STRATIGRAPHIC PROBLEMS INVOLVED IN DETERMINING THE GEOLOGIC STRUCTURE IN THE LOWER MISSISSIPPIAN OUTCROP AREA OF SOUTHERN INDIANA

PARIS B. STOCKDALE, Ohio State University

Introduction. At places in the outcrop belt of lower Mississippian rocks in southern Indiana, geologic structure is difficult to ascertain from a survey of the areal geology because of certain perplexing and confusing stratigraphic relations. Some of the data gathered for structural purposes have been incorrect as a result of failure to appreciate the nature of certain stratigraphic problems and to recognize the correct age and correlation of certain beds. One complex group of rocks, the Borden (Knobstone), has been more or less avoided in the past because of lack of sufficient acquaintance with details of the stratigraphy. Recent intensive study of the stratigraphy of the Borden and associated lower Mississippian formations of southern Indiana has brought to light several stratigraphic horizons which may be used as keys for geologic structure determinations. The same study has also revealed some perplexing and significant stratigraphic situations which should occasion caution on the part of the worker on geologic structure.[1] The aim of this paper is to clarify some of the confusion which has arisen from the misunderstanding of some of the more important stratigraphic problems. No attempt is here made to treat the subject fully.

STRATIGRAPHY OF THE LOWER MISSISSIPPIAN ROCKS OF INDIANA

The Stratigraphic Column. The stratigraphic column involved in this study consists of Mississippian formations which lie beneath the Salem limestone. In the classification of the Indiana Division of Geology these formations are all considered older than Meramecian. This classification is in harmony with the views of Keyes (1892), Weller (1908, 1914), Cumings (1922), and others. Accordingly the Warsaw (Harrodsburg limestone in Indiana) is placed with the Osagian, rather than with the Meramecian above, as it was placed by Ulrich (1911), Butts (1915, 1918, 1922), and Weller (1920). Controversy over the classification of the Warsaw was reviewed fully by Cumings in 1922.[2]

The following is a list of the lower Mississippian units in Indiana which are older than the Salem limestone:

[1] Stockdale, Paris B., The Borden (Knobstone) rocks of southern Indiana: Indiana Dept. Conservation, Div. Geology, Pub. 98, 1931.

[2] Cumings, E. R., Nomenclature and description of the geological formations of Indiana: Indiana Dept. Conservation, Div. Geology, Handbook of Indiana Geology, pt. 4, pp. 475-486, 1922.

Harrodsburg (Warsaw) **Limestone**
- Upper Harrodsburg
- Lower Harrodsburg
  - Guthrie Creek member
  - Leesville member
  - Ramp Creek member

Borden (Burlington-Keokuk) **Group**
- Edwardsville formation, with the following members locally:
  - Mt. Ebel member
  - Dry Creek member
  - Weed Patch member
  - Cutright member
  - Brownstown Hills member
- Floyds Knob formation
- Carwood formation, with the following members locally:
  - Finley Knob member
  - Lampkins member
- Locust Point formation
- New Providence formation, with the following member locally:
  - Kenwood member

Rockford Limestone

Only brief descriptions of the more important units listed above can be offered here.[3] The surface distribution of the Mississippian rocks in Indiana is indicated on Plate 1. Classification and geologic sections are shown on Plate 2.

Lowest Mississippian Formations. Since Kindle's 1899 correlation the entire New Albany shale has been generally considered by Indiana geologists as being of late Devonian age. Slight doubt exists, however, as to the truth of this in the light of numerous stratigraphic studies which suggest an early Mississippian age for at least a part of the black shales (New Albany, Ohio, Chattanooga) in Kentucky and Tennessee. Quite recent contribution to this problem was made by Savage and Sutton, who showed by faunal studies that the upper part of the black shale in south-central Kentucky is of early Mississippian age.[4] If the upper part of the New Albany shale of Indiana is Mississippian in age then it is the oldest Mississippian representative in the state.

Lying immediately above the New Albany shale in southern Indiana is the Rockford limestone, commonly referred to in the early literature as the "Goniatite limestone" or "Rockford Goniatite limestone." It is this formation that has been generally regarded as the oldest Mississippian unit in the state. It ranges in thickness from one to three feet. It has very constant lithologic characteristics. It is a firm brittle limestone with an almost lithographic texture. The fresh stone is gray in color, mottled by distinctive green specks and streaks. Because of its ferruginous quality the stone is yellowish brown on weathered surfaces. As a result of

[3] Complete descriptions of the formations are given in the previously mentioned Indiana Geological Survey publication. See footnote no. 1.

[4] Savage, T. E., and Sutton, A. H., Age of the black shale in south-central Kentucky: Am. Jour. Sci., 5th ser., vol. 22, pp. 441-448, **1931.**

