selmier Members can be traced into the subsurface of the Illinois Basin and appear to have equivalents in Illinois, Ohio, and Tennessee. The New Albany Shale above the Selmier can be divided into several lithologic units in the subsurface, but these units do not appear to be directly equivalent to named surface units. The Antrim Shale, the Ellsworth Shale, and the Sunbury Shale are Michigan Basin equivalents of the New Albany Shale, and the Ellsworth Shale extends into the northeastern part of the Illinois Basin, where it is designated a member of the New Albany.

Biostratigraphic studies indicate that New Albany deposition began in late middle Devonian time and ended in middle Kinderhookian (early Mississippian) time. The Devonian-Mississippian boundary is placed 2 to 6 feet below the top of the formation.

The New Albany Shale was deposited in a widespread marine environment. Deoxygenated conditions caused by lack of water circulation resulted in an accumulation of organic matter as an important part of the sediment. A densely intertwined mat of floating algae is postulated as the source of much of the organic matter. Such a mat may have aided in establishing reducing conditions

[1]Illinois State Geological Survey; formerly, Indiana University and Indiana Geological Survey.

by restricting wind-induced water circulation. Partial or complete destruction of the floating mat by storms or disease would have allowed deposition of sediment lacking organic matter in the areas where the floating mat was absent. The plants also might have caused precipitation of carbonate by lowering the hydrogen ion concentration of the water owing to withdrawal of carbon dioxide. A variety of evidence suggests that water depth during New Albany deposition in southeastern Indiana was less than 200 feet but also that depth was not a factor in controlling black mud deposition.

Introduction

AREA OF STUDY

In southeastern Indiana the New Albany Shale crops out at the surface and beneath thin Illinoian glacial drift from the Ohio River to Columbus, about 70 miles north of the river (fig. 1). From this point northward the bedrock is covered by thick glacial drift, most of which is Wisconsinan in age. The drift-covered outcrop belt extends to northwestern Indiana, where only scattered exposures of the New Albany Shale are found. West of the outcrop belt in Indiana, the New Albany Shale is present everywhere beneath younger rocks. Another large area of drift-covered and subsurface middle and upper Devonian and lower Mississippian rocks, which can be correlated with the New Albany Shale, lies north of the Cincinnati Arch in Indiana (fig. 1). These rocks are part of the Michigan Basin sequence and were continuous with the New Albany Shale before erosion removed upper Devonian rocks from the crest of the arch.

PURPOSE OF STUDY

The purpose of this study is to describe the lithology and stratigraphy of the New Albany Shale and equivalent strata in Indiana. Basic stratigraphic studies form the groundwork for lithologic subdivision of the formation into members, for indication of relationships of the New Albany Shale to the whole of the middle and upper Devonian and lower Mississippian black shale sequence, and for interpretation of the depositional environment of the formation.

PREVIOUS WORK AND ACKNOWLEDGMENTS

Although the name New Albany as a stratigraphic term was not

Figure 1. Map of Indiana showing distribution of the New Albany Shale and equivalent strata. Geology from Indiana Geological Survey Atlas Map 9, 1956.

proposed until 1874 (Borden, 1874, p. 158), the black shale in Indiana had for many years received the attention of geologists. The first mention of the black shale was by D. D. Owen (1838), who assigned it to the sub-Carboniferous. Hall (1842, 1843) and Clapp (1843) correlated it with the Genesee Shale (Devonian) of New York. Marine fossils of Genesee age from the lower few feet of the formation were first described by Whitfield (1875). The first chemical analyses of samples of the New Albany were made by Duden (1897), and the first comprehensive stratigraphic and paleontologic studies were made by Kindle (1899, 1901).

Reeves (1922) also analyzed samples of the formation and reported on its oil-shale potential. Brachiopods and conodonts from the New Albany Shale were described by Huddle (1933, 1934). Stratigraphic studies by Dawson (1941) and by Campbell (1946, 1956), who first proposed subdivision of the New Albany, are the most recent published reports on the formation, but Fisher (1953) included Indiana in an unpublished regional paleoecologic study. The results of the present study have appeared in abstract form (Lineback, 1963b), in a short version of this report (Lineback, 1968), and in a regional summary (Collinson and others, 1967).

The author gratefully acknowledges the support of the Indiana Geological Survey during the fieldwork and preparation of this report. Dr. Carl Rexroad is extended special thanks for identifying conodonts from the New Albany Shale and for expressing opinions with regard to their age and correlation. Thanks are extended also to Professor Donald E. Hattin, of the Department of Geology, Indiana University, who supervised the preparation of the dissertation on which this report is based (Lineback, 1964), and to Messrs. Philip Malone and Gerald Johnson, who aided in some of the fieldwork.

Principal Rock Types

Brownish-black carbon-rich shale constitutes more than 80 percent of the New Albany Shale over most of southwestern Indiana (fig. 2). Greenish-gray shale, dolomite, and quartzose rocks are interbedded with the brownish-black shale. The presence of these other lithologies

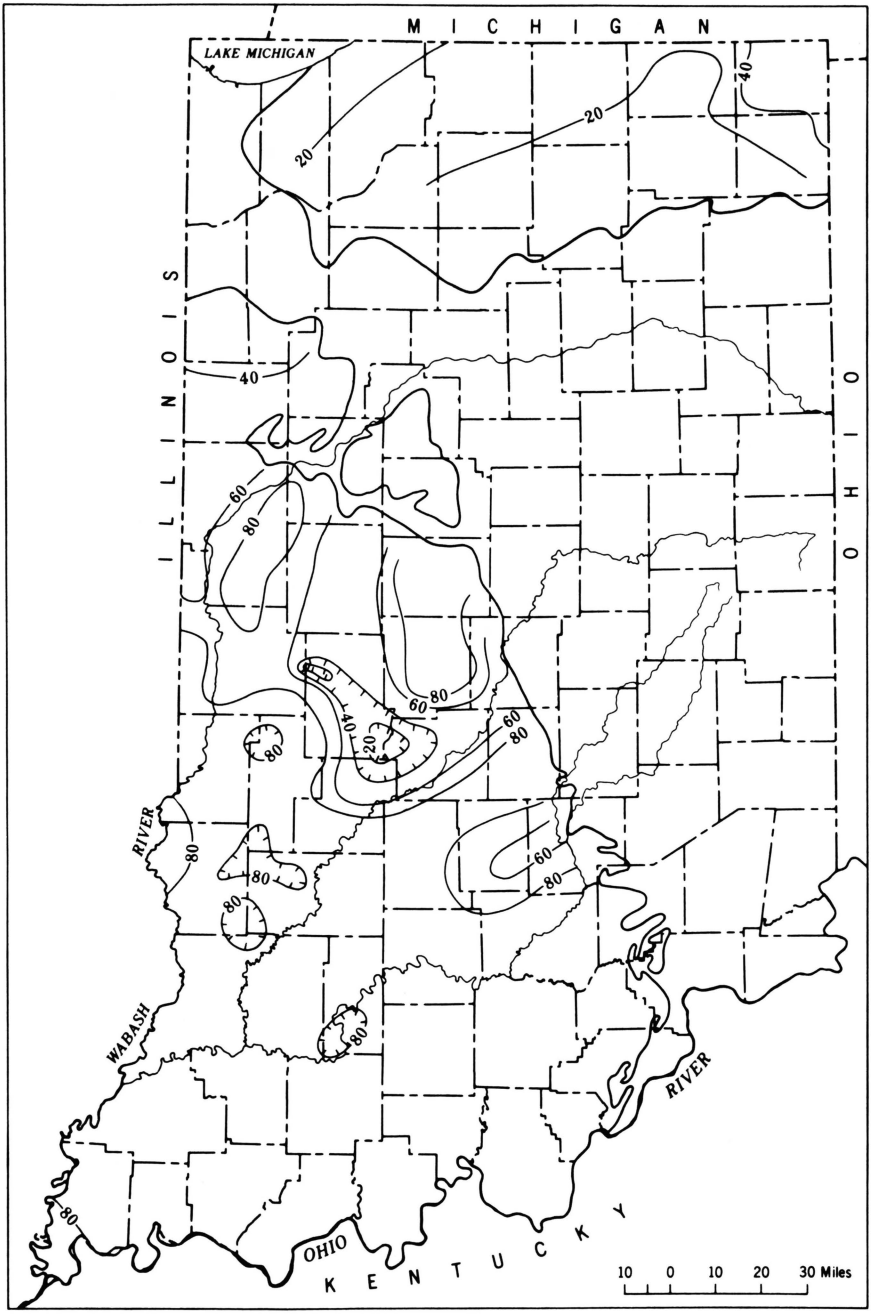

Figure 2. Map showing percentage of brownish-black carbon-rich shale darker than 5YR 3/1 in the New Albany Shale and equivalent strata. Contour interval 20 percent.

permits stratigraphic division of the New Albany Shale. Brownish-black shale is less prominent in northwestern Indiana largely owing to the greater abundance of greenish-gray shale, and in the Michigan Basin, rocks equivalent to the New Albany Shale generally have a still lower content of brownish-black shale (fig. 2). The low concentration of brownish-black shale in Putnam and Morgan Counties, however, is largely due to the fact that some of the carbon-rich shale there is brownish gray (5YR 4/1) or lighter.

BROWNISH-BLACK SHALE

The dark shale of the New Albany is characterized by as much as 20 percent by weight of organic matter and is appropriately referred to as carbon rich. The organic matter in the carbon-rich shale consists of very fine flakes of unidentifiable organic debris which is assumed to be of vegetable origin. Also present are recognizable plant fragments, including *Tasmanites* and other sporelike bodies. These exines occur either as flattened bodies in the shale or as spherical bodies filled with quartz or pyrite. The organic matter appears yellowish to reddish brown in thin section, but depending on its abundance, it colors the shale various shades ranging from brownish gray to black. The bulk of the New Albany Shale is brownish black (5YR 3/1) or darker. Some is brownish gray (5YR 4/1) or lighter, and some is black (N1). Since all carbon-rich shale in the New Albany has lithologic characteristics similar to the brownish-black shale, the several color varieties will be discussed together.

X-ray diffraction patterns show a uniformly high quartz content for brownish-black shale samples, but much of this quartz is too fine grained to be visible under the petrographic microscope. Grains of quartz silt, visible in thin section, are present in widely ranging quantity. Microscopically visible grains of dolomite are scattered throughout the shale. Pyrite occurs as microscopic spherical bodies, grains, or crystals and as irregular masses and nodules ranging in size from microscopic to 2.5 feet in diameter.

Clay minerals, less abundant than quartz in the New Albany Shale, include chlorite, illite, and mixed-layer clays. Illite is the most

abundant clay mineral. Subsurface samples from southwestern Indiana studied by Schemehorn (1956) indicated an increase in the amount of these clay minerals from west to east. According to Schemehorn, greenish-gray shale in the New Albany contains more montmorillonite and chlorite than the brownish-black shale does.

Several varieties of brownish-black carbon-rich shale are recognized in the New Albany Shale; these varieties include laminated dolomitic shale, nonlaminated dolomitic shale, and nonlaminated nondolomitic shale.

Laminated brownish-black dolomitic shale in the New Albany Shale consists of alternating laminae of carbon-rich sediment and laminae of dolomicrite or a mixture of dolomicrite and quartz silt. Dolomite laminae average 0.1 mm in thickness, are lenticular and irregularly spaced, and are essentially free of organic matter.

Laminated and nonlaminated dolomitic to calcareous brownish-black shale characterizes the lower part of the New Albany. Carbonate minerals in these beds at such places as the Clark County stone quarry (W¼ lot 90, Clark's Grant) make up more than 50 percent of the rock and occur as small grains of dolomite or calcite within a carbon-rich matrix.

Some parts of the New Albany Shale consist of siliceous brownish-black shale which is nondolomitic and not visibly laminated. Silt-sized quartz is commonly present in small amounts of these rocks, in which some spore exines retain their original shape because they are filled with quartz or pyrite. The organic content of some samples of this lithology is high.

GREENISH-GRAY SHALE

Greenish-gray shale and mudstone in the New Albany Shale contain very little organic matter. Some of these rocks are thinly laminated, but others are nonlaminated or have had the layering disturbed by burrowing organisms. In some places greenish-gray shale and brownish-black shale have been intermixed, and the resulting appearance is that of poorly mixed black and green paint. The intermixing is interpreted

as the result of partial removal of organic matter through the feeding of burrowing organisms and of infilling of burrows by overlying greenish-gray sediment.

The contacts between greenish-gray shale and brownish-black shale beds are generally sharp, and such contacts represent abrupt changes in environmental conditions. Most of the greenish-gray shale beds have a greater clay-mineral content than the brownish-black beds do. Greenish-gray shale layers contain pyrite as fillings of spherical *Tasmanites* exines and as euhedral crystals dispersed in the shale. Dolomite is present as isolated grains or aggregates of small dolorhombs. Some of the greenish shale contains quartz silt, and some is calcareous. Because greenish-gray shale beds contain more fossils than other parts of the formation, environmental conditions during their deposition were probably more favorable. In the New Albany Shale the only demonstrably benthonic faunal elements, which include burrows and tracks made by worms and arthropods, occur in or immediately beneath greenish-gray shale beds.

DOLOMITE

Dolomite is present in the New Albany Shale as dolomicrite concretions, as beds of dolomicrite, and as beds of clastic dolosparite. Dolomicrite concretions lie at various horizons, both in greenish-gray shale and in brownish-black shale. Those in greenish-gray shale are greenish gray and some are of the separian variety. Concretions in brownish-black shale are also brownish black and contain abundant organic matter.

The lower two members of the New Albany contain lenticular beds of dolomicrite which range from mere laminae to beds as much as 1 foot thick. Dolomite and less abundant micritic calcitic dolomite in the Blocher Member contain tests of pteropods in some places.

A few lenticular layers of crossbedded dolosparite are present in the New Albany Shale. Dolosparite and dolomicrite beds contain less than 12 percent angular quartz silt.

QUARTZOSE ROCKS

Rocks consisting of clastic quartz and fragmental phosphatic organic debris in a cement of sparry dolomite and pyrite are confined to the lower two members of the New Albany Shale. The average dimension of quartz grains in these rocks is 0.18 mm, and the range is 0.90 to less than 0.01 mm. The quartz grains are well sorted and rounded, are frosted, and constitute 26 to 48 percent of the rock. Organic content of the quartzose rocks ranges from 1 to 18 percent and consists of brown angular to rounded phosphatic pellets, bones and teeth of fish, and conodonts. The average size of organic particles is greater than that of the quartz grains, but size distribution is irregular.

The sparry dolomite cement consists of interlocking grains that also are larger than the quartz grains. The dolomite content exceeded 50 percent in 3 of the 10 samples examined and was as great as 57 percent.

Pyrite in the quartzose rocks occurs as irregular grains and as isolated crystals commonly associated with organic matter. Pyrite content ranges from traces to 35 percent. In some samples pyrite has replaced a large part of the dolomite, so that the rocks are now pyrite cemented.

Relation to Underlying Rocks

The New Albany Shale (middle and upper Devonian and lower Mississippian) paraconformably overlies the North Vernon Limestone (middle Devonian) in southeastern Indiana (fig. 3). Paraconformity between the two formations is indicated by a phosphatic limestone bed immediately underlying the New Albany Shale throughout most of the outcrop area. This middle Devonian phosphatic bed is a lag concentrate containing phosphatic pebbles, conodonts, fish teeth, and fish bones. Broken fragments of dark phosphatic material and phosphatic oolite-like bodies are common in the bed and impart a salt-and-pepper aspect to the rock. Burrows also occur in the upper part of the phosphatic bed. The bed is as thick as 1 foot but is absent in places.

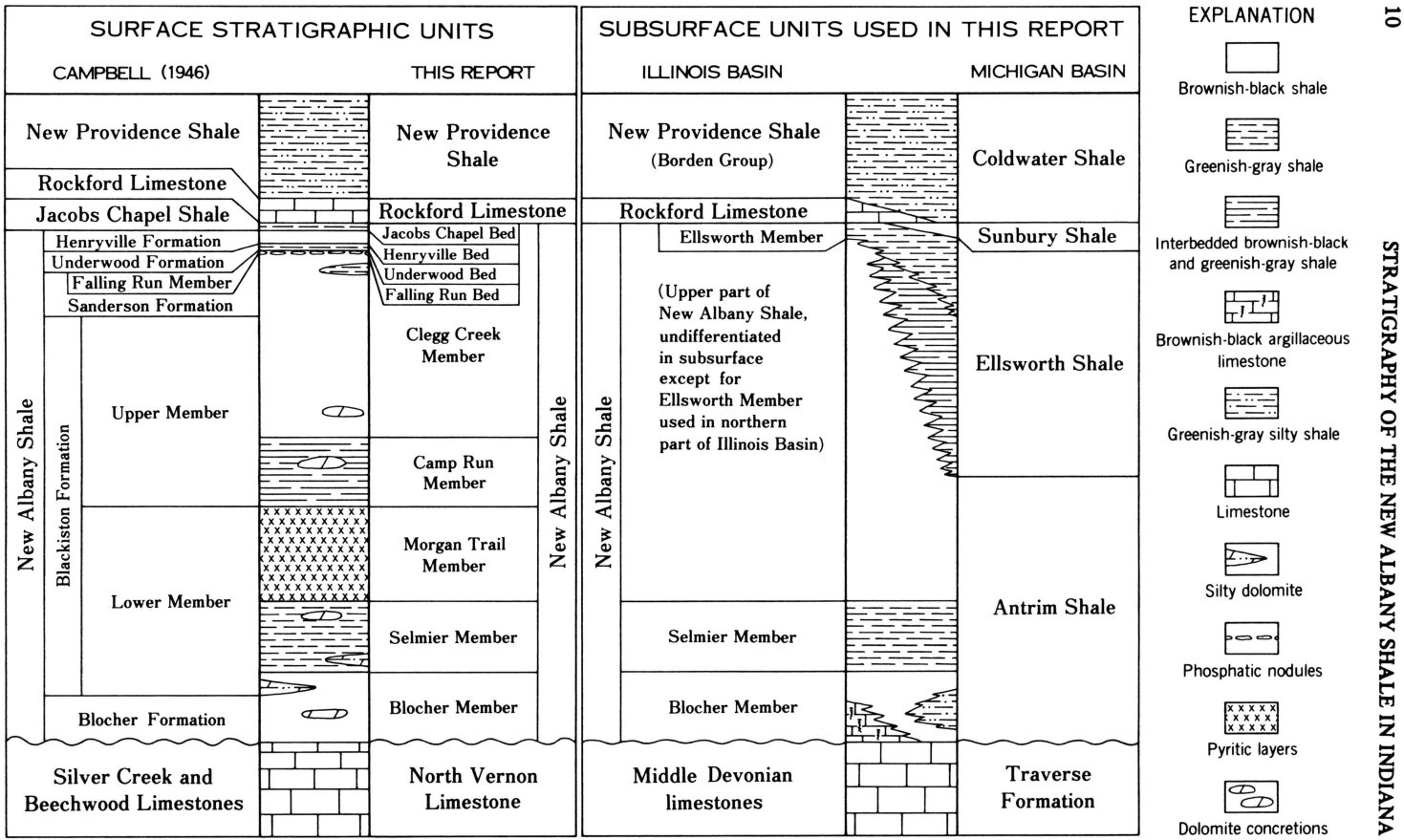

Figure 3. Columnar sections showing nomenclature of the New Albany Shale and adjacent strata.

The presence of the lag concentrate indicates a period of nondeposition before New Albany sedimentation began. During this time the upper part of the North Vernon Limestone was reworked by marine currents, and concentration of the phosphatic material resulted. The contact between the North Vernon and the New Albany is essentially a plane surface, and no evidence of subaerial exposure prior to New Albany deposition is apparent in southern Indiana. The contact is sharp and no transition zone occurs, but the lower few feet of the New Albany Shale commonly is calcareous.

In northern Kentucky and at a few places in southern Clark County, Ind., the phosphatic bed is absent, and the New Albany Shale rests on a crinoidal limestone facies of the North Vernon that has been called the Beechwood facies or Beechwood Member.

North of Columbus (fig. 1), the New Albany Shale overlies limestones of middle Devonian age except in local areas in White County, where well samples show the New Albany resting on Silurian dolomite (Melhorn, 1958). The middle Devonian limestones are about 300 feet thick in southwestern Indiana and thin to the north and east. Generally the rocks directly underlying the New Albany Shale in the subsurface are brownish-gray to light-gray crystalline limestone or crinoidal limestone.

