STRATIGRAPHIC UNITS OF THE HARRODSBURG LIMESTONE.

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Field studies of the rocks of the Borden group (Lower Mississippian) of southern Indiana[1] required the writer to make abundant observations of the overlying formation, the Harrodsburg limestone. These were especially necessary in order to establish the position and nature of the contact between the two divisions. In many places, the entire Harrodsburg formation was observed, but in most sections only the lower portion was examined because of its direct application to the stratigraphic problem of the underlying Borden group. Such observance of the Harrodsburg limestone, at closely spaced intervals throughout its unglaciated outcrop belt, served to support the testimony of other Indiana workers that the stratigraphy and fauna of the "formation" need careful attention.[2]

It is not the purpose of this paper to offer a detailed treatment of either the stratigraphy or fauna of the Harrodsburg limestone. The writer's studies have not been sufficiently complete and comprehensive, and his attention in the field has not been directly focused upon such. The broadest conclusion reached is that the Harrodsburg limestone is regionally divisible into legitimate stratigraphic units. Presentation of this phase of the Harrodsburg stratigraphy is the chief aim of this paper.

The Harrodsburg Limestone as a Unit. Recognizing the widespread occurrence, and appreciating uncertainties of correlation, Siebenthal proposed the name "Harrodsburg Limestone" for the calcareous unit which "lies above the Knobstone and between that formation and the Bedford oolitic limestone."[3] The name has been in constant usage since, in Indiana literature. The stratigraphic boundaries of the Harrodsburg limestone have been defined, therefore, as follows: The formation immediately below is the topmost one of the Borden (Knobstone) group; the formation immediately above is the Salem limestone, referred to by Siebenthal as the "Bedford Oolitic Limestone." Siebenthal's type section measured along the highway up "the north bluff of Judah's Creek at the

[1] Most of the studies were made south of the Illinoian glacial boundary, throughout a belt extending from southern Morgan County to the Ohio River at southern Harrison County, an air line distance of 100 miles.

[2] E. R. Cumings called attention to this in Appendix A of his "Nomenclature and Description of the Geologic Formations of Indiana." Indiana Dept. Cons., Div. Geol., Handbook of Indiana Geology, pt. 4, 1922, p. 531.

[3] Hopkins, T. C. and Siebenthal, C. E., The Bedford Oölitic Limestone of Indiana. Indiana Dept. Geol. and Nat. Res., 21st Ann. Rept., 1897, p. 296.

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

crossing of the Bedford-Bloomington road, one mile south of Harrodsburg"[4] follows:

Oolitic Limestone.	Feet.	Inches.
Massive fossiliferous limestone	6	0
Gray heavy-bedded limestone	16	0
Blue argillaceous shale	2	0
Limestone	0	4
Chert	0	3
Heavy-bedded blue to gray crystalline limestone	6	0
Yellow calcareous shale with geodes	1	3
Fine, heavy-bedded blue crystalline limestone	11	0
Flaggy limestone	1	0
Gray argillaceous limestone	0	10
Calcareo-argillaceous shale with bands of limestone and some geodes	18	0
Heavy limestone, weathering shaly	3	0
Calcareous shale in bed of creek	?	?
	67[5]	8

Siebenthal described the formation as follows: "The Harrodsburg limestone varies from 60 to 90 feet in thickness. It forms a belt four or five miles in width lying along the eastern outcrop of the oölitic, rising gradually toward the east at the rate of 50 or 60 feet to the mile, and bordered by the broken hills of the Knobstone region.

"The 'beds of passage' from the Knobstone to the Harrodsburg limestone contain great numbers of geodes, or, as they are more familiarly termed, 'mutton heads,' ranging from the size of a pea up to 18 or 24 inches in diameter. These geodes are confined to the lower members of the Harrodsburg limestone, though a few are scattered through the Knobstone.

"Above the geode layers there is a bright gray or blue highly crystalline and quite fossiliferous limestone with small crystals of pyrite, giving it in places a greenish tint. Many of the bedding planes are marked by 'crowfeet' (stylolites), and intercalated lenticular masses of chert are very plentiful. The residual clay is very stiff and of a deep-red color.