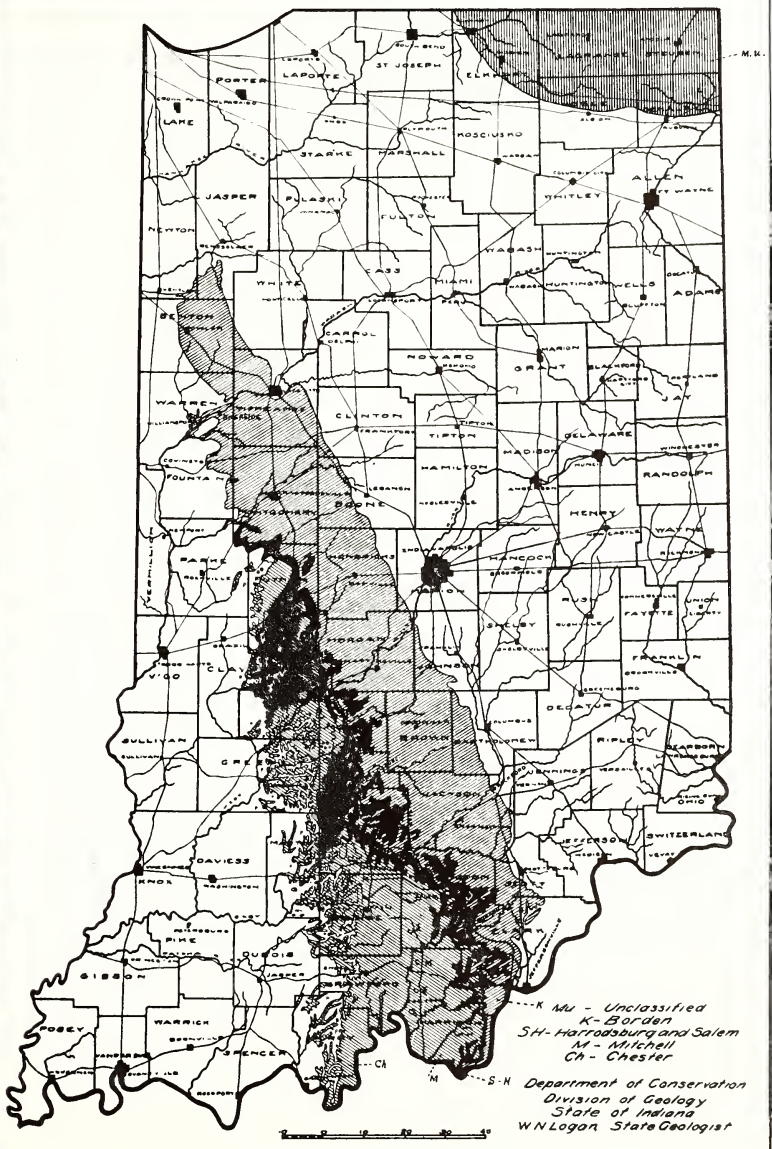


PLATE 1

Map showing surface distribution of Mississippian rocks in Indiana. (After Cumings, 1922.)

Kindle's 1899 studies the Rockford has been regarded as the "sole representative of the Kinderhook" in Indiana. Kindle (1899), Butts (1915), Cumings (1922), and others have called attention to the absence of the Rockford limestone south of the Ohio River. Kindle was of the belief

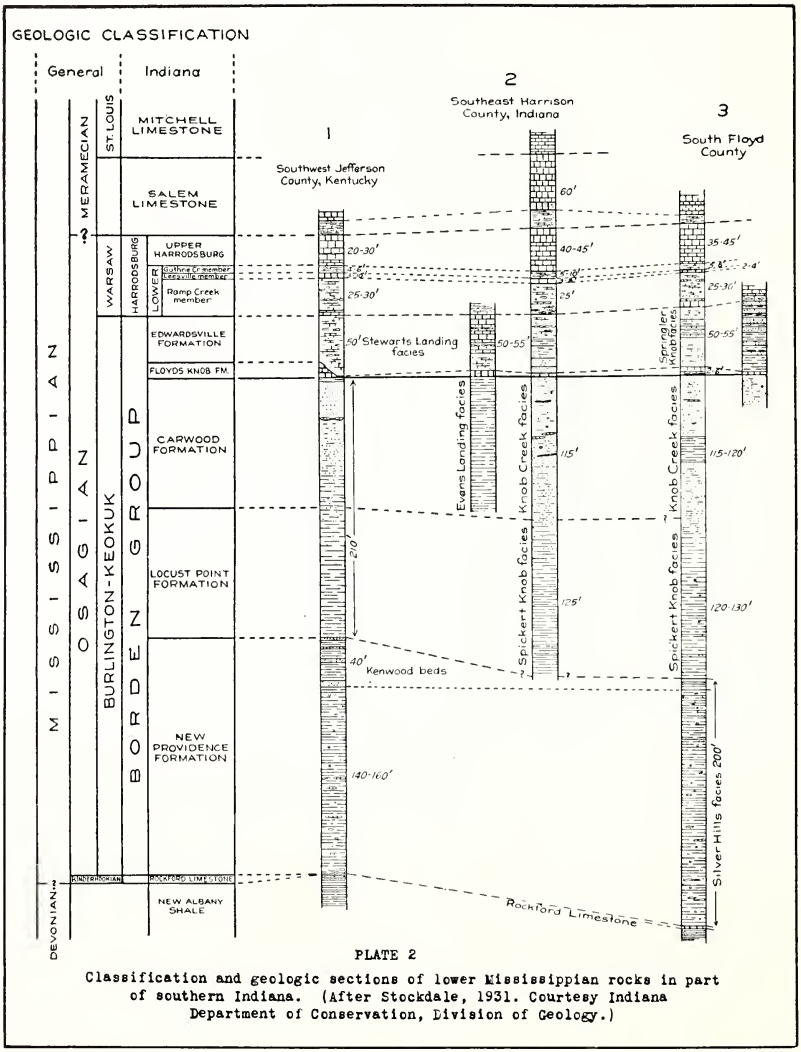


PLATE 2

Classification and geologic sections of lower Mississippian rocks in part of southern Indiana. (After Stockdale, 1931. Courtesy Indiana Department of Conservation, Division of Geology.)

that it is represented by the basal New Providence shale, whereas Butts held that the Rockford absence strengthens the testimony of an unconformity between the New Albany shale and the New Providence shale.