The upper few inches of the North Vernon Limestone is pyritized to varying degrees both in surface exposures and in cores. Possibly reducing conditions, effected at the beginning of New Albany deposition, penetrated the underlying sediment and resulted in the formation of pyrite, or the pyrite could have been carried downward in solution from the overlying pyritiferous shale.

Lithostratigraphy of the New Albany Shale

The name "New Albany black slate" was proposed by Borden (1874, p. 158) for slatelike rocks lying above the crinoidal limestone and capped by a ferruginous limestone. The type area is along the Ohio River at New Albany, Floyd County (fig. 4). The formation later became known as the New Albany Shale.

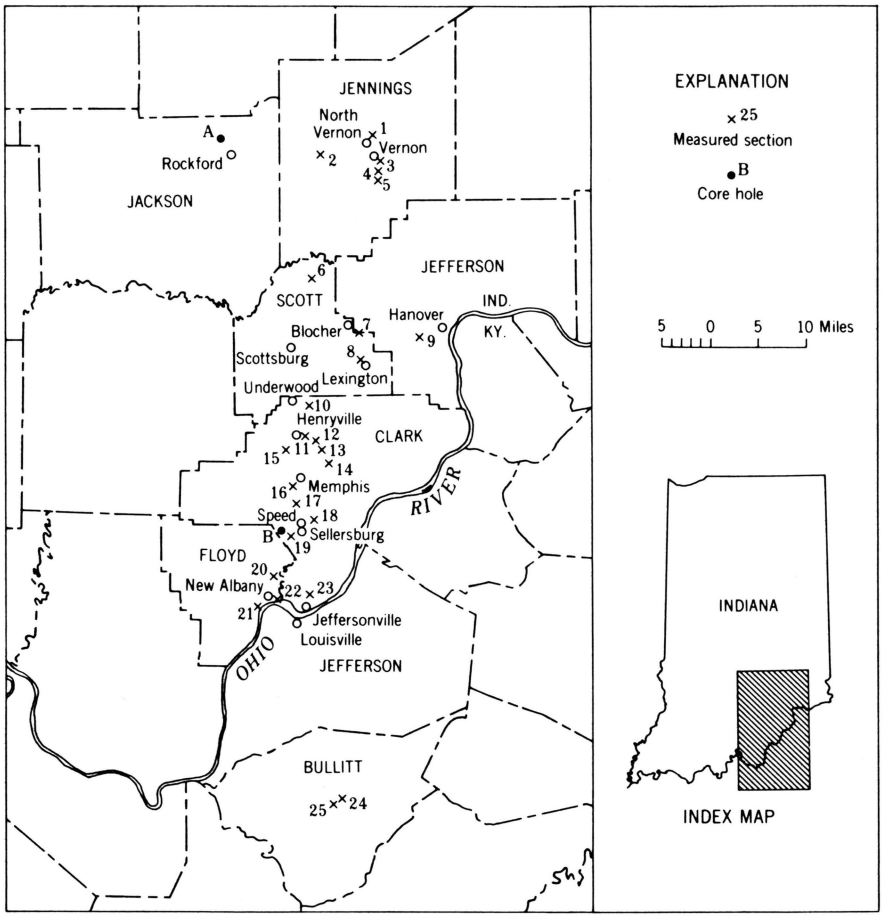

Figure 4. Map of part of southeastern Indiana showing locations of measured sections and cores used in this study.

This report follows the original definition of the New Albany Shale by placing the lower boundary of the New Albany at the top of the North Vernon Limestone and the upper boundary at the base of the Rockford Limestone (lower Mississippian) (fig. 3). The New Albany Shale is here considered to be a stratigraphic unit of formational rank. It is lithologically and depositionally distinct from rocks above and below.

In the type area the total thickness of the New Albany Shale is 104 feet. The formation is thinnest, 85 feet, in Harrison County and

thickens to 307 feet in Posey County (fig. 5). In the southern part of the Michigan Basin, in northernmost Indiana, rocks equivalent to the New Albany Shale are as much as 348 feet thick in Lagrange County, a maximum known thickness for Indiana.

The only subdivisions of the New Albany Shale in Indiana previously recognized are those of Campbell (1946), who, apparently assigning group status to the New Albany, established several formations and members (fig. 3) based on a combination of paleontologic evidence, lithology, and joint patterns. Jointing, as used by Campbell (1946, p. 832), is an unreliable criterion for stratigraphic division. Jointing is characteristic of black shale generally, and New Albany joint sets, which developed postdepositionally, are not confined to specific lithologic units.

Several of Campbell's subdivisions have proved to be unrecognizable on a lithologic basis in the field. The stratigraphic position of the top of his Blocher Formation could not be determined in the present study, and Campbell apparently failed to recognize the great lateral extent of the greenish-gray shale unit in the lower part of his Blackiston Formation. The boundary between his Lower and Upper Blackiston Members is traceable and is used as the boundary between two of the members proposed in this report (fig. 3). The overlying Sanderson Formation is not lithologically separable from the upper part of the Blackiston, having been differentiated on paleontologic evidence that is here considered impractical for the definition of these units.

Campbell did not give proper consideration to mappability and traceability when giving formational rank to some thin subdivisions of the New Albany. The Falling Run Member, Underwood Formation, and Henryville Formation of Campbell (1946) are thin units near the top of the New Albany Shale and are given the rank of bed (Lineback, 1968). Campbell also separated from the New Albany a thin greenish-gray shale overlying the black shale and called it the Jacobs Chapel Shale (fig. 3). The name Jacobs Chapel is retained with the rank of bed (Lineback, 1968), and the unit is included within the New Albany Shale as the topmost bed of the formation.

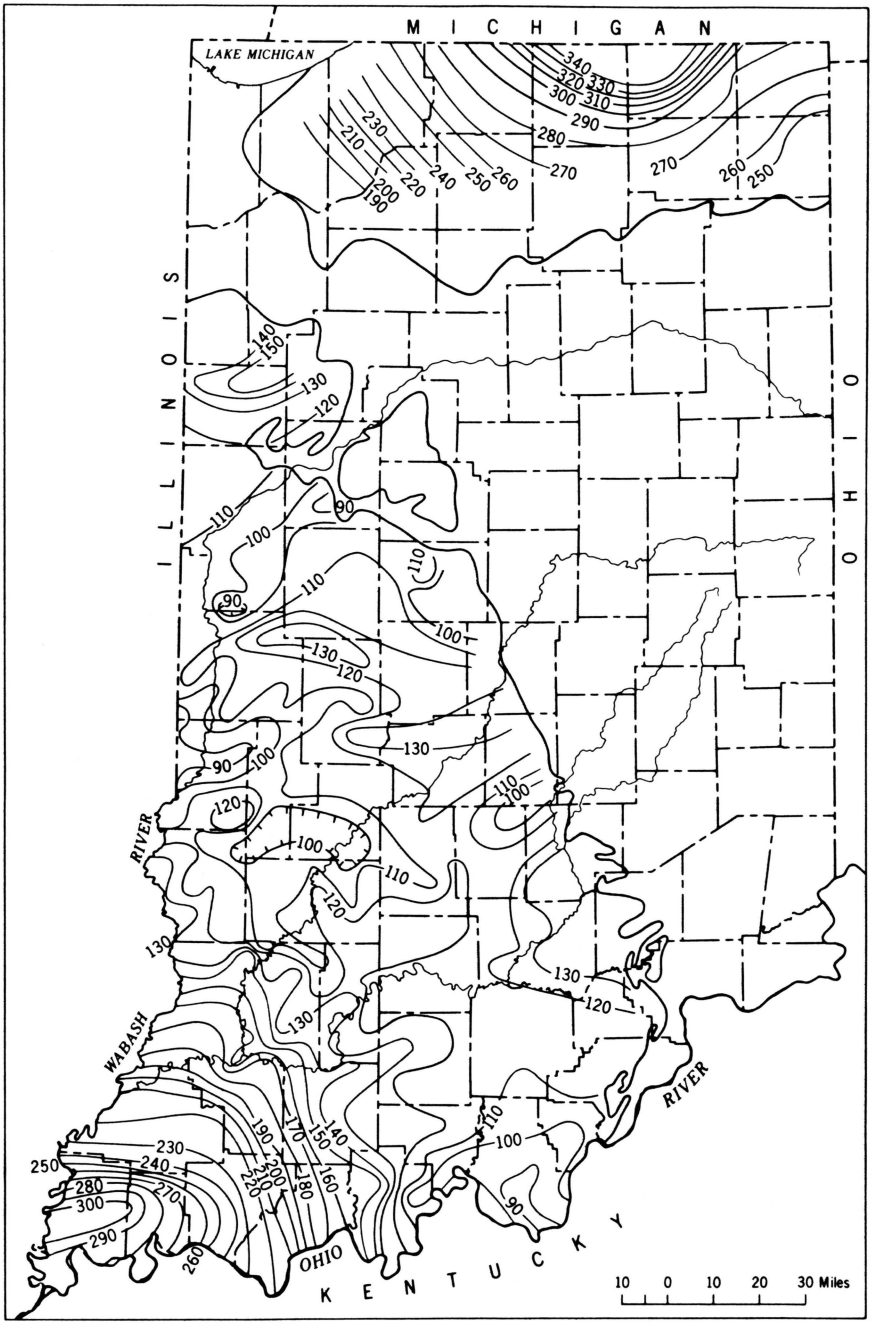

Figure 5. Isopach map showing thickness of the New Albany Shale and equivalent strata. Contour interval 10 feet.

The New Albany Shale in the outcrop area of southeastern Indiana and in northern Kentucky is divisible into five lithologically distinct, laterally persistent units of member rank (fig. 3). The Blocher Member was named by Campbell (1946) and was revised by Lineback (1968); the other members were named and described for the first time by Lineback (1968) and are here given fuller description. The members are, in descending order: (1) Clegg Creek Member—massive brownish-black silty and dolomitic pyritic shale with thin beds of greenish-gray shale and mudstone near the top, 42 to 60 feet thick; (2) Camp Run Member—interbedded brownish-black shale and thin greenish- to olive-gray mudstone and shale, 14 to 18 feet thick; (3) Morgan Trail Member—brownish-black shale containing many thin pyritic beds, 24 to 40 feet thick; (4) Selmier Member—greenish-gray dolomitic mudstone, absent to 22 feet thick; and (5) Blocher Member—brownish-black calcareous to dolomitic pyritic shale, 3 to 15 feet thick. This nomenclature was also used in a recent regional Devonian summary (Collinson and others, 1967).

Subsurface stratigraphic data on the New Albany Shale and equivalent rocks from 260 deep wells in Indiana (fig. 6) were processed by a digital computer. Isopach maps and a series of cross sections (pl. 1) were constructed to portray regional stratigraphy.

In the subsurface over much of Indiana the Blocher and Selmier Members can be identified, but the upper three members cannot (fig. 3; pl. 1). Four distinct lithologic units can be recognized, however, in the part of the New Albany above the Selmier. These units are discussed separately.

BLOCHER MEMBER

The Blocher Member of the New Albany Shale consists of shale that is brownish black, carbon rich, calcareous to dolomitic, laminated, fissile, and pyritic. The shale weathers light gray and has brown and yellow stains. Such staining is typical of brownish-black shale in the New Albany. Also present in the Blocher Member are thin beds of greenish-gray shale, quartzose rocks, and dolomite.

Figure 6. Map of Indiana showing locations of wells used in this study.

The type section of the Blocher Member is along Indiana Highway 56, 1 mile east of the intersection with Indiana Highway 3, in the SE¼SW¼SW¼ sec. 9, T. 3 N., R. 8 E., Jefferson County (Appendix, section 7; fig. 4). The Blocher is exposed in a creek bank on the north side of a highway bridge and about 20 feet from the edge of the road. This probably is the section designated by Campbell (1946, p. 845) as the type section of his Blocher Formation. The name is derived from the small town of Blocher, which is 1 mile northwest of the type exposure.

The Blocher Member of this report corresponds to the Blocher Formation of Campbell (1946), except that following Lineback (1968) the upper boundary is placed at the base of the greenish-gray shale of the Selmier Member (*Spathiocaris* Zone of Campbell). Therefore the Blocher, as revised, includes the lower few feet of Campbell's Blackiston Formation (fig. 3). During the course of this investigation, no evidence of the supposed disconformity at which Campbell drew the Blocher-Blackiston contact was found. The sandstone beds that he used to mark the boundary between these two units are lenticular and do not indicate a widespread break in the depositional record.

At the surface the Blocher ranges from 3 to 15 feet in thickness. The member is thinnest near Lexington, Scott County, and thickens both northward and southward. The Blocher reaches maximum thickness in the subsurface of Pike County, where the member is 85 feet thick (fig. 7; pl. 1, cross section A-C). The member cannot be traced with certainty into the Indiana portion of the Michigan Basin, where brownish-black shale, calcareous brownish-black shale, and greenish-gray shale, in part equivalent to the Blocher Member, are referred to the Antrim Shale (fig. 3; pl. 1, cross section A-B), nor can the Blocher be readily separated from the remainder of the New Albany Shale where the Selmier Member is absent.

Lenticular micritic dolomite and rare calcitic dolomite beds as much as 1 foot thick are present in the Blocher Member. The dolomite contains small quantities of organic matter, and some of the beds

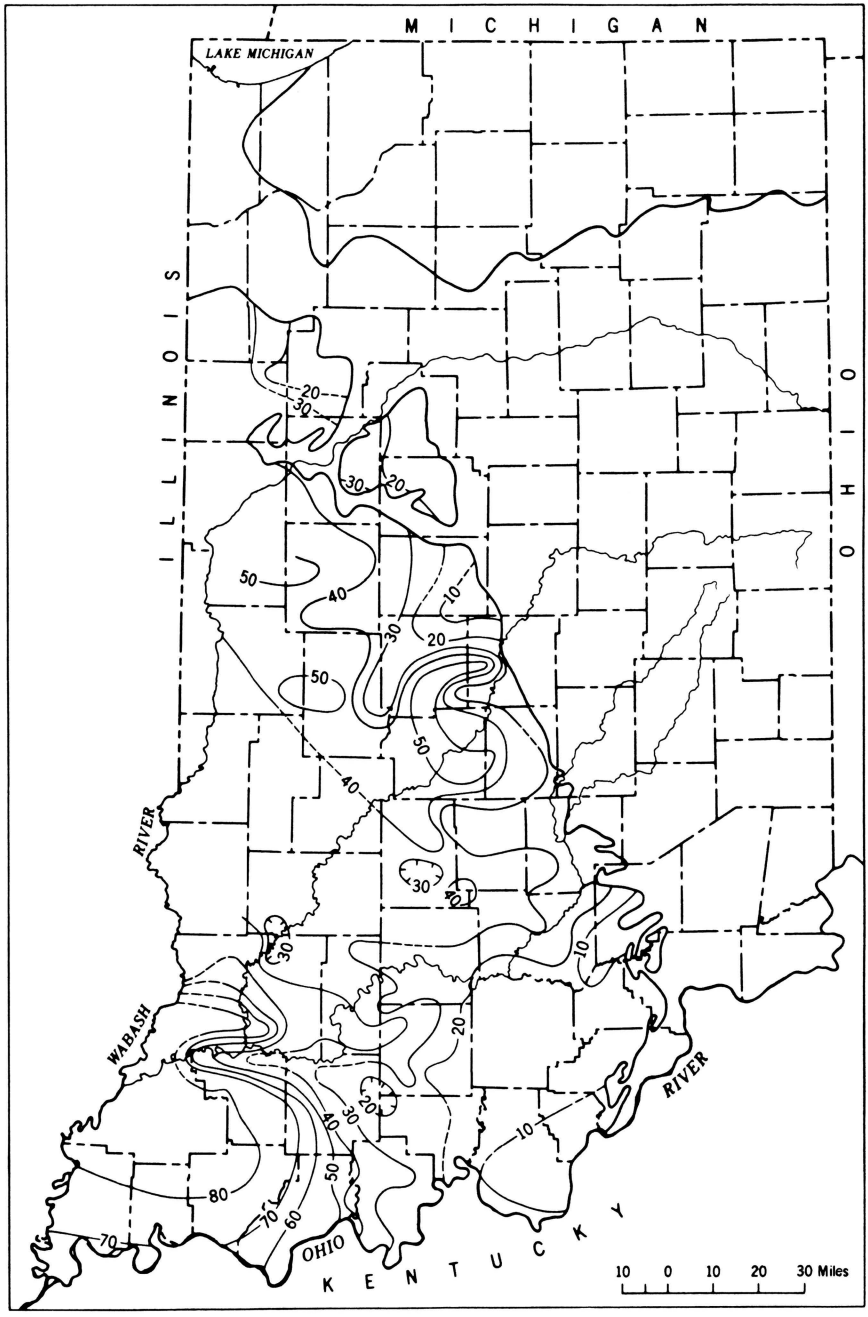

Figure 7. Isopach map showing thickness of the Blocher Member of the New Albany Shale. Contours dashed in areas where the Selmier Member is absent but thickness of the Blocher can reasonably be inferred. Contour interval 10 feet.

have a petroliferous odor when they are freshly broken. Some dolomite beds in the Blocher contain shells of pteropods, which in places make up nearly half of the rock. Quartz silt is virtually lacking from the dolomite. Dolomicritic concretions as much as 1 foot thick and 3 feet in diameter also occur in the Blocher.

Lenticular beds of dolomitic quartzose rock lie 4 to 10 feet above the base of the Blocher Member. Two such beds are present in some exposures. The quartzose rocks show faint cross stratification in places. Thin beds of light olive-gray (5Y 6/1) shale are present in the Blocher near North Vernon (Appendix, section 5, unit 4), but these beds are not persistent. The dark shales of the Blocher are characterized by as much as 50 percent carbonate in the form of dolomite or calcite grains. Most of the carbonate is apparently dolomite, and the laminations in the shale consist of dolomicrite with little or no quartz silt.

Organic content of samples of brownish-black shale in the Blocher is estimated by chemical analysis to range from 10 to 20 percent. This organic content is a weight measurement, and by volume the organic matter probably constitutes a somewhat greater portion of the shale.

A brownish-black carbon-rich argillaceous limestone lies at the base of the Blocher Member at places (fig. 3). This limestone is not persistent but grades laterally into calcareous or dolomitic shale. It is present at the Clark County stone quarry at Sellersburg (W¼ lot 90, Clark's Grant), and it can be recognized in the subsurface, where it is as much as 22 feet thick in Putnam County (fig. 8; pl. 1, cross section G-H). The limestone may be equivalent to the Alto Formation of Illinois.