"Towards the top of the limestone the strata become more massive, and at the top of the upper four to eight feet usually have lost the molluscan character of their fauna and consist almost wholly of comminuted bryozoa. . . ."[6] It should be noted that the "beds of passage" were included in the Harrodsburg unit.

Some uncertainty as to the exact contact of the formation with the overlying and underlying rocks was recognized by Beede, who wrote: "The Harrodsburg limestone is from 70 to 90 feet in thickness in the quadrangle. The lower part is interstratified with shales and some soft sandstones. The lowest limestone was taken as the base of the Harrods-

[4] Hopkins, T. C. and Siebenthal, C. E., *Ibid.*, p. 297.

[5] This should be 65 feet 8 inches. Siebenthal added incorrectly.

[6] Hopkins, T. C. and Siebenthal, C. E., *Ibid.*, pp. 297-298.

burg. However, since there is a tendency for these lower layers to be lenticular it is not certain that the mapping is absolutely uniform in this respect. In fact it is pretty certain that this is not the case. However, the variation is but a few feet, probably not varying beyond the limits of accuracy of mapping on the present base map.

"In a general way the Harrodsburg is a very coarse crinoidal limestone in its lower part, a calcirudyte, becoming finer near the central part where the crinoids and large brachiopods and pelecypods are replaced with bryozoa. Near the top it assumes very much the character of the Salem limestone or 'Bedford oolite' above, a calcarenyte. However, so far as the rocks of this quadrangle are concerned, careful inspection with the lens will differentiate them at once. At the overhead bridge across the Monon track, between Smithville and Sanders, the two are nicely separated by a strong stylolite seam. Much of the way they are separated by a brownish bituminous marl, which locally replaces the base of the oolitic limestone. At other places it is difficult to say within two to five or six feet just where the contact is. The upper part of the Harrodsburg is composed of comminuted bryozoan remains with certain elongate particles whose nature has not yet been made out. . . ."[7]

Full treatment of the Borden-Harrodsburg contact cannot be presented in this brief paper. In general, it may be said that the contact is determinable in the outcrop belt north of T. 3 S., R. 5 E., southwestern Floyd County. To the south, in Harrison County and in adjacent parts of Kentucky, the contact is clouded because of the rather quick change of facies of the uppermost Borden member to a calcareous, cherty phase which is itself very similar in appearance to the normal, basal Harrodsburg. Lack of appreciation of this facies change in the upper Borden has misled a number of observers from the proper interpretation of the Harrodsburg-Borden relationships.

Only a careful study of the Harrodsburg-Salem association will fix satisfactorily the position of the top of the Harrodsburg limestone. This is especially true because of uncertainty regarding the gray to buff, calcareous, shaly zone which appears in many places between the "typical Salem" above, and the definite Harrodsburg limestone below. This shaly zone is particularly common in southern Floyd County and in southeastern Harrison County, as well as in exposures across the Ohio River in Kentucky. In one of the quarries at Edwardsville, this zone is five to seven feet thick; at Locust Point, along the road up the steep bluff, near center sec. 13, T. 4 S., R. 5 E., it is 20 feet thick; along the road one and one-fourth miles north of Stewart Landing, southeast of the center sec. 26, T. 4 S., R. 5 E., it is 13 feet thick; near the top of the large quarry at West Point, Kentucky, a similar zone 12 feet thick can be recognized. Malott has called attention to a much greater thickness of this shale in the vicinity of the village of Buena Vista, southeastern Harrison County. In eastern Monroe County at a quarry in the hillside, immediately east of the road, west-center sec. 27, T. 8 N., R. 1 E., where there is an unusual exposure of both Harrodsburg limestone and Salem

[7] Beede, J. W., Geology of the Bloomington Quadrangle. Indiana Dept. Geol. and Nat. Res., 39th Ann. Rept., 1915, p. 195.

limestone, this buff shaly zone is found about five feet in thickness. The appearance of the Salem limestone there, which is a considerable distance east of the main outcrop belt, is on the downthrow (west) side of the fault, where the amount of throw is exceptional. The total Harrodsburg thickness there is 62 feet. The shaly zone described above is, however, in many places quite thin or non-existent.

The question of the correlation of the Harrodsburg limestone with other Mississippi Valley formations has been considered by numerous workers. Controversy over the Keokuk or Warsaw age of the formation ended finally in favor of the Warsaw. Excellent and complete treatment of the Harrodsburg correlation is given by Cumings.[8]

DIVISIONS OF THE HARRODSBURG LIMESTONE.