Borden Units and Facies. The Borden group of Indiana comprises the lower Mississippian rocks between the Rockford limestone beneath and the Harrodsburg limestone above. Prior to 1922 when Cumings pro-

posed the name "Borden,"[5] the rocks were designated by the term "Knobstone." The thickness of the unit in its unglaciated outcrop area of Indiana ranges from some 400 feet at the south to 765 feet at the north. The Borden rocks are mainly clastic—fine-grained sandstones, siltstones, and shales. Variations from the clastic type are: (*a*) the calcareous facies of the thin Floyds Knob formation; (*b*) the prominent bioherms and certain local members and facies of the Edwardsville formation; and (*c*) occasional thin calcareous layers and patches found irregularly distributed thruout the group. At most places in Indiana the Borden group is sharply delimited both below and above, and is markedly dissimilar in lithologic characteristics from the underlying and overlying strata. The most notable exception is in southeastern Harrison County, Indiana, and adjacent Jefferson County, Kentucky, where the topmost Borden formation (Edwardsville) is a calcareous facies quite similar to the overlying siliceous limestone of the Harrodsburg. This exception presents one of the significant situations to be discussed more completely later.

The lowest formation of the Borden group, the New Providence, is mainly argillaceous shale or claystone, ranging in thickness from 190 to 290 feet in southern Indiana. South of the middle of T2S, R6E, east-central Floyd County, Indiana, occasional resistant sandstone beds, with thicknesses up to about two feet, lie within a 20-foot interval at the top of the New Providence shale. These sandstone layers are Indiana's representative of what in Jefferson County, Kentucky, has been named by Butts "Kenwood sandstone."[6]

The Locust Point formation which lies above the New Providence shale is mainly a massive or shaly siltstone in the southern part of the Indiana outcrop area. Northward the formation becomes a succession of fine-grained sandstone beds and alternating shaly zones. Fossils are rare, aside from worm marks. The average thickness of the formation is about 125 feet. The overlying Carwood formation is much more complex. At the south, in Indiana, it is at most places a massive, fine-grained sandstone or siltstone. Here and there a silty facies displays a shaly appearance where weathered. The formation is highly fossiliferous at some localities; most commonly, however, it is lacking in fossils other than worm marks. The fossiliferous patches of the sandy facies of the southern area carry a fauna characterized by large brachiopods, with *Syringothyris textus*, *Orthotetes keokuk*, and various species of *Productus* prominent. The more silty facies, where fossiliferous, are featured by abundant bryozoans, mainly species of *Fenestella*, *Polypora*, *Cystodictya*, *Pinnatopora*, and *Rhombopora*. In the northern part of the unglaciated outcrop area the Carwood formation displays a number of lithologic facies varying from argillaceous shale and shaly siltstone to a bedded succession of thin resistant sandstone beds and shaly layers. Locally, abundant bryozoans occur in patches in the argillaceous phases. The more sandy sediments are practically devoid of fossils, aside from worm marks and *Taonurus* which are locally profuse. The Carwood formation ranges in thickness from 105 to 250 feet.

[5] Cumings, E. R., Op. cit., p. 487.

[6] Butts, Charles, Geology and mineral resources of Jefferson County, Kentucky: Kentucky Geol. Survey, ser. 4, vol. 3, pt. 2, pp. 148-150, 1915.

The Floyds Knob formation is the key unit in subdividing the upper Borden rocks and correlating the units of southern Indiana with those of adjacent parts of Kentucky. This formation exhibits several lithologic facies. The most common is a limestone which varies markedly from place to place. Throughout the southern half of the unglaciated Indiana outcrop belt, and in adjacent parts of Jefferson County, Kentucky, the formation varies from fairly pure crinoidal, oolitic, or crystalline rock to ferruginous, siliceous limestone. The thickness averages from 3 to 4 feet. In Jefferson County, Kentucky, and adjoining regions, the formation is the one described by Butts as the "layer of oolite" and "oolitic limestone" at the "base of the Warsaw."[7] Locally, in southern Indiana the formation is a sandstone. North of T6N in Indiana, the formation is a peculiar mixture of calcareous, ferruginous, cherty, shaly rock. Extending upward from this, locally, and involving the basal portion of the overlying Edwardsville formation, are the prominent bioherms of the Edwardsville formation, mainly in Monroe and Morgan Counties, Indiana.

The Edwardsville is in many respects the most unique of all Borden formations. It displays the greatest thickness range—40 to 200 feet. It is predominantly a formation of shale, siltstone, and sandstone. A perplexing calcareous lithology at the extreme south end of the Indiana outcrop area and in adjacent Kentucky renders it easily confused with the basal member of the overlying Harrodsburg limestone. Geologic sections for southern Floyd County, southeastern Harrison County, and southwestern Jefferson County, Kentucky, are indicated on Plate 2.

Harrodsburg Limestone. The Harrodsburg limestone lies on top of the Borden group. It is divisible into two main stratigraphic units, the Lower Harrodsburg and the Upper Harrodsburg. In the first are recognized three distinct subdivisions, or members—the Ramp Creek member, the Leesville member, and the Guthrie Creek member.[8] One of these members, the Leesville, is especially valuable as a key horizon for determining geologic structure.

To one who has made regional observations, the Harrodsburg at once appears to be of a two-fold nature: (1) a lower part, which is in the main very impure and variable, characterized by numerous geodes, much chert, and irregularly spaced crinoidal layers, one of which is persistent; (2) an upper part of fairly pure limestone in the main, in places highly crystalline and often quite fossiliferous. The contrast in lithology between these two units might be considered sufficient to warrant calling each division an independent formation.

The Lower Harrodsburg includes all the irregular and variable impure rock lying between the top of the Borden and the base of the overlying, fairly massive, more regular limestone. Except for interbedded crinoidal lenses, this division is mostly a highly siliceous, fine-grained,

[7] Butts, Charles, Geology and mineral resources of Jefferson County, Kentucky: Kentucky Geol. Survey, ser. 4, vol. 3, pt. 2, pp. 157-158, **1915**; Descriptions and correlation of the Mississippian formations of western Kentucky: Kentucky Geol. Survey, p. 26, 1918 (1917 on title page); The Mississippian series of eastern Kentucky: Kentucky Geol. Survey, ser. 6, vol. 7, p. 73, **1922**.