In the subsurface of northwestern Indiana a local lenticular body of greenish-gray silty shale lies near the base of the Blocher Member and at some places lies on the limestone that underlies the New Albany Shale (fig. 3). Generally, however, this shale is separated from the base of the New Albany by a wedge of brownish-black shale. The greenish-gray silty shale reaches a maximum thickness of 32 feet in

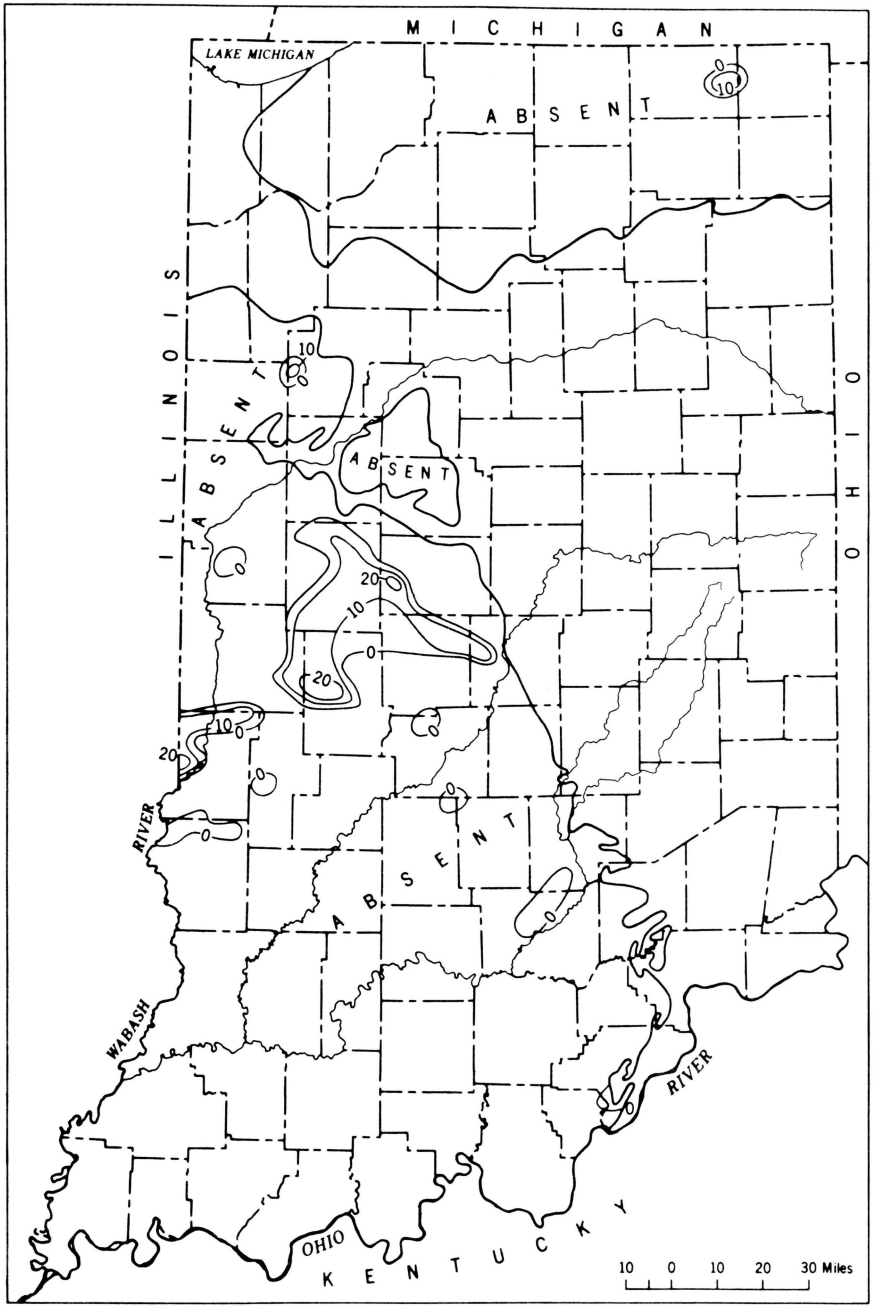

Figure 8. Isopach map showing thickness of the basal brownish-black argillaceous limestone in the lower part of the Blocher Member and at the equivalent stratigraphic position in the Michigan Basin. Contour interval 10 feet.

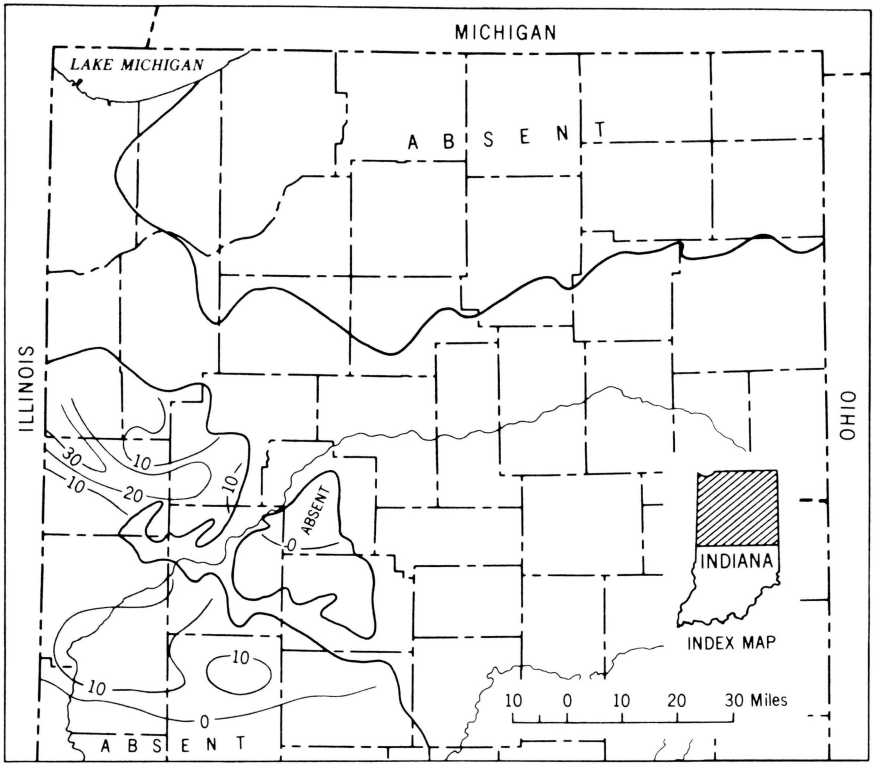

Figure 9. Isopach map showing thickness of the greenish-gray silty shale in the Blocher Member. Contour interval 10 feet.

Benton County and extends no farther south than Fountain and Montgomery Counties (fig. 9; pl. 1, cross sections A-C and A-D).

The Blocher Member contains a variety of fossils, including the calcareous brachiopods *Leiorhynchus* and *Chonetes* and the pteropods *Tentaculites* and *Styliolina.* These fossils commonly are found together on bedding planes in the lower part of the member. Pteropods are also present in calcitic dolomite and dolomite. *Lingula* is restricted to a few bedding planes. Conodonts, scolecodonts, and burrows also characterize the Blocher. Abundant carbonized logs are present in the T. J. Atkins and Co. quarry at Jeffersonville (fig. 4; Appendix, section 23), and there are sparse fragments of such logs elsewhere in the Blocher Member. *Tasmanites* occurs throughout.

SELMIER MEMBER

The name Selmier Member of the New Albany Shale is applied to greenish-gray (5GY 6/1) mudstone that lies above the Blocher Member (Lineback, 1968). Thin beds of brownish-black and olive-brown fissile shale, dolomite, and dolomitic quartzose rock are also present in the Selmier. The type section is along the south wall of the Berry Materials Co. quarry, which is on the north edge of North Vernon in the NE¼NW¼ sec. 34, T. 7 N., R. 8 E., Jennings County (Appendix, section 1; fig. 4). The name is taken from the Selmier State Forest, which is 1 mile northeast of the type exposure.

Along the outcrop the Selmier Member is absent in places in southern Clark County and reaches its maximum exposed thickness of 22 feet at the type section. Where the member is absent, the stratigraphic position of the Selmier is marked by a zone of burrows (Appendix, section 18). The Selmier extends into the subsurface, where the member is as much as 50 feet thick in Jackson County and 40 feet thick in Warrick County (fig. 10). The member is absent from a large area along the west edge of Indiana (fig. 10; pl. 1). The Selmier is lithologically uniform and is a good subsurface marker unit. Like the Blocher, however, the Selmier cannot be identified in the Michigan Basin, where equivalent rocks are included in the Antrim Shale (fig. 3; pl. 1, cross section A-B).

The Selmier Member corresponds to the *Spathiocaris* Zone of Campbell (1946), but it is lithologically distinct and is widespread enough to have member status. This greenish-gray mudstone has been noted by several authors, including Butts (1915) and Dawson (1941), but its wide distribution has not been recognized previously.

Small rhombs of dolomite are disseminated through the greenish-gray mudstone of the Selmier Member. Lenticular light-gray dolomicrite beds as much as 1 foot thick are present near the base of the member. In the North Vernon area the upper part of the Selmier contains greenish-gray dolomitic septarian concretions that are as much as 2 feet thick and 5 feet in diameter. The member also contains a few thin lenticular dolomitic quartzose beds in the lower part.

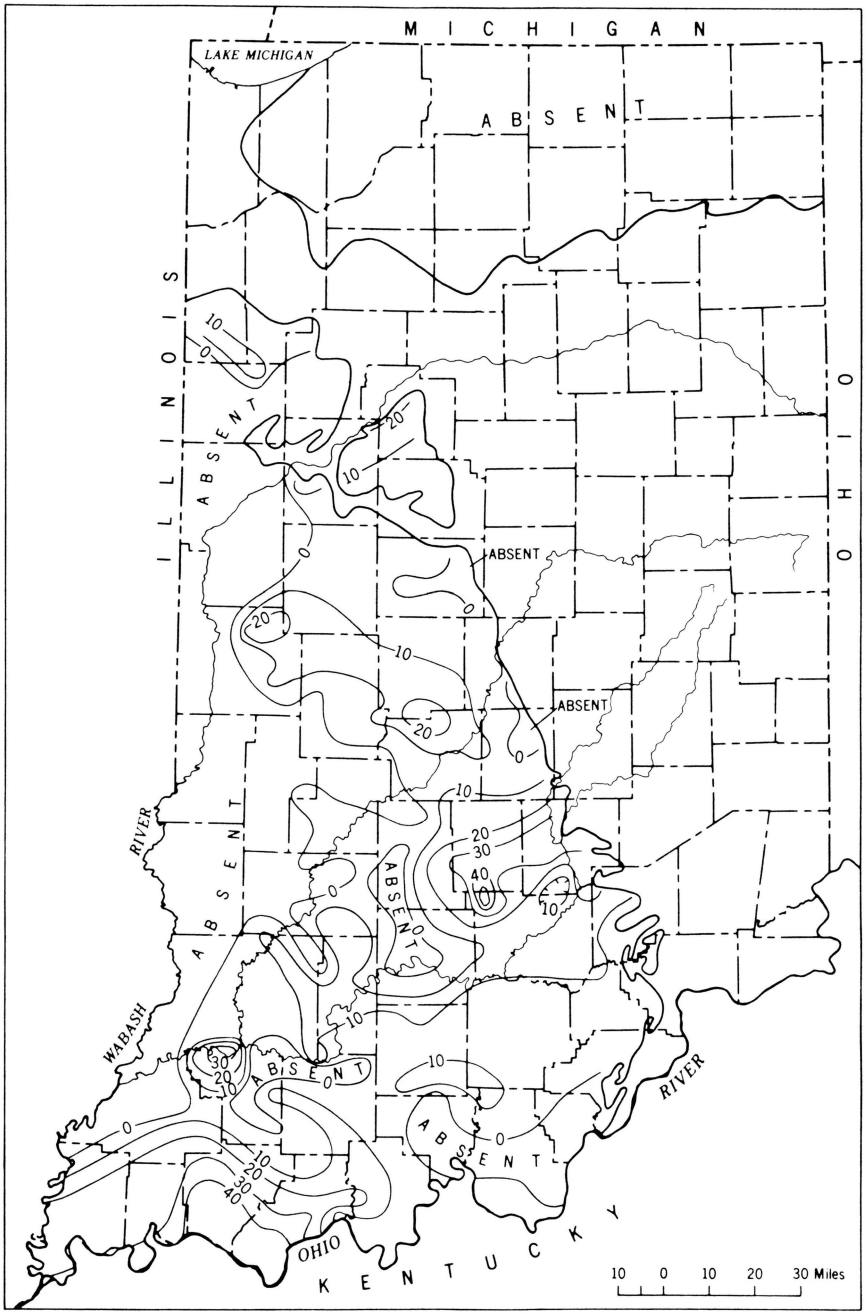

Figure 10. Isopach map showing thickness of the Selmier Member of the New Albany Shale. Contour interval 10 feet.

Pyrite occurs as euhedral grains or as fillings of spore exines in the mudstone.

Fossils in the Selmier Member include conodonts and a few pelecypods and gastropods. *Spathiocaris* and other crustaceans have been reported previously, but none were observed during the present study. Burrows filled with sediment from the Selmier are present in the upper few inches of the Blocher Member at several localities, and sandstone beds within the Selmier contain casts of worm burrows. A few quartzose beds at the type section of the Selmier show a variety of arthropod trackways.

MORGAN TRAIL MEMBER

Brownish-black fissile siliceous pyritic shale that is characterized by numerous hard pyritic beds 1 to 30 mm thick and that lies above the Selmier is assigned to the Morgan Trail Member of the New Albany Shale (Lineback, 1968). The type section of the Morgan Trail is at the same locality as that of the Blocher, except that the Morgan Trail is better exposed on the south side of Indiana Highway 56, along the north line of the NW¼ sec. 16, T. 3 N., R. 8 E., Scott County (Appendix, section 7; fig. 4). The name is taken from a roadside park on Indiana Highway 3 a mile southwest of the type section. The thickness of the member ranges from 25 to 40 feet and increases as the Selmier thins. The Morgan Trail Member cannot be separated from the overlying unit in the subsurface because its distinctive lithologic features cannot be observed in well cuttings.

The thin pyritic beds are more resistant to weathering than the adjacent shale is, and weathered exposures of the Morgan Trail Member commonly are covered with polygonal fragments of these beds. Considering their thinness, the pyritic beds are rather persistent laterally; individual beds have been traced for several hundred feet in the North Vernon area (Holland, 1953). Dolomite is present in the member but in much smaller quantity than in the lower two members. Microscopically visible quartz silt is present in small amounts. Fossils, other than silicified logs of *Callixylon,* have not been found in the Morgan Trail.

CAMP RUN MEMBER

The name Camp Run Member of the New Albany Shale was proposed by Lineback (1968) for a distinctive rock unit consisting of greenish- to olive-gray mudstone and shale interbedded with brownish-black carbon-rich pyritic fissile shale. The type section is along the south side of U.S. Highway 31W at the Interstate Highway 65 overpass west of Sellersburg, in the W¼S¼ lot 110, Clark's Grant, Clark County (Appendix, section 19; fig. 4). The name is taken from a small creek that flows just north and east of the exposure. The Camp Run Member ranges from 14 to 18 feet in thickness in the outcrop area. The member cannot be recognized in the subsurface because the greenish-gray shale beds are too thin to be seen in well cuttings.

Beds of greenish-gray shale and mudstone in the Camp Run Member range from less than 0.1 to 1.1 feet in thickness, and they are separated by brownish-black shale beds that range from 0.4 to 4.5 feet in thickness. Three greenish-gray shale beds, each about 1 foot thick and separated by brownish-black shale beds of about the same thickness, lie at the base of the member. The boundary between the Morgan Trail and Camp Run Members is placed at the base of the lowest greenish-gray bed. Brownish-black shale 4 to 4.5 feet thick separates the lower three beds of light-colored rock from the more thinly interbedded upper part of the member. The upper part consists of a sequence of 22 to 25 greenish-gray shale beds, 0.1 to 0.4 foot thick, interbedded with brownish-black shale beds that are 0.4 to 1.5 feet thick. Some individual beds in the member can be traced from exposure to exposure. The greenish-gray beds are less resistant to weathering than intervening brownish-black shale beds, and old vertical exposures of the member have a washboard appearance. The top of the Camp Run Member is placed at the top of the uppermost greenish-gray shale parting in the interbedded sequence.

Thin greenish-gray beds in the Camp Run are generally fissile and are here designated shale, but the thicker greenish-gray beds are mostly nonfissile and are appropriately called mudstone. Dolomite concretions as much as 1 foot thick and 2 feet in diameter are scattered through the brownish-black shale beds of the member.

A benthonic fauna of burrowing organisms was present during deposition of many of the greenish-gray shale beds. The brownish-black shale below such a bed is commonly perforated by tubular burrows that are filled with greenish-gray shale from above. *Taonurus*-like markings occur on the surface of some brownish-black shale beds. These structures are well exposed at the type section (Appendix, section 19). Carbonized plant remains, silicified *Callixylon,* conodonts, *Lingula,* and a few small pyritized gastropods and pelecypods are present in the Camp Run Member.

CLEGG CREEK MEMBER

Shale that is massive, brownish black, fissile, silty, and pyritic and that contains a few greenish-gray shale and mudstone beds and phosphatic nodules near the top comprises the remainder of the New Albany Shale above the Camp Run Member. It has been named the Clegg Creek Member (Lineback, 1968). The Clegg Creek Member is overlain by the Rockford Limestone. The type section of the Clegg Creek is in a road cut along Indiana Highway 160 in the N¼E¼ lot 240, Clark's Grant, 2 miles southeast of Henryville, Clark County (Appendix, section 12; fig. 4). A tributary which enters Silver Creek about 2 miles upstream from the type section provides the name for the member. The Clegg Creek is 42 feet thick in Clark County and increases northward to about 60 feet in Jackson County. The member cannot be separated from the underlying shale in the subsurface.

The Clegg Creek Member contains more quartz silt and less dolomite than the lower members of the New Albany do, but dolomitic laminae are present. Some beds contain 20 to 30 percent microscopically visible quartz silt.

The Clegg Creek Member includes part or all of six units named by Campbell (1946). These are the upper part of the upper member of the Blackiston Formation, the Sanderson Formation (including the Falling Run Member), the Underwood Formation, the Henryville Formation, and the Jacobs Chapel Shale (fig. 3). The Sanderson is lithologically unrecognizable, but the Falling Run, Underwood, Henryville, and Jacobs Chapel are recognizable and have been given the rank of bed because of their thinness (Lineback, 1968).

The upper part of the Clegg Creek Member contains several units that are of considerable paleontologic interest, not only because of their varied faunas, but also because of their importance in the placement of the Devonian-Mississippian boundary. The lowest greenish-gray shale bed in the Clegg Creek Member, 7.5 feet below the top of the member, is found in a small area in northeastern Jackson County. Huddle (1933) reported brachiopods indicating a Devonian age from this lenticular calcareous shale bed at its only surface exposure in the SE¼NE¼SE¼ sec. 30, T. 7 N., R. 6 E., near the community of Peters Switch, 2 miles north of Rockford in Jackson County. This unit is now poorly exposed in a roadside ditch. The same bed was also found in Indiana Geological Survey core hole 55 in the NW¼SW¼NE¼ sec. 36, T. 7 N., R. 5 E., Jackson County (A, fig. 4). This 2-foot-thick bed contains abundant articulate brachiopods, including the genera *Leiorhynchus, Allorhynchus, Rhynchopora, Rhipidomella, Syringothyris,* and *Delthyris,* and crinoids, gastropods, and bryozoans. The bed is overlain by dark brownish-black fissile shale bearing orbiculoid and linguloid brachiopods.

A 0.2-foot-thick zone of phosphatic nodules, called the Falling Run Member of the Sanderson Formation by Campbell (1946), occurs 0.4 to 1.4 feet below the top of the Clegg Creek Member throughout southern Indiana and northern Kentucky. The Falling Run, named for a locality at New Albany (Appendix, section 21, unit 2), is more appropriately given the rank of bed (Lineback, 1968). The nodules range in size and shape from 0.05-foot spheres to flattened nodules 0.5 to 0.7 foot long and 0.2 foot thick. Nodules of the Falling Run Bed contain articulate and inarticulate brachiopods, arthropods, fish remains, and plant fossils.

A 0.4-foot bed of greenish-gray shale containing a prolific fauna of conodonts and scolecodonts overlies the Falling Run Bed at a single locality in the NE¼SE¼ sec. 21, T. 2 N., R. 7 E., Clark County (Appendix, section 10, unit 3). This bed, named the Underwood Formation by Campbell (1946), is also, following Lineback (1968), given the rank of bed (fig. 3). Campbell erroneously correlated the calcareous shale in Jackson County, which lies below the Falling Run Bed, with the Underwood Bed, which overlies the Falling Run. The

Underwood Bed pinches out within a few hundred yards of Campbell's type exposure. Conodonts from the Underwood Bed indicate a Kinderhookian age (Carl B. Rexroad, oral communication, 1963). Phosphatic nodules enclosed by the shale of the Underwood Bed contain pelecypods, gastropods, and brachiopods of the genera *Chonetes, Rhipidomella, Camarotoechia, Tylothyris, Syringothyris, Schuchertella, Platyrachella, Delthyris, Orbiculoidea,* and *Lingula.* Nodules of the Falling Run Bed that lie at the base of the greenish-gray Underwood Bed contain borings, but the Falling Run nodules do not contain borings at other localities where they are overlain by brownish-black shale. At an exposure in lot 244, Clark's Grant, 3.5 miles southeast of the type Underwood exposure, brachiopods similar to those in the Underwood Bed are found cemented to the surface of Falling Run nodules, but no greenish-gray shale is present. The nodules at this locality do not contain borings, an indication that the environment there was unsuited for the boring organisms and probably for brachiopods as well. The Underwood fauna may have been carried into this locality by currents.

Above the Falling Run and Underwood Beds is a brownish-black to black fissile shale bed that Campbell (1946) named the Henryville Formation from a locality in the center of the NE line, lot 252, Clark's Grant, Clark County (fig. 4). Following Lineback (1968), the Henryville is also given the rank of bed (fig. 3; Appendix, section 15, unit 3). The carbon-rich Henryville Bed contains conodonts, phosphatic brachiopods, and a few plant remains. The upper surface of the Henryville Bed commonly contains burrows or trails. Thickness of the Henryville ranges from 0.4 to 1.4 feet in Indiana, but the bed is absent in places south of the Ohio River owing to erosion prior to deposition of the New Providence Shale (Borden Group).