A sub-division of the Harrodsburg limestone into units is justified by a scrutiny of many sections carefully measured, and of others casually observed. Figure 1 shows a generalized section for southern Indiana. In the first place, it is evident that the formation is divisible into two main parts, to which the writer, at this time, is not offering names, but is merely using the designations "Upper" and "Lower." In the second place, it is to be noted that these major divisions are separable into smaller units, or members. The Upper Harrodsburg has not been carefully studied by the writer, and, consequently, no attempt is made to give it a final subdividing nor a naming of probable members. The Lower Harrodsburg, which has been critically observed, reveals three recognizable and persistent units. The proposed names for these members, in ascending order, are "Ramp Creek," "Leesville," and "Guthrie Creek."

Lower Harrodsburg. The two-fold nature of the Harrodsburg is at once apparent to those who have made regional observations: (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 Lower Harrodsburg includes all the irregular and variable, impure unit lying between the uppermost Borden member below and the overlying, fairly massive, more regular limestone. Except for crinoidal lenses, this division is a highly siliceous, fine-grained stone, known to the quarryman as "bastard rock." In places it may be well-called a calcareous sandstone. When fresh it is light-gray to blue-gray. A high iron content gives it a characteristic buff to yellow color when 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 upper Borden in southeastern Harrison County, and in the adjacent parts of Kentucky.

Interbedded within the Lower Harrodsburg, and forming a large part of it in places, are hard, resistant, crinoidal lenses, ranging from a few

[8] Cumings, E. R., *Ibid.*, pp. 493-496.

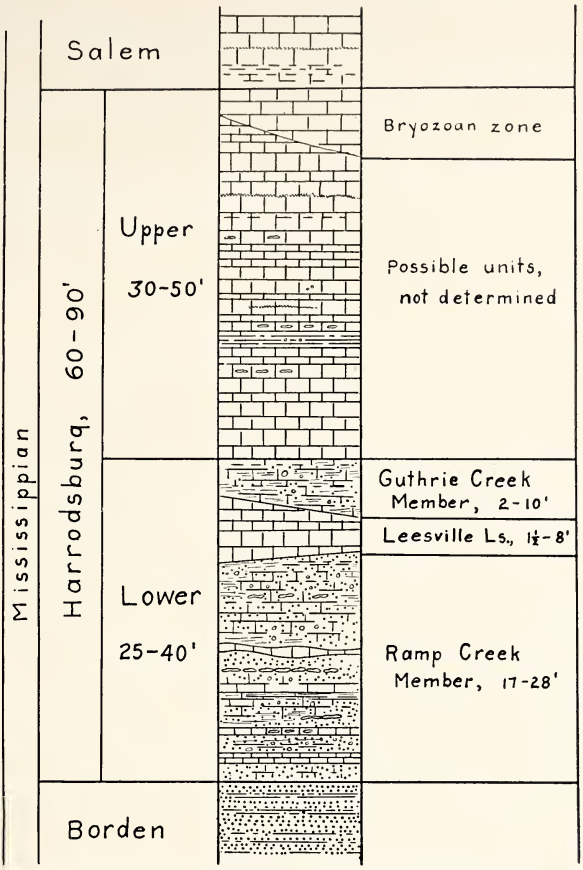

Fig. 1—Generalized section showing divisions of the Harrodsburg limestone in southern Indiana.

inches to as much as eight feet in thickness. One crinoid layer is persistent and gives a basis for subdividing the unit into its three members. Crinoid streaks and irregular patches are common. In places the rock is shaly. Stylolite-seams are not common because of the siliceous nature of most of the rock. Chert, varying in amount, is usually abundant, occurring as nodules and lenses, and is white to buff in color. Some of the chert is silicified crinoidal limestone. Geodes characterize the Lower Harrodsburg and are also in the underlying Borden strata, where they are usually much smaller and less numerous.

The following sections illustrate the general nature of the Lower Harrodsburg: (a) Section one and one-fourth miles east of Harrodsburg, Monroe County, measured along a ravine running east from the road forks, a short distance east of the center of sec. 28, T. 7 N., R. 1 W.:

Upper Harrodsburg limestone.