[8] Stockdale, Paris B., Stratigraphic units of the Harrodsburg limestone: Proc. Indiana Acad. Sci. for 1928, vol. 38, pp. 233-242, **1929**; The Borden (Knobstone) rocks of southern Indiana: Indiana Dept. Conservation, Div. Geology, Pub. 98, pp. 301-311, **1931**.

brittle stone, known to the quarryman as "bastard rock." In places it may well be called a fine-grained calcareous sandstone. Where fresh it is light gray to blue-gray in color. A high iron content gives it a characteristic buff to yellow color where weathered. This siliceous phase is quite brittle, and upon weathering splits up into irregular flattened chips, broken off in a direction diagonal to the bedding. These same features are in part characteristic of the calcareous facies of the Edwardsville formation in southeastern Harrison County, and in the adjacent parts of Kentucky. In some places the rock is quite shaly. Stylolite-seams are not common because of the impure nature of most of the rock. Chert, varying in amount, is usually abundant, occurring as nodules and lenses, sometimes as heavy ledges, white to buff in color. A part of the chert is silicified crinoidal limestone. Geodes are a characteristic feature. They are also found in the underlying Borden strata, where they are generally much smaller and less numerous.

Interbedded within the Lower Harrodsburg, and in a few places forming a large part of it, are hard, resistant crinoidal lenses, ranging from a few inches to as much as eight feet in thickness. One crinoid layer near the top is persistent and gives a basis for subdividing the unit into its three members. This crinoid layer is the previously mentioned Leesville member. This member is everywhere a fairly hard, pure, blue-gray to whitish crinoidal limestone. In many sharp ravines it produces an overhanging bench and waterfall. It ranges in thickness from one and one-half to eight feet, with an average of about four feet. Extensive study has revealed a peculiar but distinctive shaly, siliceous, calcareous zone, which weathers buff to yellow, immediately above the Leesville limestone, and between it and the overlying "typical" Harrodsburg limestone of the upper division. This zone ranges in thickness from two to 10 feet with an average of about five feet. It is the Guthrie Creek member. Beneath the waterfall-forming Leesville member is most of the variable "bastard" type of rock which dominates the Lower Harrodsburg. This lowest unit of the Harrodsburg has been named the Ramp Creek member. The thickness ranges from 17 to 28 feet.

Some uncertainty exists in separating members of the Lower Harrodsburg at places where local crinoidal lenses within the Ramp Creek zone might be confused with the Leesville member and where there is inadequate exposure of the overlying distinctive Guthrie Creek zone. Uncertainty in detecting the base of the Ramp Creek zone (base of the Harrodsburg) is one of the problems for discussion later.

In striking contrast with the Lower Harrodsburg, the upper division is a more regular, more massive, and much more pure limestone. It is usually light gray to blue-gray in color, in some places tinted green. It lacks the prominent yellow color upon weathering. Much of the stone is crystalline and much is quite fossiliferous. Stylolites are common. Chert is far less abundant than in the Lower Harrodsburg. Thin shale partings are not infrequent. Of unusual interest is a zone at the top, commonly four to 10 feet thick, consisting almost entirely of comminuted bryozoans. The thickness of the Upper Harrodsburg ranges from 30 to 50 feet, the usual thickness being about 35 feet.

HORIZONS WHICH MAY BE USED IN DETERMINING GEOLOGIC STRUCTURE

One who is sufficiently familiar with the stratigraphy of the region may, of course, use any horizon which can be detected with certainty as a basis for computing structure. The following is a list of lower Mississippian horizons which may serve with most general satisfaction:

Top of the Harrodsburg limestone
Leesville member of the Harrodsburg
Base of the Harrodsburg (Borden-Harrodsburg contact)
Floyds Knob formation
Top of the Kenwood member of the New Providence
Rockford limestone (at base of the Borden group and top of the New Albany shale)

Locally, where the above listed horizons are uncertain or not exposed, the following may aid materially:

Guthrie Creek member of the Harrodsburg
Mt. Ebel member of the Edwardsville
Dry Creek member of the Edwardsville
Weed Patch member of the Edwardsville
Cutright member of the Edwardsville
Brownstown Hills member of the Edwardsville
Lampkins member of the Carwood

Several of the above-named horizons are not traceable throughout the entire southern Indiana outcrop area. This condition applies particularly to the members of the Borden formations. The Kenwood beds exist only south of east-central Floyd County. Northward, as far as eastern Brown County, there is no clear line of demarcation between the New Providence and Locust Point formations because of the absence of these sandstone beds. The Lampkins sandstone member is restricted to southeastern and part of eastern Monroe County, and southwestern and extreme western Brown County. The Brownstown Hills sandstone member exists in northwestern Washington County, eastern and southeastern Lawrence County, and south-central and western Jackson County. The Cutright sandstone member and the Mt. Ebel sandstone member are found in northern Lawrence County and southeastern, eastern, and northeastern Monroe County. The Weed Patch member is present in eastern Monroe County, and central and western Brown County.