The topmost bed of the Clegg Creek Member is a greenish-gray calcareous glauconitic mudstone that is 0.2 to 0.6 foot thick in the outcrop area and is too thin to be recognized in the subsurface. This unit was named the Jacobs Chapel Shale by Campbell (1946), who designated it as a separate formation between the New Albany Shale and the Rockford Limestone (fig. 3). The original definition of the

New Albany, however, placed the upper boundary at the base of the Rockford, and prior to Campbell's work, no one differentiated the thin greenish-gray shale. The Jacobs Chapel is too thin to be recognized as a formation, or even as a member, and it is more appropriately ranked as the uppermost bed of the Clegg Creek Member (Lineback, 1968). The Jacobs Chapel Bed represents a transition from shale deposition to limestone deposition. It is lithologically similar to some greenish-gray shale beds lower in the New Albany except that it contains more glauconite and calcite, and in this respect it resembles the Rockford and higher units. The Jacobs Chapel is absent in places in southern Indiana where it was removed by erosion prior to deposition of still younger beds.

UPPER PART OF THE NEW ALBANY SHALE IN THE SUBSURFACE

In the subsurface of western and northern Indiana the Morgan Trail, Camp Run, and Clegg Creek Members cannot be distinguished because the thin greenish-gray shale beds that characterize the Camp Run Member cannot be identified in well cuttings. That part of the New Albany Shale that lies above the Selmier Member is less than 100 feet thick over much of central western Indiana, but it thickens southwestward to more than 200 feet in Posey County (fig. 11; pl. 1, cross section K-L). In only a part of the area where the Selmier is absent can the upper part of the New Albany Shale be separated from the Blocher Member (pl. 1). The post-Selmier part of the New Albany Shale can be divided into four major lithologic units in the subsurface (fig. 3; pl. 1). In ascending order these are (1) a thick brownish-black carbon-rich shale that makes up much of the upper New Albany, especially in the Indiana part of the Illinois Basin, (2) a unit of interbedded greenish-gray and brownish-black shale that is prominent in Benton, Newton, Jasper, and White Counties and in the Indiana part of the Michigan Basin, (3) a greenish-gray shale that is prominent in the Michigan Basin and also present in places in the Illinois Basin, and (4) a thin but distinctive black shale that marks the top of the New Albany and equivalent strata in many areas.

The brownish-black shale of unit 1 has a maximum thickness of

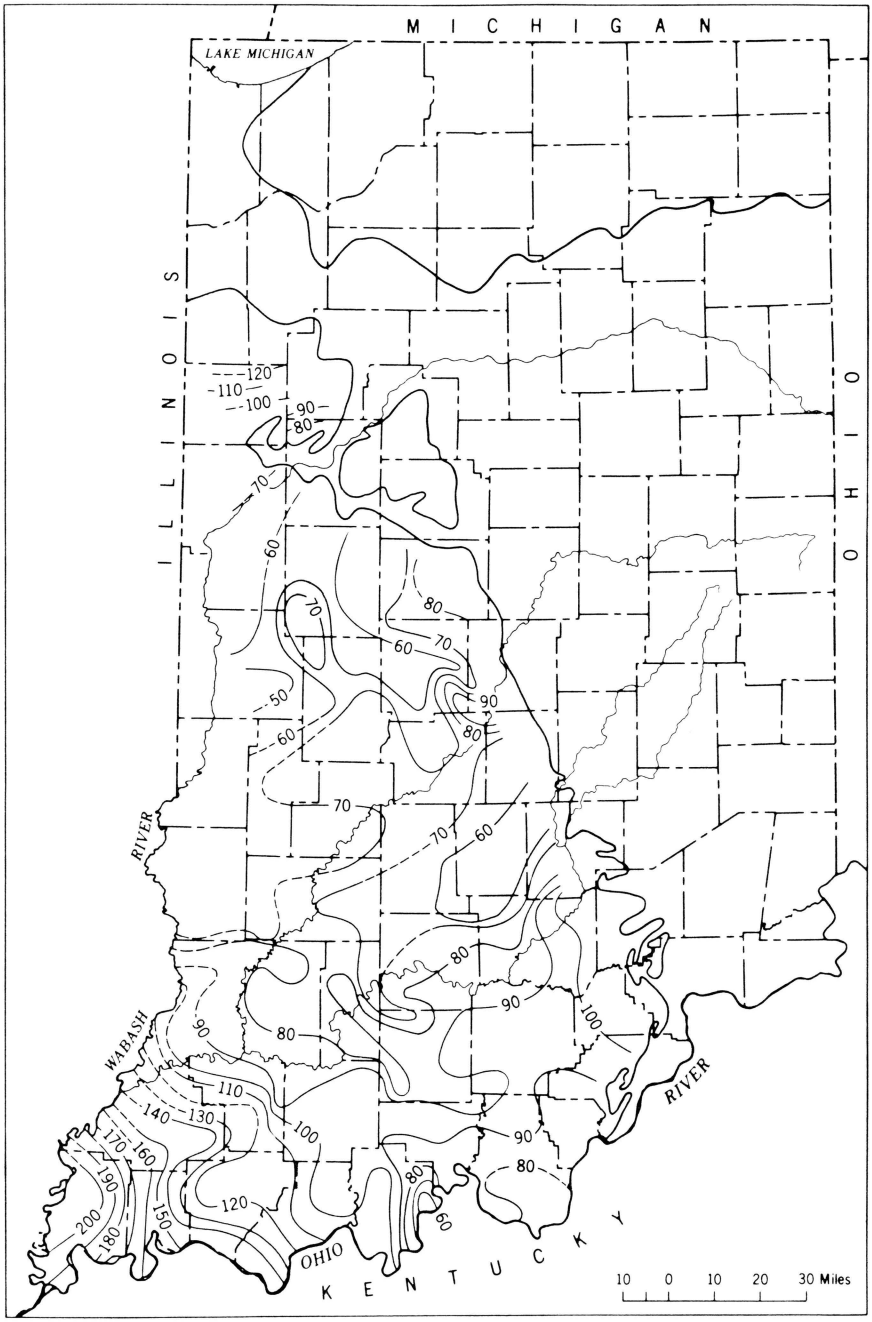

Figure 11. Isopach map showing thickness of the New Albany Shale above the Selmier Member. Contours dashed in areas where the Selmier is absent but thickness of upper unit can reasonably be inferred. Contour interval 10 feet.

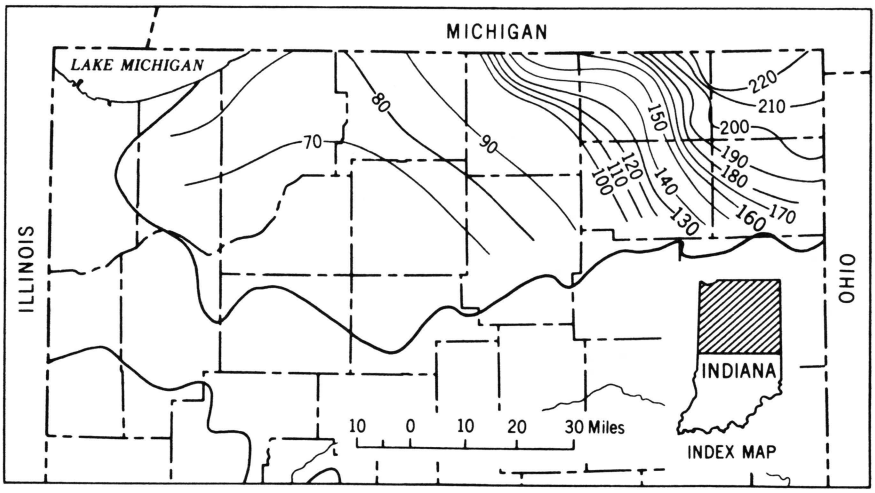

Figure 12. Isopach map showing thickness of the Antrim Shale. Contour interval 10 feet.

207 feet in Posey County (pl. 1, cross section K-L). The lower part of this brownish-black carbon-rich shale is equivalent to the upper part of the Antrim Shale of the Michigan Basin (fig. 3). The upper part grades northward and upward into the interbedded shale of unit 2 and the greenish-gray shale of unit 3 (pl. 1, cross sections A-C, A-D). Units 2 and 3 are equivalent to the Ellsworth Shale, and the black shale of unit 4 is equivalent to the Sunbury Shale (fig. 3; pl. 1, cross section A-B), both terms of Michigan Basin usage. Lineback (1968) recognized these Michigan Basin units in Indiana north of the crestal area of the Cincinnati Arch and also extended use of the name Ellsworth, as Ellsworth Member of the New Albany Shale, into the northeastern part of the Illinois Basin (fig. 3).

ANTRIM SHALE

The Antrim Shale of the Michigan Basin is equivalent to the Blocher Member, Selmier Member, and part of the New Albany Shale above the Selmier Member (fig. 3). The Antrim is mostly brownish-black shale but includes greenish-gray shale in the lower part. The formation is more than 220 feet thick in Steuben County (fig. 12), grades westward into the overlying Ellsworth Shale (pl. 1, cross section A-B), and thins to 65 feet in Marshall County (fig. 12).

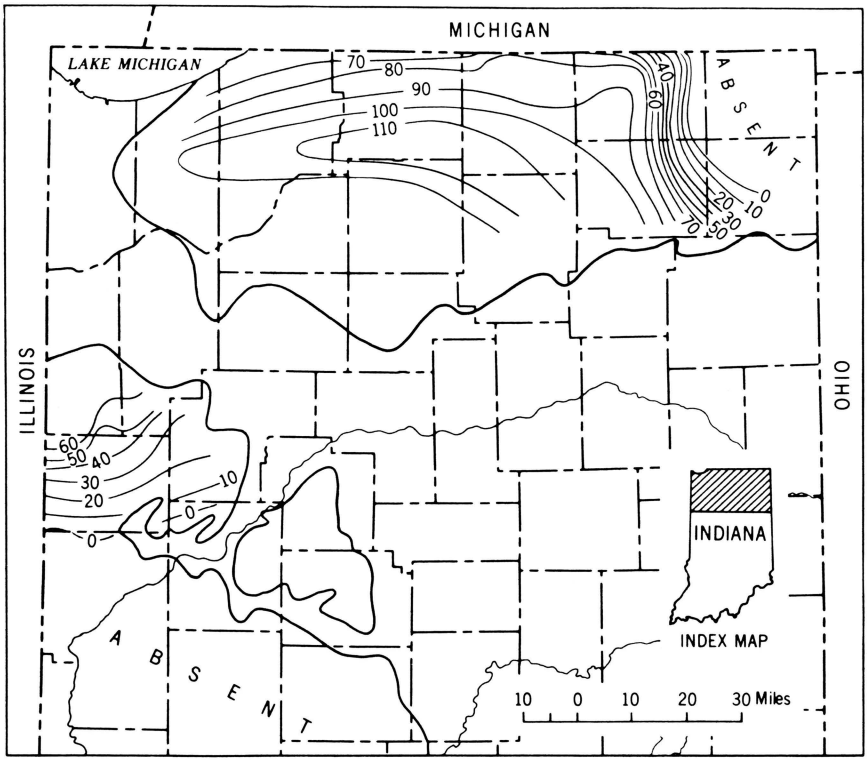

Figure 13. Isopach map showing thickness of the interbedded brownish-black and greenish-gray shale that comprises the lower part of the Ellsworth Shale. Contour interval 10 feet.

ELLSWORTH SHALE

The Ellsworth Shale is present not only in that part of the Michigan Basin that extends into Indiana, where it is accorded formation rank, but also south of the arch in the northern part of the Illinois Basin, where it is termed the Ellsworth Member of the New Albany Shale (Lineback, 1968). The Ellsworth Shale consists of two parts (fig. 3), a lower part of thinly interbedded brownish-black carbon-rich shale and greenish-gray shale which grade upward and perhaps laterally as well into an upper part of greenish-gray shale. Both of these parts extend into the Illinois Basin (pl. 1).

The interbedded brownish-black and greenish-gray shale, which is

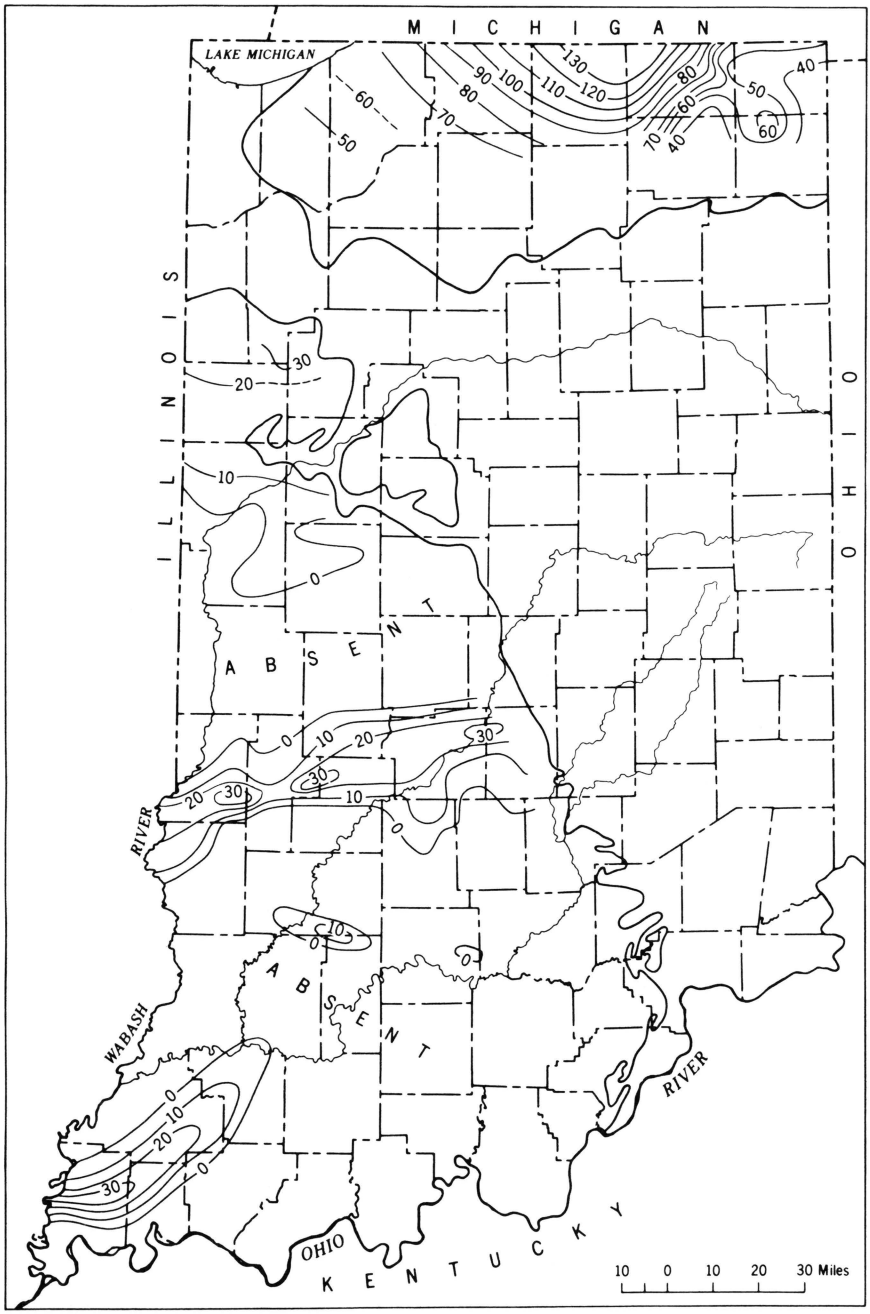

Figure 14. Isopach map showing thickness of the greenish-gray shale that forms the upper part of the Ellsworth Shale and greenish-gray shales that occupy a similar stratigraphic position in the New Albany Shale. Contour interval 10 feet.

absent from Steuben County, where it is replaced by the brownish-black Antrim Shale (pl. 1, cross section A-B), thickens rapidly westward to 110 feet in St. Joseph County (fig. 13). In the Illinois Basin the interbedded part of the Ellsworth extends to the south line of Benton County and is 62 feet thick in Newton County (fig. 13). The greenish-gray shale that forms the upper part of the Ellsworth Shale is estimated to be more than 130 feet thick in Elkhart County, thins southward, and extends as far south as Montgomery County in the Illinois Basin (fig. 14; pl. 1).

Isolated elongate bodies of greenish-gray shale that are oriented east-west and that are in places more than 30 feet thick are present in the upper part of the New Albany Shale in the Illinois Basin (fig. 14; pl. 1). Although these shale bodies occupy the same stratigraphic position as the greenish-gray part of the Ellsworth, they do not appear to have been connected with the Ellsworth. In eastern Michigan and in Ohio greenish-gray shale and sandstone in the same position as the greenish-gray part of the Ellsworth Shale are referred to the Bedford Shale and the Berea Sandstone. The linear greenish-gray shale bodies in the upper part of the New Albany in central and southern Indiana may represent tongues of the Bedford.

SUNBURY SHALE

A bed of black shale (N1) less than 10 feet thick separates the Ellsworth Shale from the Coldwater Shale over most of the Michigan Basin (fig. 3; pl. 1, cross section A-B). This is the Sunbury Shale (Lineback, 1968), and where it is absent, as in Elkhart and St. Joseph Counties, the Ellsworth cannot readily be separated from the overlying Coldwater Shale.

A similar bed of black shale less than 10 feet thick is present in much of the Illinois Basin, where it overlies greenish-gray shale (pl. 1, cross sections A-C, A-D, G-H, K-L). In some wells where the greenish-gray shale is absent, this black shale bed can be distinguished from underlying brownish-black shale. This bed is probably equivalent to the Sunbury Shale, but because it cannot be separated from the remainder of the New Albany in most wells or in surface sections,

the use of the name Sunbury in the Illinois Basin would serve no purpose. The black shale pinches out or grades laterally into greenish-gray shale in the northern part of the Illinois Basin. In the Benton County area (pl. 1), where the black shale bed was not recognized, the Rockford Limestone separates the Ellsworth Member from the Borden Group.

The Jacobs Chapel Bed overlies the black shale bed in the Illinois Basin, but it cannot be separated lithologically from the Ellsworth Member in Benton County. As the Rockford Limestone is absent in the Michigan Basin and as the Jacobs Chapel Bed probably occupies a position above the Sunbury Shale, the Jacobs Chapel may correlate with the basal part of the Coldwater in northeastern Indiana.

Relation to Overlying Rocks

ROCKFORD LIMESTONE

The Rockford Limestone overlies the New Albany Shale conformably (fig. 3). The Rockford is a distinctive light greenish-gray (5GY 8/1) very fine-grained dolomitic limestone or dolomite. Greenish splotching is common. The formation is as much as 2.4 feet thick in the southeastern Indiana outcrop belt and as much as 25 feet thick in the subsurface (fig. 15). Buschbach (1953) correlated the Rockford with the Chouteau Limestone of western Illinois. The Rockford resembles the Chouteau lithologically and is at least in part the same age (Rexroad and Scott, 1964). The Rockford is absent from some areas of southern Indiana, owing to pre-New Providence erosion. Fossils, except for crinoid remains and conodonts, are sparse. A cephalopod fauna from the Valmeyeran part of the Rockford, however, is found near the type locality at Rockford, Ind. (Lineback, 1963a). The formation is not recognized in the Michigan Basin.