SIGNIFICANT STRATIGRAPHIC PROBLEMS

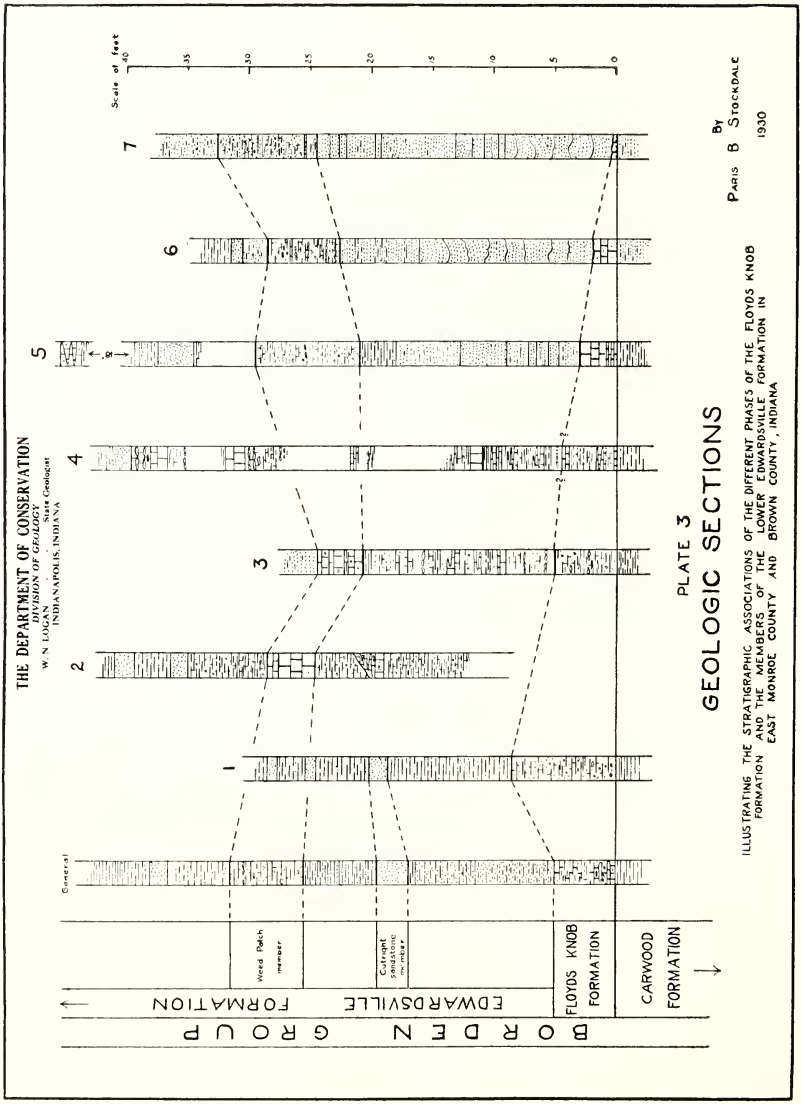
It has already been emphasized that there are certain perplexing stratigraphic conditions in the lower Mississippian rocks of southern Indiana which must be properly understood before field data for determining geologic structure can be used correctly. The most significant problems arise from *(a)* the complexity of the Floyds Knob limestone, *(b)* the bioherms, and *(c)* the uncertainty of the Borden-Harrodsburg contact in places. No pretense is here made to treat these problems as fully as desired.

Complexity of the Floyds Knob Limestone. Much of the geologic structure in the outcrop area under discussion has been studied by numerous geologists on the basis of the position of the Borden-Harrodsburg contact (base of the Harrodsburg). Considerable limitation arises from the fact that this contact is available only over a restricted area. Wherever this contact is not exposed and only the underlying Borden rocks crop out, geologists have generally been lost. This confusion can be clarified, however, upon finding the Floyds Knob formation (usually a thin limestone) whose position ranges from 40 to 200 feet beneath the base of the Harrodsburg. At other places where the Borden-Harrodsburg contact is absent or not recognizable, but the rocks of the overlying Harrodsburg are present, the Leesville limestone member may serve as a splendid key bed.

At most places within its outcrop area south of northern Lawrence County, as far as Harrison County, Indiana, the Floyds Knob formation can be successfully used as a key formation, since it is generally clearly demarcated from both the underlying Carwood and the overlying Edwardsville units. In this area the Floyds Knob is generally a thin limestone without uniform characteristics. Its properties range between two extremes—an almost pure limestone on the one hand; a highly siliceous, dolomitic, ferruginous limestone that weathers with a deep yellow to chocolate-colored hue, on the other hand. The basal part is conglomeratic at a few places. A sandstone phase (Fordyce Knob sandstone facies), instead of limestone, exists in western Clark County and in limited parts of northeastern Floyd County, southwestern Scott County, and southeastern Washington County. Some difficulty may at first be experienced in locating the Floyds Knob limestone bed because: (*a*) it may be obscured by cover; (*b*) it may be badly weathered; or (*c*) it may have been dissolved away, with only a bed of residual clay left to indicate its original existence.[9]

North of northern Lawrence County through eastern Monroe, western Brown, and southern Morgan counties, the Floyds Knob formation is at many places not separable from the basal Edwardsville rocks above because of lithologic similarities between the two divisions. At some places in this northern region, however, the Floyds Knob formation *is* clearly demarcated and recognizable where it is: (*a*) a hard, brown, crinoidal limestone bed, two to three feet thick; or (*b*) a thin zone of irregular, slightly calcareous rock, brittle, shaly, and arenaceous, usually with lumps of chert, commonly exposed in a partially weathered form with a light buff, yellow, or occasional chocolate-colored hue. In a few places the formation is no more than a thin band of limestone conglomerate resembling that of numerous exposures near the type locality to the south. These facies grade into one another. At those places where the boundary between the Floyds Knob formation and the overlying Edwardsville *can not* be ascertained, one of two situations commonly exists: (*a*) an irregular zone, built up from the base of the Floyds Knob, which is devoid of any definite limestone lenses but consists of slightly calcareous, brittle, sandy shale usually carrying chert lumps and small geodes, con-

[9] Stockdale, Paris B., Intraformational solution of the Floyds Knob limestone: Proc. Indiana Acad. Sci, for 1929, vol. 39, pp. 213-220, 1930.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DIVISION OF GEOLOGY
W. N. LOGAN, State Geologist
INDIANAPOLIS, INDIANA
PLATE 3
GEOLOGIC SECTIONS
ILLUSTRATING THE STRATIGRAPHIC ASSOCIATIONS OF THE DIFFERENT PHASES OF THE FLOYDS KNOB FORMATION AND THE MEMBERS OF THE LOWER EDWARDSVILLE FORMATION IN EAST MONROE COUNTY AND BROWN COUNTY, INDIANA
By
PARIS B STOCKDALE
1930
Scale of feet
40
35
30
25
20
15
10
5
0
General
1
2
3
4
5
6
7
Weed Patch member
Cutrupt sandstone member
EDWARDSVILLE FORMATION
FLOYDS KNOB FORMATION
CARWOOD FORMATION
BORDEN GROUP

siderably thicker than the normal Floyds Knob unit (as much as 25 feet or more); or (*b*) a limestone mass extending from the Floyds Knob base up into the overlying Edwardsville formation to a height as great as 70 feet, formed where organisms, particularly crinoids, established themselves in restricted patches for a prolonged time. These organically-made masses are the bioherms. Stratigraphic confusion and misinterpretations of geologic structure have been an outgrowth of erroneous presumptions that various limestone beds and calcareous zones exposed in different sections were at the horizon only of the thin Floyds Knob formation.

At the many places in the northern area where the position of the Floyds Knob formation is in doubt, the situation can be clarified by a study of the associated rocks. (See Plate 3.) The Weed Patch member of the Edwardsville formation lies some 25 feet above the base of the Floyds Knob formation in parts of eastern Monroe County and western and central Brown County. It is at places very similar to some facies of the Floyds Knob, with which it may be readily confused. In its most common weathered occurrence, the Weed Patch member is an irregular sandy zone with a characteristic buff to ocherous color, containing brittle, calcareous, chocolate-colored patches, and usually a few small geodes and nodules of chert. Lithologic variations are noted from place to place. At numerous places both the Weed Patch member and the Floyds Knob limestone are exposed in the same section. At such situations, of course, the two units need not be confused. The sandy rocks lying between the units have at some places, particularly in central Brown County, sufficiently distinctive characteristics to be identifiable. Plate 3 illustrates the stratigraphic associations of various phases of the Floyds Knob formation and the lower members of the overlying Edwardsville formation in eastern Monroe County and western and central Brown County. Locations of the geologic sections shown on this plate are as follows: No. 1, section along Bloomington-Brownstown road, across SE¼ sec. 21, T8N, R1E, eight miles southeast of Bloomington, two miles northeast of old Payne Post Office; bottom of section, three-fourths mile northwest of bridge over Salt Creek; No. 2, section at bluff east side of Stevens Creek, and along sharp tributary ravine, near center sec. 20, T9N, R1E, where road crosses stream, two and three-quarter miles northwest of old Stobo Post Office; No. 3, section near center SE¼ NW¼ sec. 33, T9N, R1E, three-fourths mile northwest of old Stobo Post Office; No. 4, section along old Gosport-Columbus road (abandoned), up steep hill, SE¼ SW¼ sec. 14, T10N, R1E, five miles north, slightly east of old Unionville; No. 5, section along road and in ravine west of road, SE¼ NE¼, near middle of east section line, sec. 9, T9N, R2E, two and one-half miles south of Helmsburg; No. 6, section at Kelly Hill, along State Highway No. 46, NE¼ NW¼ sec. 35, T9N, R2E, two and one-fourth miles southwest of Nashville; No. 7, section along road leading north from Weed Patch Hill, just north of intersection with secondary road which leads west, west-center sec. 32, T9N, R3E, two and one-half miles southeast of Nashville.

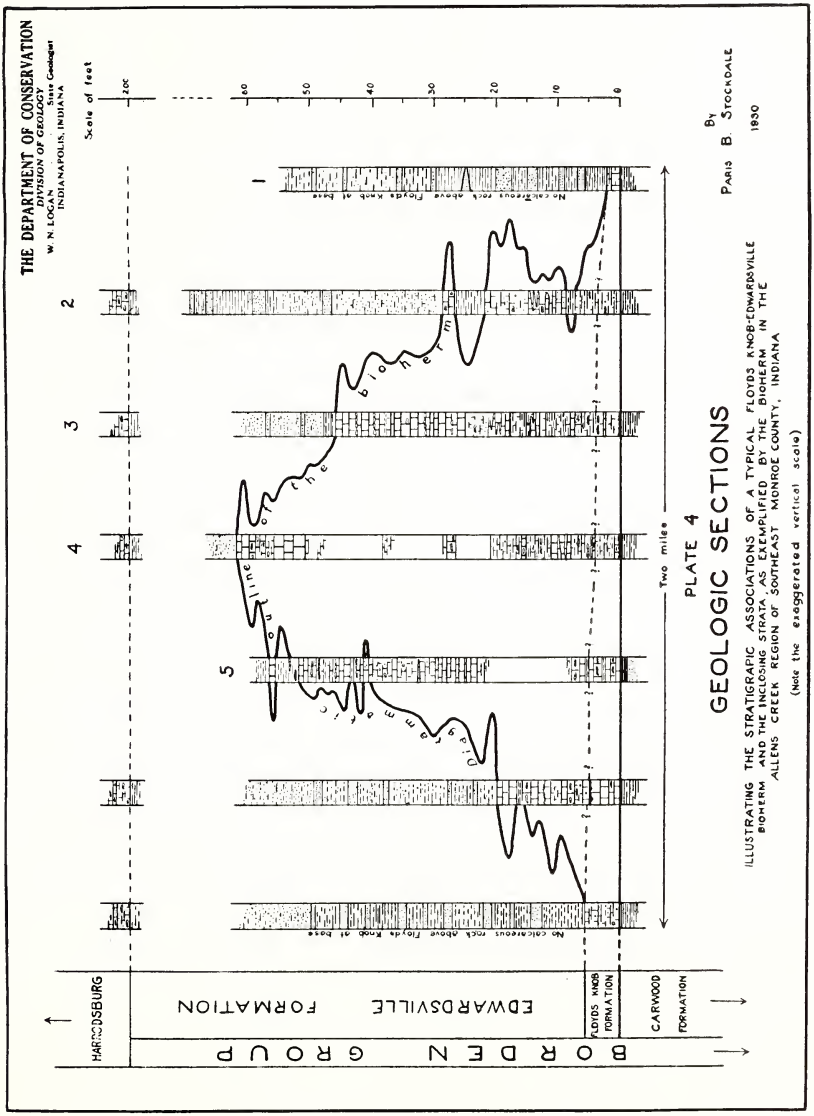
Bioherms and Their Significance. Considerable error in interpreting geologic structure in parts of eastern Monroe, western Brown, and southern Morgan counties may arise from misunderstanding the stratigraphic location of limited beds of limestone whose position may be anywhere within the midst of a large, buried calcareous deposit inclosed in the normal clastic strata. Such circumscribed limestone masses are the bioherms referred to earlier. The term "bioherm" has had frequent usage since its proposal by Cumings and Shrock in 1928.[10]