NEW PROVIDENCE SHALE

The basal part of the New Providence Shale (Borden Group) is a greenish-gray silty mudstone. In southern Indiana the formation normally rests on the Rockford Limestone, but it directly overlies the New Albany Shale in places where pre-New Providence erosion

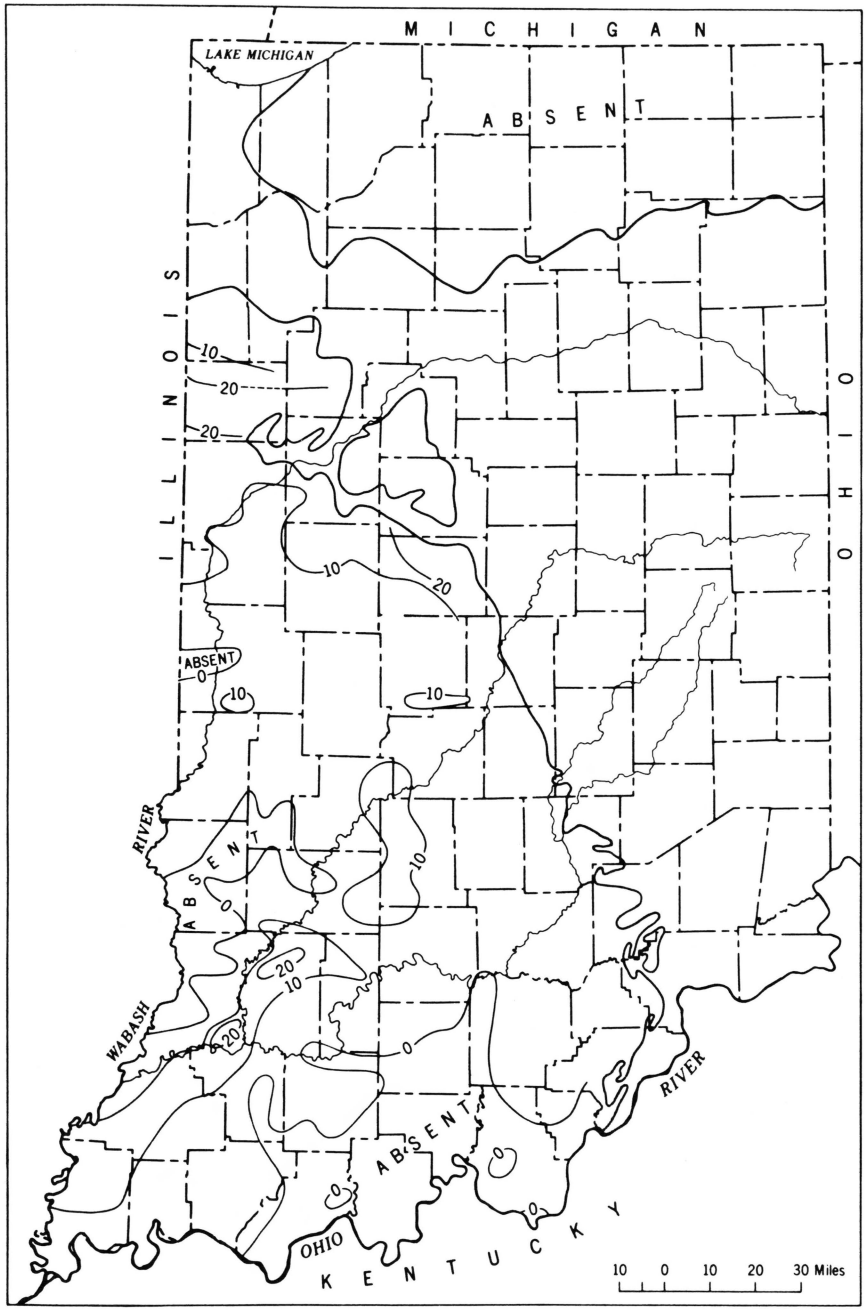

Figure 15. Isopach map showing thickness of the Rockford Limestone. Contour interval 10 feet.

has removed the Rockford. Evidence of this erosion can be observed along Falling Run at the west edge of New Albany (Appendix, section 21). At places in Kentucky the New Providence contains a basal conglomerate of phosphatic nodules derived from the Falling Run Bed, which lies near the top of the New Albany Shale (Appendix, section 25). The depth of pre-New Providence erosion probably did not exceed 4 or 5 feet in the area studied.

Biostratigraphy of the New Albany Shale

Conodonts provide the only reliable means for biostratigraphic zonation and age determination in the black shale sequence. Collinson, Scott, and Rexroad (1962) have established conodont zones in upper Devonian and Mississippian rocks of the upper Mississippi Valley and have indicated the relationship of these zones to zones established in Europe. The standard upper Devonian sequence in Germany is divided into six zones, *to*I to *to*VI, on the basis of conodonts and ammonites (Ziegler, 1962). Conodonts recovered from the New Albany Shale during the present study can be used to indicate the age of various parts of the formation by relating them to the European zones (fig. 16).

Conodonts appear to indicate a middle Devonian age for the lower part of the Blocher Member (C. W. Collinson, personal communication, 1967). Conodonts from the upper part of the Blocher and from the Selmier Member fall within the range of the German upper Devonian Zone *to*I. The Morgan Trail, which yielded no conodonts, is assumed to be about the same biostratigraphic position as Zone *to*II, because the overlying Camp Run Member has conodonts assignable to Zone *to*III (Lineback, 1964). The greenish-gray shale bed that lies 7.5 feet below the top of the Clegg Creek Member in Jackson County (p. 27) contains no conodonts, but its brachiopod fauna is similar to that of the Louisiana Limestone of Missouri. The Louisiana has yielded conodonts and was assigned to Zone *to*VI of the upper Devonian by Collinson (1961). Thus Zones *to*IV and *to*V are presumed to be represented by the lower part of the Clegg Creek Member.

The Underwood Bed of the Clegg Creek Member contains a cono-

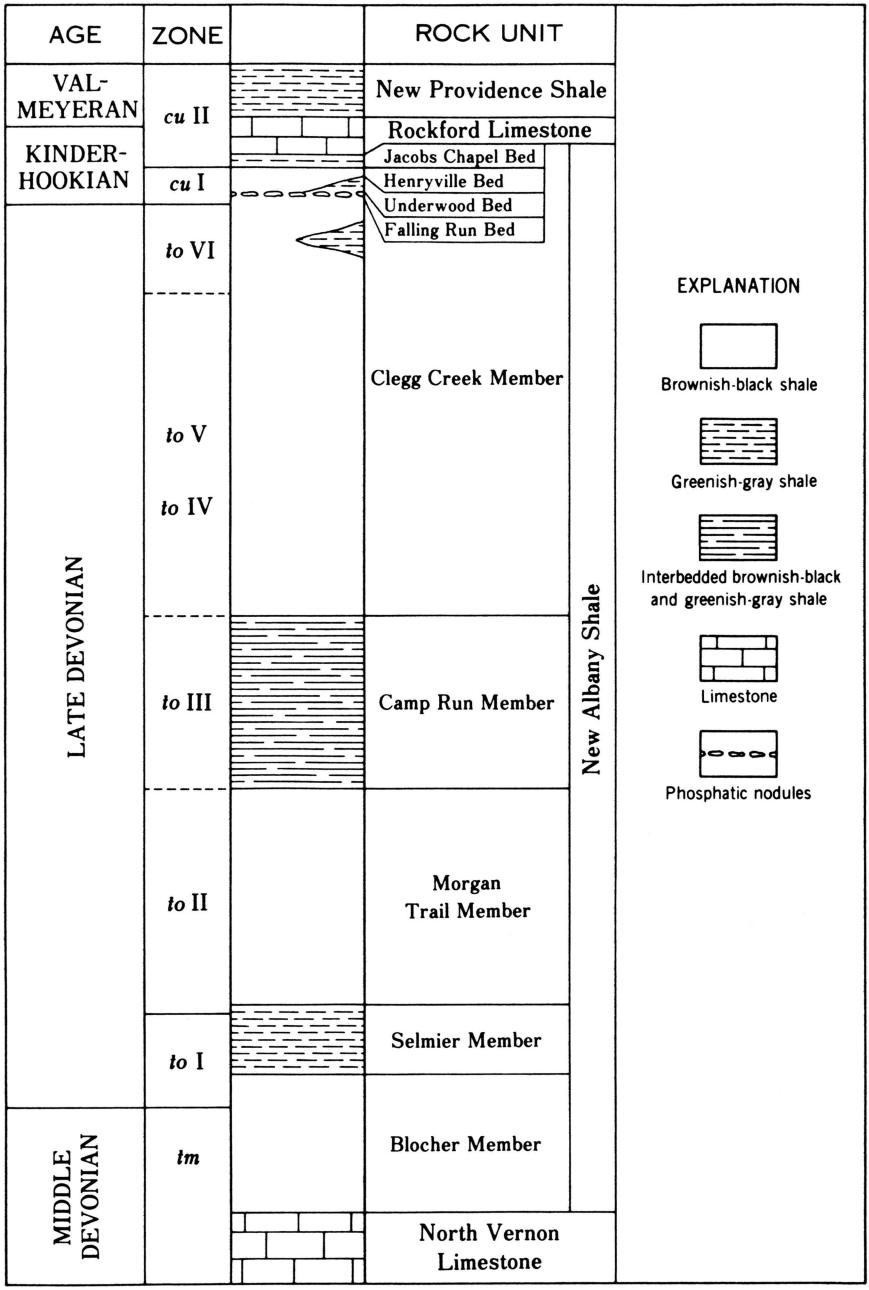

Figure 16. Correlation of the New Albany Shale with European biostratigraphic zones based on conodont faunas.

dont fauna similar to that of the lower part of the Hannibal Shale (Kinderhookian) of Missouri and Illinois (*Siphonodella sulcata* Assemblage Zone). The Henryville Bed contains conodonts that are the same as those of the middle part of the Hannibal Shale, and conodonts from the Jacobs Chapel Bed are similar to those found in the upper part of the Hannibal (Carl B. Rexroad, oral communication, 1963). The Rockford Limestone is Kinderhookian and Valmeyeran in age (Lineback, 1963a; Rexroad and Scott, 1964).

The Devonian-Mississippian boundary thus lies near the top of the Clegg Creek Member, close below the Underwood Bed (fig. 16). The lowermost Mississippian conodont fauna, found in the Glen Park Limestone of Missouri, has not been found in the New Albany Shale, but rocks deposited during this time interval may be represented by the Falling Run Bed and by part of the brownish-black shale immediately below the Falling Run. Because of the paucity of conodonts below the Underwood Bed, it is impossible to pinpoint the Devonian-Mississippian boundary, but in Jackson County it lies no more than 3.7 feet below the Falling Run Bed. As thus defined, the Mississippian part of the New Albany Shale in the southern Indiana outcrop area is the uppermost 2 to 6 feet of the formation. Conodonts from the Ellsworth Member in Jasper County indicate that the Devonian-Mississippian boundary there lies about 6 feet below the Rockford Limestone (Carl B. Rexroad, oral communication, 1963).

Regional Stratigraphic Relationships

The New Albany Shale is in large part equivalent to the New Albany Group of Illinois; to the Antrim, Ellsworth, and Sunbury Shales of Michigan; to the Olentangy, Ohio, and Bedford Shales, the Berea Sandstone, and the Sunbury Shale of Ohio; and to the Chattanooga Shale of Tennessee (fig. 17). These correlations are based on conodont zonation, macrofossil content, lithologic similarity, and stratigraphic position.

The name Blocher is used in Illinois with the rank of formation for rocks equivalent to the Blocher Member of the New Albany Shale as described here (fig. 17). The Blocher is the same age as the Alto For-

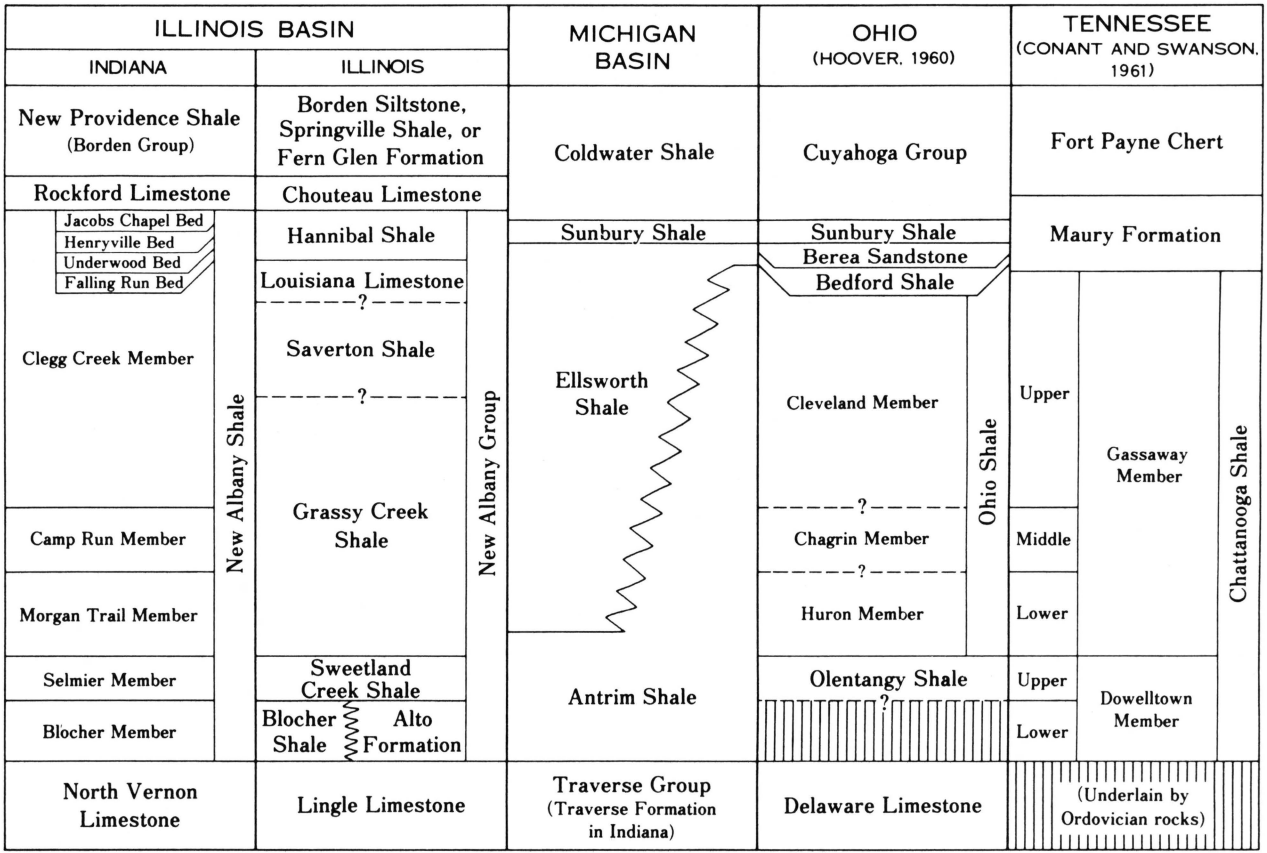

Figure 17. Stratigraphic terminology of rocks equivalent to the New Albany Shale in nearby states.

mation of Illinois (Orr, 1964) and grades laterally into the Alto (Meents and Swann, 1965). The lower division of the Dowelltown Member of the Chattanooga Shale in Tennessee is probably correlatable with the Blocher Member. The Blocher is included in the Antrim Shale of the Michigan Basin, but rocks equivalent to the Blocher may be absent in Ohio where the greenish-gray Olentangy Shale lies at the base of the black shale sequence. The Olentangy contains ammonites of the genus *Manticoceras* (Baker, 1942) and therefore is correlated with Zone *to*I as are the upper part of the Blocher Member and the Selmier Member. The Olentangy Shale is lithologically similar to the Selmier Member and is most likely equivalent to the Selmier, with the Blocher being overlapped eastward. The basal greenish-gray shale bed in the northern Indiana subsurface (pl. 1, cross section A-B) may also be equivalent to the Olentangy as interpreted from its stratigraphic position.

Rocks equivalent to the Selmier are included in the Antrim Shale in the Michigan Basin. Greenish-gray shale equivalent to the Selmier Member is called the Sweetland Creek Shale in western Illinois (fig. 17). The upper division of the Dowelltown Member of the Chattanooga Shale is also equivalent to the Selmier Member, as well as the Olentangy Shale of Ohio, as previously mentioned.

The Morgan Trail Member of the New Albany Shale may be equivalent to the Huron Member of the Ohio Shale and to the lower division of the Gassaway Member of the Chattanooga Shale (fig. 17). The Morgan Trail and Camp Run Members cannot be recognized in the subsurface of the Illinois and Michigan Basins, where their equivalents are included in the Grassy Creek Shale in Illinois and in the Antrim and Ellsworth Shales of the Michigan Basin.

Greenish-gray shale beds in the Camp Run Member of the New Albany are at about the same stratigraphic position as the Chagrin Member of the Ohio Shale and the middle division of the Gassaway Member of the Chattanooga Shale, both of which have similar lithologies.

The Clegg Creek Member is equivalent to part of the Grassy Creek

Shale of Illinois and to the Saverton Shale, Louisiana Limestone, and Hannibal Shale (fig. 17). The Hannibal is equivalent to the Falling Run, Underwood, Henryville, and Jacobs Chapel Beds. The Clegg Creek is also equivalent to most of the Ellsworth Shale and to the Sunbury Shale of Michigan, and to the Cleveland Member of the Ohio Shale and the Bedford Shale, Berea Sandstone, and Sunbury Shale of Ohio. The upper division of the Gassaway Member of the Chattanooga Shale is mostly equivalent to the Clegg Creek Member, but the Devonian-Mississippian boundary lies at the top of the Gassaway Member at most localities in Tennessee (Hass, 1956). Therefore, the Jacobs Chapel, Henryville, Underwood, and Falling Run Beds, and a small thickness of black shale below the Falling Run Bed, are chronologically equivalent to part of the Maury Formation, which overlies the Chattanooga Shale in Tennessee. Rocks called Chattanooga are also present in Georgia, Alabama, Mississippi, Arkansas, Oklahoma, and Kansas, and are at least in part equivalent to the New Albany Shale.

Depositional Environment of the New Albany Shale

PALEOGEOGRAPHIC SETTING

Sediment that ultimately became black shale was deposited in a transgressing epicontinental sea that covered much of eastern and central United States during late Devonian and early Mississippian time (fig. 18). Even though the sea in which the New Albany and its equivalents were deposited covered a vast area, the sea was essentially landlocked, bordered on the east by rising mountains and on the south, west, and north by presumed shorelines. Lack of large-scale communication with the open ocean freed the epicontinental sea from the effects of oceanic currents and from tidal mixing of oceanic and epicontinental waters. The self-contained nature of the epicontinental sea undoubtedly contributed to establishing an environment that produced black mud.

Evidence for transgression includes the overlap relationships noted by Conant and Swanson (1961) in Tennessee, where the Gassaway Member of the Chattanooga Shale overlaps the underlying Dowelltown

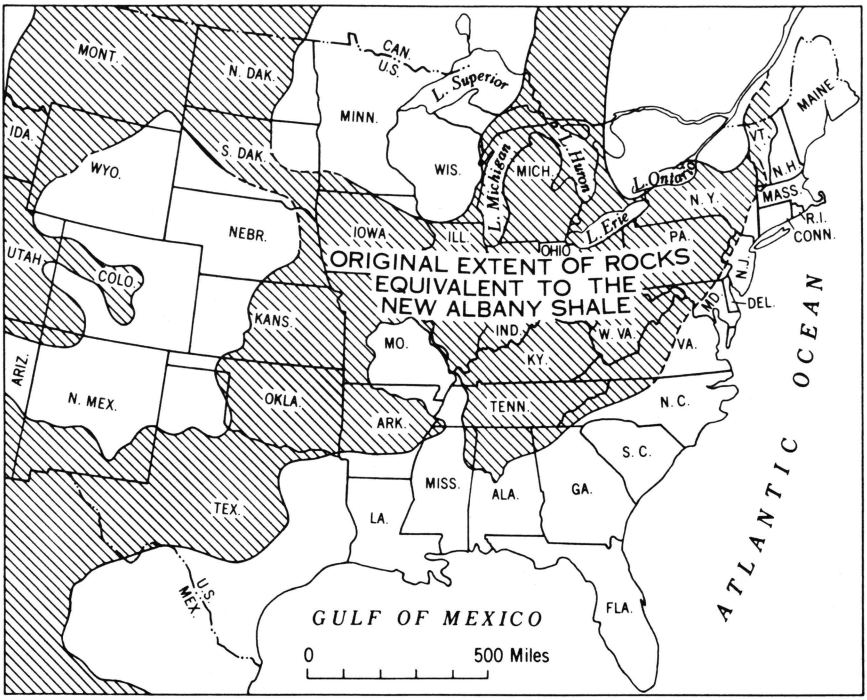

Figure 18. Map showing presumed original distribution of upper Devonian and lower Mississippian rocks in east and central United States. Modified from Conant and Swanson, 1961.