"For several years Indiana workers have been perplexed by a number of disconnected occurrences of heavy crinoidal limestone within the heart of the Borden outcrop belt . . . The 'Knobstone' (Borden) of these investigators was thought to be composed entirely of sandstones and shales. Some suspected the limestone beds to be outliers of the Harrodsburg, made possible by local downfolding or faulting. Others looked upon the masses as odd 'lenses' in the 'Knobstone,' but did not have definite knowledge of the exact stratigraphic positions. The stone of some of these beds has been quarried and crushed for road building. In places the limestone exists in such quantities and with sufficient purity to permit development of sink holes and fair-sized caverns, features extremely unique in the Borden belt.

"The writer has found these limestone masses to be bioherms built up in most cases from the base of the Floyds Knob formation (Cisco Branch facies) and extending varying distances into the basal Edwardsville formation (Allens Creek facies). They may be as much as 70 feet thick and two miles in diameter, but the exact size and shape are usually indeterminable because of insufficient exposures. In ground plan these bioherms are more or less roundish. The bases of the masses are essentially flat and their upper surfaces are no doubt quite uneven. There are lateral offshoots from the main masses furnishing isolated limestone beds at various positions above the horizon of the Floyds Knob in sections exposed near the peripheries of the bioherms. At the margins the limestone grades rather sharply into the inclosing, non-calcareous beds.

"Lower Allens Creek of southeast Monroe County cuts across a typical bioherm of the above described type. Good exposures occur in parts of sections 13 and 24, township 7 north, range 1 west, and sections 18 and 19, township 7 north, range 1 east. The center of the bioherm is near the southeast corner of section 13. Here calcareous deposition went on to the greatest height (about 65 feet) above the base of the Floyds Knob formation. One mile to the east, the bioherm is absent and the stratigraphic interval is a succession of sandstone beds and shaly zones. Geologic sections between these places show progressively more and more limestone to the west toward the center of the bioherm. The exact size of the structure is not determinable because the western part has been cut away at the valley of Salt Creek. Sections exposed along the west side of the valley, a mile or so to the

[10] Cumings, E. R., and Shrock, R. R., Niagaran coral reefs of Indiana and adjacent states and their stratigraphic relations: Bull. Geol. Soc. America, vol. 39, p. 599, 1928. Cumings, E. R., Lists of species from the New Corydon, Kokomo and Kenneth formations of Indiana, and from reefs in the Mississinewa and Liston Creek formations: Proc. Indiana Acad. Sci., for 1929, vol. 39, p. 207, 1930.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State Geologist
INDIANAPOLIS, INDIANA
Scale of feet
200
60
50
40
30
20
10
0
1
2
3
4
5
Outline of the Biotherm
Non-calcareous rock above Floyds Knob at base
Two miles
By
PARIS B. STOCKDALE
1930
PLATE 4
GEOLOGIC SECTIONS
ILLUSTRATING THE STRATIGRAPHIC ASSOCIATIONS OF A TYPICAL FLOYDS KNOB-EDWARDSVILLE BIOHERM AND THE INCLOSING STRATA, AS EXEMPLIFIED BY THE BIOHERM IN THE ALLENS CREEK REGION OF SOUTHEAST MONROE COUNTY, INDIANA
(Note the exaggerated vertical scale)
HARRODSBURG
FORMATION
EDWARDSVILLE
GROUP
BORDEN
FLOYDS KNOB FORMATION
CARWOOD FORMATION

west of the place of greatest limestone thickness, give no indications of an excessive thickness of limestone. The diameter of the original bioherm was probably not more than two miles. Aside from outcrops demonstrating the excessive thickness of the limestone, a large sink hole in northeast ¼ southeast ¼ section 13, township 7 north, range 1 west, and a good-sized cave in north-center southwest ¼ section 18, township 7 north, range 1 east, bear testimony of this unusual mass of limestone." [11]