Member. A similar relationship seems likely where the Selmier Member of the New Albany Shale possibly overlaps the Blocher Member eastward to become the Olentangy Shale in Ohio. The Huron Member of the Ohio Shale overlaps the Olentangy Shale still farther to the east in Ohio. In southern Indiana the New Albany lies on middle Devonian rocks, but the black shale lies on rocks as old as Ordovician in other areas, thus also an indication of transgression. Widespread Mississippian deposits overlapping the black shale attest to the continued spread of the epicontinental sea following New Albany time.

DEPOSITIONAL FACTORS

DEPTH: Modern black muds are forming today in water ranging in depth from inches to more than a mile. Depth, therefore, is not

considered to be a controlling factor in the formation of a black shale environment, but several lines of evidence suggest deposition of the New Albany sediment in southern Indiana in a shallow sea.

Criteria indicating that the Chattanooga Shale of Tennessee was deposited in shallow water were listed by Conant and Swanson (1961, p. 60) as follows: (a) The Chattanooga shale, or its thin basal sandstone, lies directly on the unconformity; (b) the shale contains sedimentary features indicative of a shallow-water origin; (c) the black shale beds overlap to extinction, so that most parts of the formation lie on the pre-Chattanooga rocks; (d) the black shale does not grade upward into shallow-water sedimentary rocks; (e) since Precambrian time most of the area in which the Chattanooga shale is present has been one of shallow-water sedimentation; (f) the succeeding Mississippian sea, generally considered shallow, was more widespread and thus presumably deeper than the Chattanooga sea; (g) linguloid brachiopods are common in the black shale.

From present knowledge, the depth of the sea in which the New Albany Shale was deposited cannot be determined accurately. A very general figure can be inferred, however, from studies of modern *Lingula.* This genus thrives today in water less than 20 fathoms deep and has never been found living deeper than 50 fathoms (Ferguson, 1963). Abundant *Lingula* may thus indicate a water depth of less than 120 feet, unless the specimens have been transported. Linguloid brachiopods in the New Albany Shale are confined largely to a few bedding planes and are disarticulated, but because of the fragile nature of the shells it is unlikely that they were transported far. The depth of water in the New Albany sea in southern Indiana was probably near the maximum depth at which *Lingula* can live, or about 100 to 200 feet. A comparable conclusion regarding depth was arrived at by Fisher (1953) on consideration of the entire Devonian and Mississippian black-shale sequence.

Greater subsidence near the center of the Illinois Basin is indicated by thicker New Albany Shale (fig. 5) and may have resulted in water depths there in excess of 200 feet during late Devonian time. By the

end of Kinderhookian time in southern Illinois, water was more than 600 feet deep in places (Swann, Lineback, and Frund, 1965). Even though the water depth ranged from a possible 600 feet in southern Illinois to 200 feet in southern Indiana, and possibly to near zero in Tennessee, the New Albany Shale and its equivalents were uniformly brownish black and carbon rich.

CURRENTS: Cross-stratification is rare and ripple marks are unknown in the New Albany Shale, but laminations, current-transported fossils, and beds of sandstone indicate gentle and perhaps sporadic current activity. This is the expectable situation, because the long-continued existence of a stagnant black-mud environment in a shallow epicontinental sea precludes continuously active currents. Such currents as were developed were weak and probably were wind induced within the area of the epicontinental sea.

TOXIC CONDITIONS: The rarity of fossils in most parts of the New Albany Shale is an excellent indication of the toxic conditions that must have existed during deposition. Evidence for indigenous benthonic animals is lacking in brownish-black shale beds of the New Albany. Small brachiopods, such as *Chonetes, Leiorhynchus,* and *Schizobolus,* are confined to bedding planes in the Blocher Member and are interpreted as epiplanktonic in habitat. The *Lingula* found in the black shales of the New Albany are disarticulated and were probably washed in from a more favorable environment, perhaps from nearby areas where greenish-gray shale was being deposited.

A cephalopod faunule was reported by Kindle (1901) from brownish-black shale in the New Albany at Delphi in west-central Carroll County (fig. 1). Other nektonic organisms found in the New Albany include pteropods, fish, and conodonts. Fossils of nektonic organisms in the brownish-black shale indicate a zone of low toxicity near the surface.

Burrows made by unknown soft-bodied organisms are abundant at the base of and within greenish-gray shale in the Selmier and Camp Run Members. Arthropod trackways are also present in quartzose beds of the Selmier. These benthonic faunas indicate that conditions

were less toxic during deposition of greenish-gray shale than during deposition of brownish-black shale. The Underwood Bed (p. 27) and the greenish-gray shale beds in Jackson County (p. 27) and their brachiopod faunas represent local areas where the conditions were oxygenated for long enough periods of time to permit development of a more or less normal marine benthonic fauna.

ORIGIN OF THE SEDIMENT

ORGANIC MATTER: A floating mat of algae or other plants, similar to that described by Zangerl and Richardson (1963), was probably the source of most organic matter in the New Albany Shale. An autochthonous source from simple plants is indicated by the lack of structural preservation of most of the organic matter. It is difficult to conceive of such a vast quantity of organic matter being transported from distant terrestrial source areas in such a manner as to produce uniform distribution of organic matter over the basin. The presence of probable marine plants in the New Albany sea is indicated by the genera *Tasmanites, Foerstia,* and *Protosalvinia.* These genera represent reproductive bodies of primitive plants generally considered to be algae (Andrews, 1961).

The floating mat, called a flotant by Zangerl and Richardson (1963), need not have been continuous, and greenish-gray shale would presumably have been deposited in areas lacking a flotant and thus escaping a continual rain of organic matter. Widespread disruption of the flotant by storms, disease, or unfavorable water conditions may have resulted in deposition of extensive greenish-gray shale beds such as those of the Selmier Member.

Minor amounts of organic material in the New Albany were derived from land areas. Carbonized and silicified logs of trees, such as *Callixyon newberryi,* are found in the formation. The upper part of the Clegg Creek Member in southern Indiana and northern Kentucky contains a transported terrigenous flora of interesting and botanically important plant fragments (Cross and Hoskins, 1951, 1952). The terrestrial plants floated into the New Albany environment from distant shore areas.

CARBONATE CONTENT: The carbonate in the New Albany Shale is dominantly dolomite. Much of the dolomite is extremely fine grained, and there is little evidence of recrystallization or replacement. This dolomite is probably primary in nature and was deposited by biochemical activity. Dolomite is present throughout the formation but is most abundant in the Blocher and Selmier Members. Calcite is present in the Blocher.

The lower members of the New Albany contain amounts of carbonate comparable to those in sediments of the Black Sea. Caspers (1957) reported that sulfate-reducing bacteria cause precipitation of calcite in the Black Sea. Bacterial precipitation of calcite under conditions of high temperature and high organic content was also noted by LaLou (1957). Primary dolomite being precipitated today has been reported only in Australia (Alderman and Skinner, 1957), where it forms in saline lakes and restricted arms of the sea when the hydrogen ion concentration of the water is lowered owing to withdrawal of carbon dioxide from the water by growth of plants.

In the New Albany depositional environment, carbonate may have been produced by bacterial action or by changes in hydrogen ion concentration of the water due to withdrawal of carbon dioxide by plants of the flotant. Primary dolomite may have been precipitated if conditions of salinity and magnesium ion content were favorable.

PYRITE: The New Albany Shale is characterized by abundant pyrite. Iron sulfide in the form of black hydrotroilite ($FeS.nH_2O$) is precipitated by biochemical means under reducing conditions and is a common constituent of modern black muds. The hydrotroilite changes to pyrite and marcasite in time.

TERRIGENOUS DETRITUS: Quartz silt and clay in the New Albany Shale were derived from a terrestrial source area. Erosion of rising mountains in the Appalachian area is the most likely source for most of the clastic sediment in the New Albany. Black shale interfingers with light-colored clastic deposits in the upper Devonian Catskill Delta in New York and with the Mississippian deltaic clastics of the Bedford Shale and Berea Sandstone in Ohio. Other possible source areas

include shore areas on the south and north sides of the epicontinental sea and the area of the Ozark Dome. Long transportation of the clastic sediment in the New Albany is indicated by its fine size and by the good sorting and relative cleanness of included quartzose beds.

SYNTHESIS

The New Albany Shale in Indiana was deposited in a shallow epicontinental sea under reducing conditions that were caused by lack of water circulation. This lack of circulation apparently resulted from a combination of the more or less landlocked nature of the basin, the shallowness of the water, and the presence of a wave-damping plant flotant. The reducing conditions permitted accumulation of organic matter derived from the flotant and prevented the development of a normal marine benthonic fauna. Sulfate-reducing bacteria were present, and hydrotroilite was precipitated. Carbonate sediment was precipitated as a result of temporary changes in hydrogen ion concentration that were caused by the physiologic activity of plants in the flotant, by bacterial activity, or by both. Terriginous detritus was derived through erosion of the rising Appalachian Mountains to the east.

Local breaks in the flotant probably resulted in lateral lithologic variations in the New Albany. Extensive disruption and (or) destruction of the flotant by storms, disease, or other cause resulted in deposition of extensive greenish-gray shale beds having little or no organic matter.

This environment developed near the end of middle Devonian time and continued without significant interruption in Indiana until the middle of Kinderhookian time.

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Appendix: Descriptions of Measured Sections

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Section 1. Type section of the Selmier Member. South wall of the Berry Materials Co. quarry in the NE¼NW¼ sec. 34, T. 7 N., R. 8 E., North Vernon, Jennings County. Butlerville Quadrangle.

	Ft
New Albany Shale: 46.8 ft exposed	
Morgan Trail Member: 13.0 ft exposed	
23. Shale, brownish-black (5YR 2/1), fissile; weathers dark gray, brown, and yellow; pyritic beds as much as 0.1 ft thick are harder than the rest of the shale and form polygonal blocks on talus slope	13.0
Selmier Member: 22.0 ft	
22. Shale, greenish-gray (5GY 6/1), blocky; weathers greenish-gray to gray	2.1
21. Dolomite, weathered, brown; ferruginous	0.1
20. Shale, greenish-gray (5GY 6/1), blocky; weathers greenish-gray to gray	3.3
19. Dolomite in lenticular beds, greenish-gray (5GY 6/1), micritic, pyritic	0.2
18. Shale, greenish-gray (5GY 6/1), blocky; weathers greenish-gray to gray	6.0
17. Concretions, dolomitic, septarian, as much as 2 ft in diameter and 0.5 ft thick, dark greenish-gray (5GY 4/1), micritic; weathers brown; veins of pink dolomite	0.5
16. Shale, greenish-gray (5GY 6/1), blocky; weathers greenish-gray to gray	1.0
15. Shale, olive-gray (5Y 4/1), platy; weathers light gray	2.5
14. Shale, olive-gray (5Y 3/1), fissile; harder than unit 15	0.5
13. Shale, olive-gray (5Y 4/1), blocky	0.8
12. Shale, olive-gray (5Y 3/1), platy	0.3
11. Shale, olive-gray (5Y 4/1), blocky to platy, soft; contacts gradational	1.6
10. Shale, brownish-gray (5YR 3/1), fissile to platy; weathers medium gray; contains spores	1.0
9. Dolomitic quartzose rock, light brownish-gray (5YR 6/1), pyritiferous; worm tubes; weathers light brown	0.4
8. Shale, olive-gray (5Y 4/1), flaky, soft	1.3
7. Dolomitic quartzose rock; weathers brown; worm burrows on upper surface	0.4

New Albany Shale—Continued	Ft
Blocher Member: 11.8 ft	
6. Shale, brownish-black (5YR 2/1), fissile to platy, hard, calcareous, pyritic; weathers light gray; pteropods and brachiopods present on some bedding planes	1.6
5. Dolomite, brownish-black (5YR 2/1), lenticular; weathers brown	0.1
4. Shale, brownish-black (5YR 2/1), fissile to platy, hard, calcareous, pyritic; weathers light gray; pteropods and brachiopods present on some bedding planes	10.1
North Vernon Limestone: 3.8 ft exposed	
3. Lag concentrate of phosphatic limestone, pyritic, weathered; fills burrows in underlying limestone. Altitude 690 ft	0.1
2. Limestone, medium-gray (N5), coarsely crystalline, crinoidal, phosphatic	0.7
1. Limestone, light-gray (N7), fine-grained, pyritic, fossiliferous; weathers gray	3.0

Section 2. From mouth of tributary to Sixmile Creek in the SW¼SW¼ sec. 2 to Baltimore & Ohio Railroad cuts in the NW¼ sec. 11, T. 6 N., R. 7 E., Jennings County. Hayden Quadrangle.

New Albany Shale: 67.8 ft exposed	Ft
Camp Run Member: 15.0 ft exposed	
20. Shale; greenish-gray (5GY 6/1) beds 0.1 to 0.2 ft thick alternating with brownish-black (5YR 2/1) beds 0.1 to 1.8 ft thick; weathered in upper part	10.0
19. Shale, brownish-black (5YR 2/1), fissile; weathers brown	2.5
18. Shale, dark greenish-gray (5GY 4/1), blocky	0.7
17. Shale, brownish-black (5YR 2/1), fissile; weathers brown	0.9
16. Shale, dark greenish-gray (5GY 4/1), blocky, soft	0.9
Morgan Trail Member: 21.7 ft	
15. Shale, brownish-black (5YR 2/1), fissile; hard silty pyritic beds less than 0.1 ft thick; mostly covered; lower few feet exposed in creek bed on the south side of U.S. Highway 50	21.7
Selmier Member: 17.2 ft	
14. Shale, olive-gray (5Y 4/1), blocky, soft	1.4
13. Dolomitic concretions, septarian, as much as 3 ft in diameter and 1.5 ft thick	1.5

New Albany Shale—Continued	Ft
Selmier Member—Continued	
12. Shale, greenish-gray (5GY 6/1), blocky, largely covered; some brownish-gray shale near base	12.8
11. Shale, brownish-gray (5YR 3/1), platy, weathered	0.7
10. Shale, greenish-gray (5GY 6/1), dolomitic, sandy, ferruginous, weathered	0.8
Blocher Member: 13.9 ft	
9. Shale, brownish-gray (5YR 3/1), fissile; burrows in upper part	0.6
8. Dolomitic quartzose rock, light brownish-gray (5YR 6/1), pyritic, fine-grained	0.7
7. Shale, brownish-black (5YR 2/1), fissile	3.0
6. Dolomitic concretions, dark-gray (N3), as much as 3 ft in diameter and 1.0 ft thick	1.0
5. Shale, brownish-black (5YR 2/1), platy; calcareous layers and pteropods	5.3
4. Dolomite, dark-gray (N3), micritic, lenticular	0.4
3. Shale, brownish-black (5YR 2/1), fissile, pyritic; pteropods and brachiopods	2.9
North Vernon Limestone: 2.2 ft exposed	
2. Limestone, light-gray (N7), phosphatic; salt and pepper texture. Altitude 585 ft	0.2
1. Limestone, medium light-gray (N6), crystalline, phosphatic in upper few inches	2.0

Section 3. Road cut along Indiana Highway 3 half a mile south of Vernon in the SE¼NW¼ sec. 11, T. 6 N., R. 8 E., Jennings County. Vernon Quadrangle.

New Albany Shale: 6.2 ft exposed	Ft
Blocher Member: 6.2 ft exposed	
7. Shale, brownish-black (5YR 2/1), fissile; weathers gray and brown	2.0
6. Dolomitic concretion, brownish-gray (5YR 5/1); about 2.0 ft in diameter	0.4
5. Shale, brownish-black (5YR 2/1), fissile; a few gray dolomitic beds	2.5
4. Dolomite, medium dark-gray (N4); petroliferous odor; pteropods oriented N. 27° E	0.1

New Albany Shale—Continued	Ft
Blocher Member—Continued	
3. Shale, brownish-black (5YR 2/1), fissile, dolomitic; brachiopods and pteropods	1.2
North Vernon Limestone: 4.1 ft exposed	
2. Limestone, phosphatic, pyritic; fish bones. Altitude 680 ft	0.1
1. Limestone, light brownish-gray (5YR 6/1), thick-bedded, crinoidal	4.0

Section 4. Road cut along Indiana Highway 3 a mile south of Vernon in the SE¼SW¼ sec. 11 and the NE¼NW¼ sec. 14, T. 6 N., R. 8 E., Jennings County. Vernon Quadrangle.

New Albany Shale: 27.7 ft exposed	Ft
Selmier Member: 14.0 ft exposed	
9. Shale, greenish-gray (5GY 6/1), blocky; unit is cut out laterally by till; weathers brown	14.0
8. Covered interval; includes Blocher-Selmier contact	6.0
Blocher Member: 7.7 ft exposed	
7. Shale, brownish-black (5YR 2/1), fissile; weathers gray	5.0
6. Dolomite, medium light-gray (N6), micritic, lenticular; petroliferous odor; weathers brownish gray	0.1
5. Shale, brownish-black (5YR 2/1), fissile; weathers gray	0.3
4. Dolomite, medium light-gray (N6), micritic, lenticular; petroliferous odor; pteropods	0.1
3. Shale, brownish-black (5YR 2/1), fissile; very thin layers of dolomicrite containing pteropods and brachiopods	2.2
North Vernon Limestone: 2.1 ft exposed	
2. Limestone, gray; phosphatic fragments. Altitude 680 ft	0.1
1. Limestone, light-gray (N7), medium crystalline	2.0

Section 5. Road cut along Indiana Highway 3 a mile and a half south of Vernon in the center of sec. 14, T. 6 N., R. 8 E., Jennings County. Vernon Quadrangle.

New Albany Shale: 43.7 ft exposed	Ft
Morgan Trail Member: 16.0 ft exposed	
12. Shale, brownish-black (5YR 2/1), fissile to platy; pyritic beds less than 0.05 ft thick; weathers gray, brown, and yellow	16.0

New Albany Shale—Continued	Ft
Selmier Member: 15.6 ft	
11. Shale, greenish-gray (5GY 6/1), blocky; weathers brown	5.5
10. Weathered dolomite	0.1
9. Shale, greenish-gray (5GY 6/1), blocky; weathers brown	6.7
8. Dolomite, light-gray (N7), lenticular, micritic; weathers brownish gray	0.8
7. Shale, greenish-gray (5GY 6/1), blocky; weathers brown	2.0
6. Weathered ferruginous sandy layer	0.5
Blocher Member: 12.1 ft	
5. Shale, brownish-black (5YR 2/1), platy to fissile, hard; weathers gray	7.0
4. Shale, weathered, soft, olive-gray; in three beds 0.4 to 0.8 ft thick separated by two brownish-black hard beds 0.4 to 0.5 ft thick	2.6
3. Shale, brownish-black (5YR 2/1), fissile to platy; weathers light gray	2.5
North Vernon Limestone: 3.3 ft exposed	
2. Limestone, medium-gray; black phosphatic grains. Altitude 680 ft	0.3
1. Limestone, medium bluish-gray (5B 5/1), finely crystalline, hard; weathers gray	3.0

Section 6. Stream cut and road cut along Quick Creek in the NE¼NE¼ sec. 15, T. 4 N., R. 7 E., Scott County. Deputy Quadrangle.

New Albany Shale: 25.3 ft exposed	Ft
Morgan Trail Member: 2.0 ft exposed	
8. Shale, brownish-black (5YR 2/1), fissile; hard pyritic beds less than 0.1 ft thick; weathers brown	2.0
Selmier Member: 12.0 ft	
7. Shale, dark greenish-gray (5GY 4/1), blocky; mostly covered	11.7
6. Ferruginous sandy zone, weathered	0.3
Blocher Member: 11.3 ft	
5. Shale, brownish-black (5YR 2/1), fissile; weathers gray	7.6
4. Dolomite, dark-gray (N3), micritic, lenticular; weathers brown	0.1
3. Shale, brownish-black (5YR 2/1), fissile; irregular sandy dolomitic lenses near base; pteropods; weathers gray	3.6

North Vernon Limestone: 2.2 ft exposed	Ft
2. Limestone, dark-gray (N3), phosphatic, pyritic. Altitude 554 ft	0.2
1. Limestone, medium-gray (N5), coarsely crystalline, fossiliferous	2.0

Section 7. Type section of the Blocher and Morgan Trail Members. Road cut along Indiana Highway 56 beginning in the stream bed at the SE¼SW¼SW¼ sec. 9, thence along north line of the NW¼ sec. 16, T. 3 N., R. 8 E., Jefferson and Scott Counties. Blocher Quadrangle.

New Albany Shale: 47.8 ft exposed	Ft
Camp Run Member: 7.5 ft exposed	
13. Shale, brownish-black (5YR 2/1), fissile to platy	3.5
12. Shale, dark greenish-gray (5GY 4/1), flaky to blocky	0.5
11. Shale, brownish-black (5YR 2/1), fissile	0.8
10. Shale, dark greenish-gray (5GY 4/1), flaky to blocky	0.9
9. Shale, brownish-gray (5YR 4/1), fissile	1.4
8. Shale, dark greenish-gray (5GY 4/1), flaky	0.4
Morgan Trail Member: 29.5 ft	
7. Shale, brownish-black (5YR 2/1), fissile to platy, carbon-rich; has several hard pyritic beds less than 0.05 ft thick in lower part; weathers gray, brown, and yellow	29.5
Selmier Member: 3.1 ft	
6. Shale, greenish-gray (5GY 6/1), blocky, very weathered and poorly exposed	3.0
5. Dolomitic quartzose rock, brownish-gray (5YR 4/1), weathered	0.1
Blocher Member: 7.7 ft	
4. Shale, brownish-black (5YR 2/1), fissile to platy, hard; brachiopods and pteropods in lower few feet; weathers gray	7.7
North Vernon Limestone: 1.3 ft exposed	
3. Weathered ferruginous layer. Altitude 600 ft	0.2
2. Limestone, medium bluish-gray (5B 5/1), coarsely crystalline, fossiliferous; weathers gray	0.4
1. Limestone, light-gray (N7), coarsely crystalline, fossiliferous; weathers brownish gray	0.7

Section 8. Road cut along Indiana Highway 203 a mile northwest of Lexington in the NW¼NE¼ sec. 33, T. 3 N., R. 8 E., Scott County. Blocher Quadrangle.

New Albany Shale: 13.5 ft exposed	Ft
Morgan Trail Member: 6.0 ft exposed	
5. Shale, brownish-black (5YR 2/1), platy; weathers gray, yellow, and brown; contains thin hard pyritic layers that weather out as polygonal plates	6.0
Selmier Member: 1.7 ft	
4. Shale, greenish-gray (5GY 6/1), soft, blocky; weathers brown; weathered sandy zone at base	1.7
Blocher Member: 5.8 ft	
3. Shale, brownish-black (5YR 2/1), fissile to platy; rare pteropods and brachiopods; weathers light gray	5.8
North Vernon Limestone: 4.4 ft exposed	
2. Weathered ferruginous layer. Altitude 600 ft	0.4
1. Limestone, medium light-gray (N6), coarsely crystalline, fossiliferous, hard, in thick irregular beds; weathers pale brown	4.0

Section 9. Standard Materials Corp. quarry, east wall, 4 miles west of Hanover in the SW¼NE¼ sec. 16, T. 3 N., R. 9 E., Jefferson County. Kent Quadrangle.

New Albany Shale: 15.6 ft exposed	Ft
Morgan Trail Member: 8.0 ft exposed	
5. Shale, brownish-black (5YR 2/1), fissile to platy; pyritic layers and rare carbonized plants; weathers gray, brown, and yellow	8.0
Selmier Member: 3.0 ft	
4. Shale, greenish-gray (5GY 6/1), blocky, soft; weathers gray	2.9
3. Dolomitic quartzose rock, pyritic; irregular in thickness, very fine grained; weathered	0.1
Blocher Member: 4.6 ft	
2. Shale, brownish-black (5YR 2/1), fissile to platy, hard; some greenish-gray layers in a zone 1.0 ft thick and 0.4 ft below top	4.6

North Vernon Limestone: 10.0 ft exposed — Ft

1. Limestone, medium bluish-gray (5B 5/1), finely crystalline, fossiliferous; upper 0.1 ft highly pyritized and phosphatic and contains fish bones. Altitude of top, 750 ft ---------- 10.0

Section 10. Type section of the Underwood Bed. Stream cut along north bank of Silver Creek about 2 miles southeast of Underwood, in the NE¼SE¼ sec. 21, T. 2 N., R. 7 E., Clark County. Otisco Quadrangle.

Rockford Limestone: 1.7 ft exposed — Ft

6. Limestone, light-gray (N7), micritic; sparse crinoids; weathered. Altitude 560 ft ---------- 1.7

New Albany Shale: 10.1 ft exposed

Clegg Creek Member: 10.1 ft exposed

5. Shale, greenish-gray (5GY 6/1), soft, calcareous, glauconitic; *Jacobs Chapel Bed*---------- 0.4
4. Shale, brownish-black (5YR 2/1), fissile; weathers gray, yellow, and brown; *Henryville Bed* ---------- 0.8
3. Shale, greenish-gray (5GY 6/1), soft, blocky; fossiliferous phosphatic nodules; *Underwood Bed*---------- 0.4
2. Phosphatic nodules, as much as 0.7 ft long and 0.2 ft thick; fossiliferous; *Falling Run Bed* ---------- 0.1
1. Shale, brownish-black (5YR 2/1), fissile; weathers gray to brown---------- 8.4

Section 11. Road cut along Indiana Highway 160 a quarter of a mile east of Henryville in the W¼ lot 255, Clark's Grant, Clark County. Henryville Quadrangle.

Rockford Limestone: 2.2 ft — Ft

5. Limestone, light brownish-gray (5YR 6/1), micritic, fossiliferous; upper bed rubbly and ferruginous; has greenish streaks and vertical joints; weathers brown. Altitude 538 ft 2.2

New Albany Shale: 16.5 ft exposed

Clegg Creek Member: 16.5 ft exposed

4. Shale, greenish-gray (5GY 6/1), soft, calcareous, glauconitic; *Jacobs Chapel Bed*---------- 0.5

New Albany Shale—Continued Ft

Clegg Creek Member—Continued

3. Shale, brownish-black (5YR 2/1), fissile; weathers dark gray; *Henryville Bed* ---------- 0.9
2. Phosphatic nodules; 0.1 to 0.5 ft in diameter and 0.1 ft thick; *Falling Run Bed* ---------- 0.1
1. Shale, brownish-black (5YR 2/1), fissile, pyritic; weathers papery and gray, yellow, and brown ---------- 15.0

Section 12. Type section of the Clegg Creek Member. Road cut along Indiana Highway 160, 2 miles southeast of Henryville in the N¼E¼ lot 240, Clark's Grant, Clark County. Otisco Quadrangle.

Rockford Limestone: 1.0 ft exposed Ft

9. Limestone, light-brown (5YR 5/6) to light brownish-gray (5YR 6/1), micritic; has a few fossils and greenish bands; weathers light brown. Altitude 570 ft ---------- 1.0

New Albany Shale: 61.6 ft exposed

Clegg Creek Member: 42.9 ft

8. Shale, greenish-gray (5GY 6/1), glauconitic, calcareous, soft; *Jacobs Chapel Bed*---------- 0.6
7. Shale, brownish-black (5YR 2/1), fissile; weathers dark gray; *Henryville Bed* ---------- 1.4
6. Phosphatic nodules; *Falling Run Bed* ---------- 0.1
5. Shale, brownish-black (5YR 2/1), fissile, massive, pyritic; weathers gray, yellow, and brown; sparse large concretions as much as 3 ft in diameter and 1 ft thick ---------- 40.8

Camp Run Member: 17.7 ft

4. Shale, greenish-gray (5GY 6/1); beds 0.1 to 0.5 ft thick alternating with brownish-black (5YR 2/1) fissile beds 0.5 to 1.7 ft thick ---------- 11.1
3. Shale, brownish-black (5YR 2/1), fissile ---------- 3.0
2. Shale, poorly exposed; three greenish-gray beds 0.5 to 1.0 ft thick separated by brownish-black beds 1.0 ft thick ---- 3.6

Morgan Trail Member: 1.0 ft exposed

1. Shale, brownish-black (5YR 2/1), fissile; covered -------- 1.0

Section 13. Road cut along Indiana Highway 160, 3 miles southwest of Henryville in the N¼ lot 223, Clark's Grant, Clark County. Otisco Quadrangle.

	Ft
Rockford Limestone: 1.6 ft exposed	
6. Limestone, gray to brown (5YR 5/6 to 5YR 6/1), micritic; contains greenish bands, sparse fossils, and vertical joints; weathers medium brown. Altitude 580 ft	1.6
New Albany Shale: 43.2 ft exposed	
Clegg Creek Member: 43.1 ft	
5. Shale, weathered, mostly covered; *Jacobs Chapel Bed*	0.1
4. Shale, black (N1), fissile to platy, poorly exposed; *Henryville Bed*	1.4
3. Phosphatic nodules; 0.3 to 0.5 ft in diameter and 0.05 to 0.2 ft thick; *Falling Run Bed*	0.1
2. Shale, brownish-black (5YR 2/1), fissile, pyritiferous; weathers gray, yellow, and brown; few partings	41.5
Camp Run Member: 0.1 ft exposed	
1. Shale, greenish-gray (5GY 6/1); lies on largely covered brownish-black shale	0.1

Section 14. Road cut along Indiana Highway 160, 4.5 miles southeast of Henryville in the W¼E¼ lot 206, Clark's Grant, Clark County. Otisco Quadrangle.

	Ft
New Albany Shale: 15.3 ft exposed	
Camp Run Member: 14.3 ft exposed	
9. Shale, brownish-black (5YR 2/1), fissile; greenish-gray (5GY 6/1) partings about 0.1 ft thick; weathered	5.6
8. Shale, brownish-black (5YR 2/1), fissile, hard; weathers brown	2.2
7. Shale, brownish-gray (5YR 3/1), fissile, soft	2.0
6. Shale, greenish-gray (5GY 6/1), soft, flaky	0.4
5. Shale, brownish-black (5YR 2/1), fissile	0.9
4. Shale, greenish-gray (5GY 6/1), soft, blocky	0.9
3. Shale, brownish-black (5YR 2/1), flaky to platy	1.6
2. Shale, greenish-gray (5GY 6/1), flaky	0.7
Morgan Trail Member: 1.0 ft exposed	
1. Shale, brownish-black (5YR 2/1), fissile; mostly covered	1.0

Section 15. Type section of the Henryville Bed. Stream bank on Lodge Creek just east of road, center of SW line of lot 253, Clark's Grant, Clark County. Henryville Quadrangle.

	Ft
Rockford Limestone: 2.4 ft exposed	
5. Limestone, light brownish-gray (5YR 6/1), micritic, in irregular wavy beds, ferruginous; green bands and rare fossils; weathers brown. Altitude 509 ft	2.4
New Albany Shale: 4.2 ft exposed	
Clegg Creek Member: 4.2 ft exposed	
4. Shale, greenish-gray (5GY 6/1), calcareous, glauconitic, weathered; *Jacobs Chapel Bed*	0.4
3. Shale, grayish-black (N2), fissile; weathers dark gray and brown; *Henryville Bed*	0.7
2. Phosphatic nodules; *Falling Run Bed*	0.1
1. Shale, brownish-black (5YR 2/1), fissile to platy; weathers medium gray to brown	3.0

Section 16. Road cut along east side of Interstate Highway 65 a mile southwest of Memphis in the W¼E¼ lot 202, Clark's Grant, Clark County. Speed Quadrangle.

	Ft
Rockford Limestone: 1.5 ft exposed	
6. Limestone, light-gray (N7), micritic, in irregular wavy beds; greenish bands; weathers brown. Altitude 520 ft	1.5
New Albany Shale: 44.8 ft exposed	
Clegg Creek Member: 39.8 ft	
5. Shale, weathered, poorly exposed; *Jacobs Chapel Bed*	0.2
4. Shale, brownish-black (5YR 2/1), fissile; contains conodonts; weathers gray and brown; *Henryville Bed*	1.0
3. Phosphatic nodules, as much as 0.3 ft in diameter and 0.2 ft thick; *Falling Run Bed*	0.1
2. Shale, brownish-black (5YR 2/1), fissile, pyritic; dark limy concretions 7 ft above base; middle 20 ft largely covered; weathers gray and brown	38.5
Camp Run Member: 5.0 ft exposed	
1. Shale; dark greenish-gray (5GY 4/1) beds 0.1 to 0.3 ft thick alternating with brownish-black (5YR 2/1) fissile beds 0.1 to 1.1 ft thick; burrows at base of greenish-gray beds	5.0

Section 17. Road cut along west side of Interstate Highway 65, 2 miles north of Speed in the W¼ lot 167, Clark's Grant, Clark County. Speed Quadrangle.

New Albany Shale: 23.5 ft exposed	Ft
Clegg Creek Member: 8.5 ft exposed	
3. Shale, brownish-black (5YR 2/1); few irregularly spaced partings of brownish-gray (5YR 4/1) shale; weathers brown and yellow	8.5
Camp Run Member: 15.0 ft exposed	
2. Shale; dark greenish-gray (5GY 4/1) blocky beds 0.2 to 0.8 ft thick alternating with brownish-black (5YR 2/1) fissile beds 0.6 to 1.0 ft thick; outcrop has washboard appearance	11.0
1. Shale, brownish-black (5YR 2/1); poorly defined partings	4.0

Section 18. North wall of Louisville Cement Co. quarry at Speed in lot 132, Clark's Grant, Clark County. Charlestown Quadrangle.

New Albany Shale: 13.9 ft exposed	Ft
Morgan Trail Member: 2.8 ft exposed	
3. Shale, brownish-black (5YR 2/1), hard, pyritic, fissile; silty pyritic layers; weathers brown, yellow, and gray	2.8
Blocher Member: 11.1 ft	
2. Shale, brownish-black (5YR 2/1), fissile, hard; few carbonized plants; weathers light gray; extensive zone of burrows at top marks position of Selmier Member, here absent	11.1
North Vernon Limestone: 2.0 ft exposed	
1. Limestone, greenish-gray; pyritic and phosphatic layer in upper 0.5 ft. Altitude 490 ft. Limestone below this unit is gray and fossiliferous	2.0

Section 19. Type section of the Camp Run Member. Road cut along U.S. Highway 31W just west of Interstate Highway 65 overpass west of Sellersburg in the center of the southeast line, W¼S¼ lot 110, Clark's Grant, Clark County. Speed Quadrangle.

New Albany Shale: 32.3 ft exposed	Ft
Clegg Creek Member: 12.0 ft exposed	
10. Shale, poorly exposed	5.0

New Albany Shale—Continued	Ft
Clegg Creek Member—Continued	
9. Shale, brownish-black (5YR 2/1), fissile, hard; weathers brown, yellow, and gray; has pyrite nodules, dolomitic concretions 2 to 3 ft in diameter near top, partings of soft brownish-black shale, and rare carbonized plant fragments	7.0
Camp Run Member: 18.3 ft	
8. Shale, brownish-black (5YR 2/1), fissile; beds 0.1 to 1.4 ft thick interbedded with 23 to 25 greenish-gray (5GY 6/1) blocky shale beds 0.05 to 0.2 ft thick; dolomitic concretions as much as 1.8 ft thick and 4.0 ft in diameter near top; burrows at base of several greenish-gray beds	10.8
7. Shale, brownish-black (5YR 2/1), fissile	4.2
6. Shale, greenish-gray (5GY 4/1), flaky	0.6
5. Shale, brownish-black (5YR 2/1), fissile to platy	0.9
4. Shale, greenish-gray (5GY 2/1), flaky	0.6
3. Shale, brownish-black (5YR 2/1), fissile to platy	0.4
2. Shale, dark greenish-gray (5GY 4/1), flaky	0.8
Morgan Trail Member: 2.0 ft exposed	
1. Shale, brownish-black (5YR 2/1), fissile to platy; base covered	2.0

Section 20. Stream cut beginning at Blackiston Mill on Silver Creek and continuing westward a quarter of a mile along Slate Run, on the north edge of New Albany in lot 63, Clark's Grant, Floyd County. New Albany Quadrangle.

New Albany Shale: 25.9 ft exposed	Ft
Clegg Creek Member: 5.0 ft exposed	
5. Shale, brownish-black (5YR 2/1), fissile, massive; weathers gray, brown, and yellow	5.0
Camp Run Member: 17.9 ft	
4. Shale; 22 to 25 dark olive-gray (5Y 4/1) beds less than 0.1 ft thick alternating with brownish-black (5YR 2/1) fissile hard beds 0.3 to 0.7 ft thick	11.3
3. Shale, brownish-black (5YR 2/1), fissile to platy; weathers light gray	4.6
2. Shale; two or three olive-gray (5Y 4/1) beds alternating with brownish-black (5YR 2/1) beds; poorly exposed	2.0
Morgan Trail Member: 3.0 ft exposed	
1. Shale, brownish-black (5YR 2/1), fissile, poorly exposed	3.0

Section 21. Type section of the Falling Run Bed. Stream cut along Falling Run just below the bridge to Silver Hills, on the west side of New Albany in the SW¼NE¼ sec. 3, T. 3 S., R. 6 E., Floyd County. New Albany Quadrangle.

	Ft
New Providence Shale: 6.0 ft exposed	
6. Shale, greenish-gray (5GY 6/1), blocky, silty	6.0
Rockford Limestone: 0.8 ft	
5. Limestone, gray to brown, ferruginous; greenish bands and irregular upper surface; removed in places by pre-New Providence erosion. Altitude 410 ft	0.8
New Albany Shale: 3.1 ft exposed	
Clegg Creek Member: 3.1 ft exposed	
4. Shale, greenish-gray (5GY 6/1), glauconitic, soft, weathered; *Jacobs Chapel Bed*	0.5
3. Shale, brownish-black to black (5YR 2/1 to N1), fissile; contains conodonts; *Henryville Bed*	0.5
2. Phosphatic nodules, as much as 0.7 ft long and 0.2 ft thick; *Falling Run Bed*	0.1
1. Shale, brownish-gray (5YR 3/1), fissile, weathered	2.0

Section 22. North bank of Ohio River from K & IT Bridge to mouth of Silver Creek at New Albany, in the east corner of lot 28 and the south corner of lot 29, Clark's Grant, Clark County. New Albany Quadrangle.

	Ft
New Albany Shale: 23.1 ft exposed	
Morgan Trail Member: 10.0 ft exposed	
10. Shale, brownish-black (5YR 2/1), platy to fissile, pyritic	10.0
Selmier Member: 0.5 ft	
9. Shale, greenish-gray (5GY 6/1); worm burrows at base extend into unit below. Altitude 395 ft	0.5
Blocher Member: 12.6 ft exposed	
8. Shale, brownish-black (5YR 2/1), platy to fissile, soft; contains spores; weathers brown	1.2
7. Shale, brownish-black (5YR 2/1), platy; weathers gray	2.8
6. Dolomitic quartzose rock, medium-gray (N5), very fine	0.2
5. Shale, light brownish-gray (5YR 6/1), platy to fissile	0.7
4. Shale, brownish-black (5YR 2/1), fissile to platy, pyritic; carbonized plant fossils	1.8

New Albany Shale—Continued	Ft
Blocher Member—Continued	
3. Dolomite, gray, nodular, micritic	0.1
2. Shale, brownish-black (5YR 2/1), platy to flaky; weathers light gray	1.8
1. Shale, black (N1), pyritic, platy	4.0

Section 23. T. J. Atkins and Co., Inc., quarry north of Jeffersonville, in the W¼ lot 10, Clark's Grant, Clark County. Jeffersonville Quadrangle.

New Albany Shale: 17.8 ft exposed	Ft
Morgan Trail Member: 4.0 ft exposed	
8. Shale, silty, brownish-gray (5YR 3/1), soft, weathered; pyritic layers	4.0
Selmier Member: 0.1 ft	
7. Shale, greenish-gray (5GY 6/1), blocky; worm burrows at base extend into bed below	0.1
Blocher Member: 13.7 ft	
6. Shale, brownish-black (5YR 2/1), soft, weathered	3.9
5. Dolomitic quartzose rock, brownish-gray, pyritic, very fine-grained, lenticular; weathers brown	0.4
4. Shale, brownish-black (5YR 2/1), fissile, hard; lenticular dolomicrite beds and carbonized logs on some bedding planes; weathers gray and brown	9.4
North Vernon Limestone: 9.5 ft exposed	
3. Limestone, phosphatic, pyritic, weathered. Altitude 480 ft	0.8
2. Limestone, light-gray (N7), medium-grained, crystalline, fossiliferous	3.7
1. Limestone, light-gray (N7), cherty	5.0

Section 24. Burnheim Forest, 4,000 ft north of lookout tower, Bullitt County, Ky.; lat 37° 54′ 45″ N., long. 85° 37′ 32″ W. Shepherdsville Quadrangle.