Plate 4 shows several geologic sections illustrating the nature of a typical Floyds Knob-Edwardsville bioherm, as exemplified by the bioherm in the Allens Creek region. Sections 1, 2, 3, and 4 were taken at intervals of about one-fourth to three-tenths of a mile apart. Section number 1 is at the southeast margin of the bioherm, measured along a secondary road which runs northeast at the abandoned Allens Creek Post Office, SE¼ NE¼ sec. 19, T7N, R1E. The thin Floyds Knob formation is present with a thickness of one and one-half feet. There is no limestone above, but instead there is a succession of resistant sandstone beds up to two feet thick, and alternating shale zones. Section number 2 was measured in a sharp ravine in the bluff on the south side of Allens Creek, three-tenths of a mile west of section number 1, SW¼ NE¼ sec. 19, T7N, R1E. In this section variable limestone is present up to 29 feet above the base of the Floyds Knob formation. All but the basal three or four feet of this limestone must be looked upon as belonging to the Edwardsville. Overlying the limestone is normal Edwardsville clastic rock—sandstone, siltstone, and shale. Section number 3, showing 46 feet of calcareous rock above the bottom of the Floyds Knob, was taken from another sharp ravine, one-fourth of a mile northwest of section number 2, at west-center NE¼ NW¼ sec. 19, T7N, R1E. Again, the upper boundary of the Floyds Knob formation can not be demarcated. Some 40 feet of limestone in this section must belong to the Edwardsville division. Section number 4 is near the heart of the bioherm, about four-tenths of a mile northwest of section 3, at south-center SW¼ SW¼ sec. 18, T7N, R1E. Limestone dominates this section from the base of the Floyds Knob upwards for 62 feet. Nearly 60 feet of the limestone comprises the basal Edwardsville in this section, contrasted with about 40 feet in section number 3, 25 feet in section number 2, and no limestone in section number 1. Section number 5 depicts a readily accessible exposure near the bridge across Salt Creek, one-half of a mile northwest of section number 4.

In the Monroe-Brown-Morgan county area, in southern Indiana, there are at least seven distinct bioherms of the above-described type.

Uncertainty of the Borden-Harrodsburg Contact. The contact between the Borden group and the Harrodsburg limestone is a conformable one. It has at many places served quite adequately in the detection of geologic structure. Too much reliance, however, has been placed by numerous workers on the presumption that the upper Borden rocks (those of the now-named Edwardsville formation) are everywhere clastic in nature in Indiana and are everywhere markedly dissimilar to the

[11] Stockdale, Paris B., Bioherms in the Borden group of Indiana: Bull. Geol. Soc. America, vol. 42, pp. 712-714, 1931.

overlying calcareous beds of the basal Harrodsburg limestone (those of the Ramp Creek member). Altho this presumption is correct for most of the localities north of southern Floyd County, it is quite erroneous for Harrison County, Indiana, and Jefferson County, Kentucky, to the south. Even in the northern areas where there is generally good lithologic contrast, there are locally some beds of the Ramp Creek member which are so arenaceous and so similar to some of the top Edwardsville beds, which themselves may be slightly calcareous, that difficulty is experienced in finding the exact formational boundary.

Greatest confusion has arisen from the Borden-Harrodsburg relationships south of Floyd County. A careful tracing of the rocks southward from the north side of T4S, R5E into Harrison County, Indiana, and Jefferson County, Kentucky, has shown that they become calcareous to lower and lower depths beneath the Harrodsburg. (See Plate 2.) Edwardsville rocks have characteristics identical to those of the Ramp Creek member of the overlying Harrodsburg. Thus the stratigraphic boundary between the two formations is obscured. Because the Borden group includes clastic rocks all the way to the top thruout the better known sections of the Indiana outcrop area, and the group, therefore, has been considered by past workers to be clearly demarcated from the overlying Harrodsburg which is typically a limestone, the Borden division of the southernmost region has generally been thought to terminate with the lowest calcareous, cherty rock, and all limestone beds have been considered as belonging to the Harrodsburg formation.

Thruout practically all of Floyd County the Edwardsville comprises some 50 to 55 feet of sandstone, siltstone, and shale. Beneath it is the thin Floyd Knob limestone; above, 25 to 30 feet of variable impure limestone and calcareous sandstone comprising the Ramp Creek member. Lying upon this is the Leesville limestone member. The 75 to 85-foot interval between the Floyds Knob limestone and the Leesville limestone is one containing both clastic rock (Edwardsville) and calcareous rock (Ramp Creek). But thruout the exposed area south of the middle of T5S, R5E, in Harrison County, Indiana, and Jefferson County, Kentucky, the entire interval is characterized by the variable, impure calcareous rock of the type which to the north is restricted to the Lower Harrodsburg. This stratigraphic condition has led past workers to place the base of the Harrodsburg (Warsaw) at the bottom of the calcareous unit rather than *within* the unit some 50 or more feet above the base. For Jefferson County, Kentucky, Butts correlated all of the above-described zone with the Harrodsburg, after considering the limestone layer which is at the top of his "Holtsclaw sandstone" as marking the "base of the Warsaw."[12] This interpretation, of course, allows an excess of some 50 odd feet to the normal thickness of the Harrodsburg. This excess thickness, in turn, has led some to misinterpret the position of the top of the Harrodsburg as well as the base, and to include the Upper Harrodsburg with the overlying Salem limestone. The two stratigraphic units which serve as keys in clarifying the above-described problem are the Floyds Knob limestone and the Leesville limestone. Both are, as

[12] Butts, Charles. See footnote no. 7.

previously stated, recognizable persistent units, on the average about 75 feet apart at their southernmost Indiana occurrences. (See Plate 2.)

Workers who use the Borden-Harrodsburg contact as a key horizon in detecting geologic structure should not lose sight of the fact that dips computed from this horizon will not be in exact agreement with those calculated from lower horizons because of non-uniformity in thickness of the intervening beds. The Borden group as a whole ranges in thickness in Indiana from 400 feet or more at the south to about 765 feet in central Brown County, 85 miles to the north. The thickness at Bloomington is about 110 feet less than at Nashville, 16 miles (air-line) to the east. The rate of thickness increase between these cities is, therefore, about seven feet per mile. This factor must not be overlooked in comparing geologic structures computed from the horizon of the Borden-Harrodsburg contact with those computed from, let us say, the horizon of the Rockford limestone as determined from well records.