New Albany Shale: 58.6 ft exposed	Ft
Clegg Creek Member: 17.8 ft exposed	
10. Shale, brownish-black (5YR 2/1), fissile; weathers brown, gray, and yellow	17.8

New Albany Shale—Continued	Ft
Camp Run Member: 16.6 ft	
9. Shale; greenish-gray or olive-gray (5GY 6/1 to 5Y 4/1) beds 0.1 to 0.3 ft thick alternating with brownish-black (5YR 2/1) beds 1.0 to 2.0 ft thick	9.5
8. Shale, brownish-black (5YR 2/1), fissile; weathers yellowish-	4.5
7. Shale; three greenish-gray (5GY 6/1) beds 0.2 ft thick separated by brownish-black beds 1.0 ft thick	2.6
Morgan Trail Member: 20.3 ft	
6. Shale, brownish-black (5YR 2/1), fissile; weathers gray, brown, and yellow	10.2
5. Shale, dark greenish-gray (5GY 4/1), lenticular, blocky	1.2
4. Shale, brownish-black (5YR 2/1), fissile; weathers brown and yellow	8.9
Selmier Member: 0.4 ft	
3. Shale, olive-gray (5Y 4/1), blocky	0.4
Blocher Member: 3.5 ft	
2. Shale, brownish-black (5YR 2/1), fissile to platy; weathers gray	3.5
North Vernon Limestone: 1.0 ft exposed	
1. Limestone, light-gray (N7), crinoidal, coarsely crystalline, pyritic	1.0

Section 25. Log Cabin Hollow, 4,000 feet west of lookout tower, Burnheim Forest, Bullitt County, Ky.; lat 37° 54′ 10″ N., long. 85° 38′ 25″ W. Shepherdsville Quadrangle.

New Providence Shale: 1.0 ft exposed	Ft
5. Shale, dark greenish-gray (5GY 4/1), blocky; contains a basal conglomerate of nodules derived from the Falling Run Bed	1.0
New Albany Shale: 37.1 ft exposed	
Clegg Creek Member: 35.1 ft	
4. Shale, brownish-black (5YR 2/1), fissile; contains conodonts; *Henryville Bed*	0.4
3. Phosphatic nodules; *Falling Run Bed*	0.1
2. Shale, brownish-black (5YR 2/1), fissile; weathers light gray, yellow, and red brown	34.6

New Albany Shale—Continued Ft

Camp Run Member: 2.0 ft exposed

1. Shale, brownish-black (5YR 2/1), poorly exposed, fissile; greenish-gray shale partings and burrows at base of greenish-gray shales ---------- 2.0

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OVERSIZED DOCUMENT

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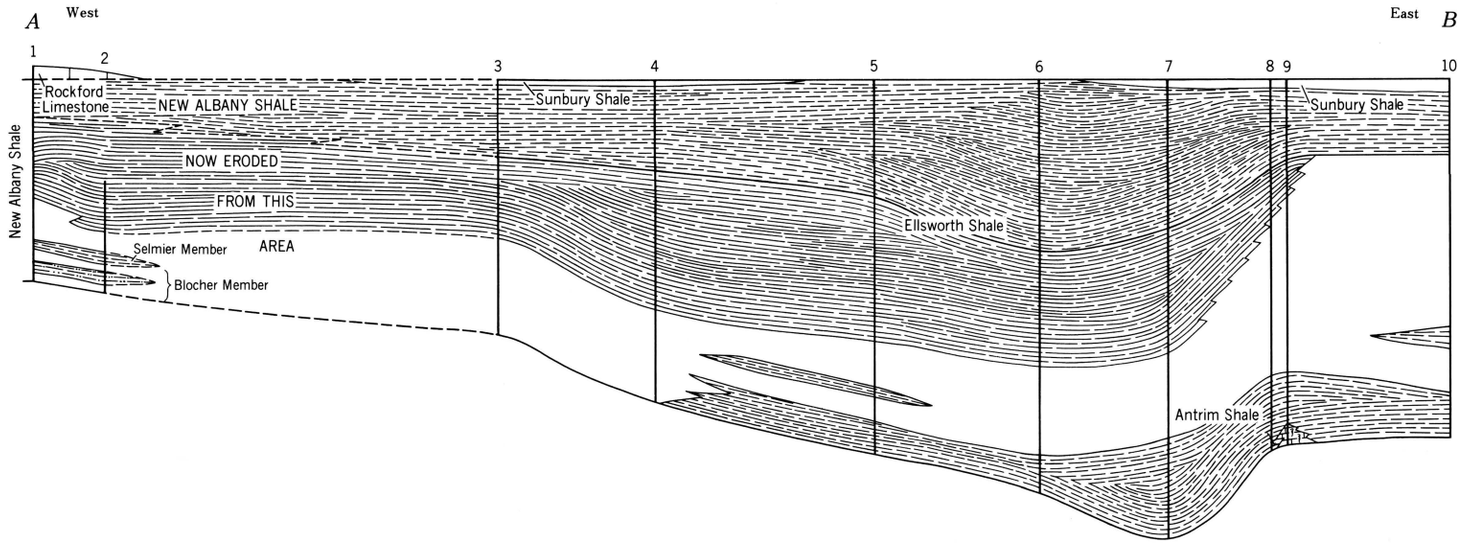

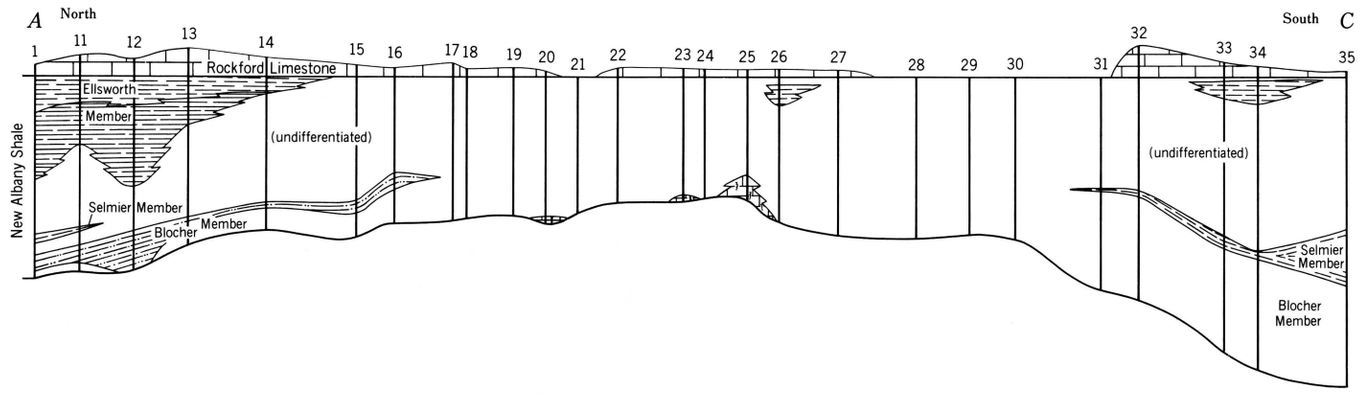

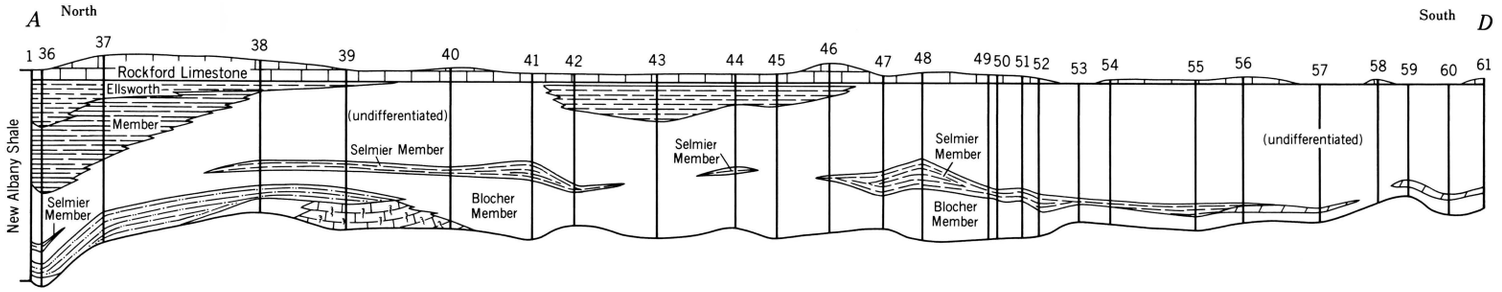

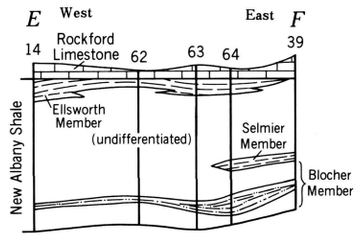

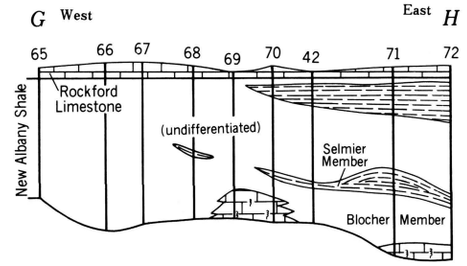

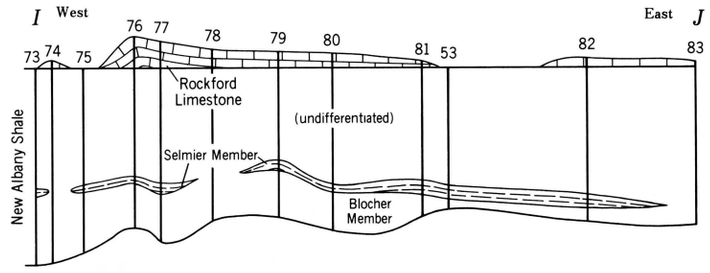

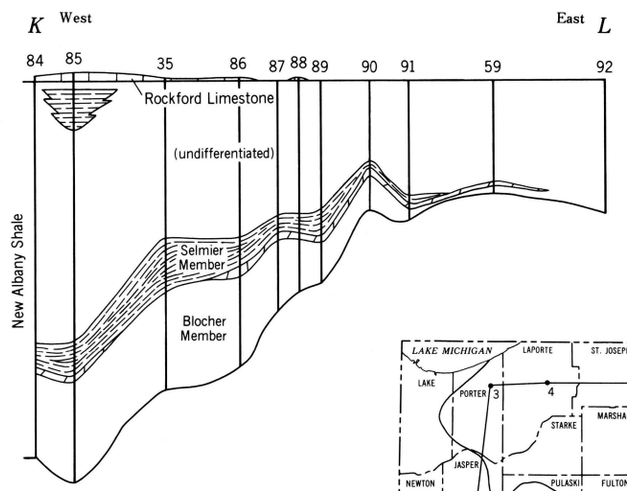

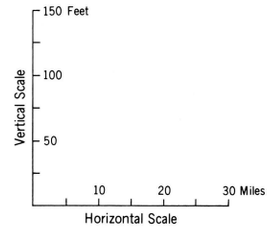

INDEX MAP OF INDIANA SHOWING LINES OF CROSS SECTION AND NEW ALBANY SHALE BOUNDARY

EXPLANATION

- Brownish-black shale
- Greenish-gray shale
- Interbedded brownish-black and greenish-gray shale
- Brownish-black argillaceous limestone
- Greenish-gray silty shale
- Limestone
- Dolomite

Datum is top of New Albany Shale or Sunbury Shale

LIST OF WELLS USED IN CROSS SECTIONS

1 NW¼NW¼NW¼ sec. 36, T. 27 N., R. 7 W., Jasper County
2 NW¼NW¼SE¼ sec. 15, T. 28 N., R. 6 W., Jasper County
3 SW¼NW¼SE¼ sec. 19, T. 36 N., R. 5 W., Porter County
4 NW¼ sec. 5, T. 36 N., R. 2 W., LaPorte County
5 NE¼SE¼SE¼ sec. 11, T. 36 N., R. 3 E., St. Joseph County
6 NW¼NW¼SW¼ sec. 30, T. 37 N., R. 7 E., Elkhart County
7 NE¼SW¼SW¼ sec. 2, T. 37 N., R. 9 E., Lagrange County
8 SE¼SE¼SE¼ sec. 23, T. 37 N., R. 11 E., Lagrange County
9 NE¼NE¼SE¼ sec. 13, T. 37 N., R. 11 E., Lagrange County
10 SE¼SW¼SW¼ sec. 16, T. 38 N., R. 15 E., Steuben County
11 SE¼SE¼SE¼ sec. 21, T. 27 N., R. 8 W., Newton County
12 SE¼NW¼SW¼ sec. 14, T. 26 N., R. 9 W., Benton County
13 NW¼NW¼NW¼ sec. 27, T. 25 N., R. 9 W., Benton County
14 NE¼NE¼SE¼ sec. 24, T. 23 N., R. 10 W., Warren County
15 SW¼SE¼SW¼ sec. 19, T. 21 N., R. 8 W., Warren County
16 SE¼SE¼SW¼ sec. 13, T. 20 N., R. 9 W., Fountain County
17 NW¼NW¼SE¼ sec. 33, T. 19 N., R. 9 W., Vermillion County
18 NW¼SE¼NE¼ sec. 9, T. 18 N., R. 9 W., Fountain County
19 NE¼NE¼NE¼ sec. 16, T. 17 N., R. 9 W., Vermillion County
20 NW¼ sec. 9, T. 16 N., R. 9 W., Vermillion County
21 SE¼SW¼SE¼ sec. 3, T. 15 N., R. 9 W., Vermillion County
22 NW¼SW¼NW¼ sec. 4, T. 14 N., R. 9 W., Vermillion County
23 NW¼NW¼ sec. 28, T. 13 N., R. 9 W., Vigo County
24 SE¼NE¼SE¼ sec. 5, T. 12 N., R. 9 W., Vigo County
25 NE¼NE¼SE¼ sec. 35, T. 12 N., R. 10 W., Vigo County
26 NW¼SE¼ sec. 25, T. 11 N., R. 10 W., Vigo County
27 SE¼SE¼NE¼ sec. 8, T. 9 N., R. 9 W., Sullivan County
28 SW¼SW¼ sec. 3, T. 7 N., R. 9 W., Sullivan County
29 NE¼SE¼NW¼ sec. 17, T. 6 N., R. 9 W., Sullivan County
30 Location 46, T. 5 N., R. 9 W., Knox County
31 Donation 54, T. 3 N., R. 9 W., Knox County
32 SE¼SW¼SE¼ sec. 19, T. 2 N., R. 8 W., Knox County
33 SW¼SE¼SW¼ sec. 25, T. 1 S., R. 9 W., Pike County
34 NW¼NW¼SW¼ sec. 23, T. 2 S., R. 9 W., Gibson County
35 SW¼SE¼SE¼ sec. 36, T. 4 S., R. 9 W., Warrick County
36 SW¼ sec. 31, T. 27 N., R. 6 W., Jasper County
37 SW¼NW¼NW¼ sec. 33, T. 26 N., R. 5 W., White County
38 NE¼NE¼ sec. 6, T. 21 N., R. 4 W., Tippecanoe County
39 SW¼SW¼ sec. 2, T. 19 N., R. 4 W., Montgomery County
40 SW¼SW¼SW¼ sec. 14, T. 17 N., R. 3 W., Montgomery County
41 SE¼SE¼NE¼ sec. 14, T. 15 N., R. 4 W., Putnam County
42 SW¼SW¼NE¼ sec. 17, T. 14 N., R. 3 W., Putnam County
43 SE¼SW¼SW¼ sec. 12, T. 12 N., R. 3 W., Putnam County
44 NW¼NW¼ sec. 15, T. 11 N., R. 1 W., Morgan County
45 NE¼SW¼SW¼ sec. 10, T. 10 N., R. 1 W., Monroe County
46 NW¼NW¼NW¼ sec. 20, T. 9 N., R. 1 W., Monroe County
47 NW¼ sec. 25, T. 8 N., R. 1 W., Monroe County
48 SW¼NW¼NW¼ sec. 15, T. 7 N., R. 1 E., Monroe County
49 NE¼NE¼SW¼ sec. 35, T. 6 N., R. 1 E., Lawrence County
50 SW¼SW¼NE¼ sec. 1, T. 5 N., R. 1 E., Lawrence County
51 SE¼SE¼ sec. 20, T. 5 N., R. 2 E., Lawrence County
52 NW¼SE¼ sec. 4, T. 4 N., R. 2 E., Lawrence County
53 SW¼SW¼SE¼ sec. 34, T. 4 N., R. 2 E., Washington County
54 SW¼NE¼NW¼ sec. 20, T. 3 N., R. 2 E., Orange County
55 NW¼NE¼ sec. 10, T. 1 N., R. 3 E., Washington County
56 SW¼ sec. 7, T. 1 S., R. 4 E., Washington County
57 NW¼NE¼ sec. 33, T. 2 S., R. 4 E., Harrison County
58 NW¼NW¼NE¼ sec. 11, T. 4 S., R. 3 E., Harrison County
59 SW¼SW¼NE¼ sec. 2, T. 5 S., R. 3 E., Harrison County
60 NE¼NW¼SE¼ sec. 1, T. 6 S., R. 3 E., Harrison County
61 NW¼NW¼NE¼ sec. 15, T. 6 S., R. 4 E., Harrison County
62 SW¼SW¼NW¼ sec. 33, T. 22 N., R. 7 W., Fountain County
63 SW¼SE¼NW¼ sec. 9, T. 22 N., R. 6 W., Warren County
64 SW¼ sec. 18, T. 22 N., R. 5 W., Tippecanoe County
65 SE¼SW¼SE¼ sec. 27, T. 14 N., R. 10 W., Vermillion County
66 NE¼NW¼NW¼ sec. 20, T. 14 N., R. 8 W., Parke County
67 NW¼NW¼NW¼ sec. 17, T. 14 N., R. 7 W., Parke County
68 SE¼SE¼NE¼ sec. 16, T. 14 N., R. 6 W., Parke County
69 NW¼SW¼NW¼ sec. 9, T. 14 N., R. 5 W., Putnam County
70 SW¼NE¼NE¼ sec. 17, T. 14 N., R. 4 W., Putnam County
71 NW¼NW¼NE¼ sec. 16, T. 13 N., R. 1 W., Morgan County
72 NE¼SW¼SW¼ sec. 10, T. 13 N., R. 2 E., Morgan County
73 SE¼SW¼SE¼ sec. 26, T. 4 N., R. 10 W., Knox County
74 Donation 182, T. 4 N., R. 9 W., Knox County
75 SW¼SE¼SW¼ sec. 3, T. 4 N., R. 8 W., Knox County
76 SE¼SW¼NE¼ sec. 2, T. 4 N., R. 7 W., Daviess County
77 SW¼SW¼NE¼ sec. 9, T. 4 N., R. 6 W., Daviess County
78 NW¼ sec. 2, T. 4 N., R. 5 W., Daviess County
79 SE¼SE¼NE¼ sec. 16, T. 4 N., R. 3 W., Martin County
80 NE¼NE¼SE¼ sec. 34, T. 4 N., R. 2 W., Lawrence County
81 NW¼ sec. 6, T. 3 N., R. 2 E., Lawrence County
82 NW¼SW¼SW¼ sec. 16, T. 3 N., R. 6 E., Scott County
83 E¼ lot 260, Clark's Grant, Clark County
84 NW¼NW¼NW¼ sec. 4, T. 7 S., R. 14 W., Posey County
85 NW¼SE¼NE¼ sec. 36, T. 5 S., R. 13 W., Posey County
86 SE¼SW¼SE¼ sec. 25, T. 5 S., R. 7 W., Spencer County
87 NE¼SW¼NE¼ sec. 21, T. 5 S., R. 5 W., Spencer County
88 NW¼NE¼SE¼ sec. 27, T. 5 S., R. 4 W., Spencer County
89 SW¼ sec. 30, T. 5 S., R. 3 W., Spencer County
90 SW¼NW¼SW¼ sec. 5, T. 5 S., R. 1 W., Perry County
91 NW¼SE¼NW¼ sec. 3, T. 5 S., R. 1 E., Crawford County
92 SE¼SE¼ sec. 32, T. 4 S., R. 5 E., Harrison County

CROSS SECTIONS SHOWING SUBSURFACE CORRELATION OF THE NEW ALBANY SHALE AND ADJACENT STRATA

By Jerry A. Lineback

1970

Drafted by John E. Peace