Lower Harrodsburg:	Feet
Partially covered, buff shaly zone (Guthrie Creek member)	3½
Crinoidal limestone, in layers of varying thickness (Leesville limestone)	4½
Shaly, siliceous limestone, weathering yellow	3½
Crinoidal limestone	½
Siliceous limestone, gray to buff	1½
Slabby, coarse, crinoidal limestone, with siliceous streaks	3½
Siliceous limestone, gray to yellow, with crinoid streaks	3½
Irregular crinoidal limestone, with chert and geodes	2½
Siliceous limestone, gray to yellow	6½
Siliceous, crinoidal zone	1½

Borden, blue-gray, sandy shale.

The lower 23 feet of the above section constitute the Ramp Creek member. Chert and geodes are common to the brittle siliceous zones.

(b) Leesville section, measured in quarries and along U. S. highway No. 50, immediately west of the bridge across Guthrie Creek, one-fourth mile southeast of Leesville, Lawrence County, near center NE. ¼ sec. 27, T. 5 N., R. 2 E.:

Upper Harrodsburg, mainly coarse, crinoidal limestone.

Lower Harrodsburg:	Feet
Blue-gray, calcareous, sandy shale, weathering buff to yellow (Guthrie Creek member)	7
Coarse, blue-gray, crystalline and crinoidal limestone (Leesville limestone)	6
Blue-gray, variable, siliceous, brittle limestone, with irregular streaks and small patches of crinoids; weathers to yellow color; small geodes; much chert	20
Crinoidal limestone	0 to 2
Brittle, sandy limestone	1½

Borden, massive sandstone.

(c) Edwardsville section, measured along State highway No. 62 and adjacent quarry, immediately northeast of Edwardsville, Floyd County, NE. ¼ NE. ¼ sec. 1, T. 3 S., R. 5. E.:

Salem Limestone, massive, typical.	Feet
Argillaceous limestone, weathering buff, with shaly appearance	7
Upper Harrodsburg limestone	32
Lower Harrodsburg:	
Gray to yellow, shaly, siliceous limestone (Guthrie Creek member)	5
Gray, compact, coarsely crinoidal limestone (Leesville limestone)	2
Siliceous, gray to blue limestone, with thin, irregular crinoidal lenses	7
Irregular crinoidal limestone, with siliceous patches	4

Gray, weathering yellow, very irregular limestone; mostly siliceous, with small geodes and much chert..... 10
Brown, crinoidal limestone..... 2½
Dark-gray, brittle, calcareous sandstone, with crinoid streaks 4½
Borden standstone.

The lower 28 feet of the Lower Harrodsburg of the above section constitute the Ramp Creek member (see fig. 2).

The most persistent feature of the Lower Harrodsburg, which impresses one who has made many observations throughout the entire outcrop belt, is a hard limestone layer which often displays itself as an overhanging bench in sharp ravines, producing a waterfall. The possibility of this "waterfall-former" being a continuous layer and a definite

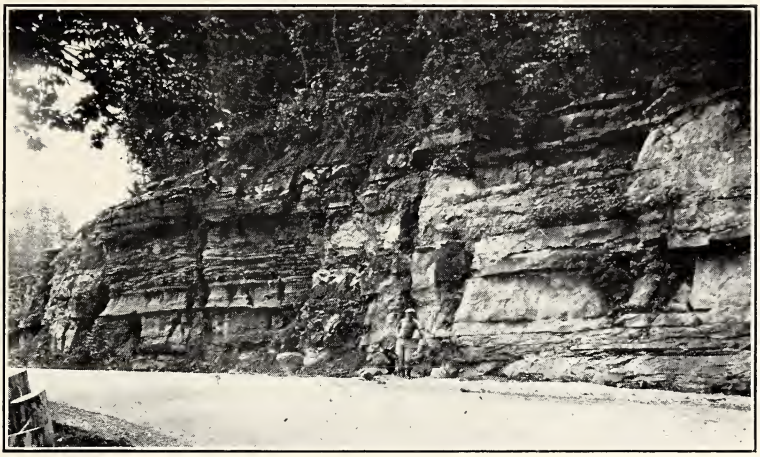

Fig. 2—The Ramp Creek member as seen in the Edwardsville section, exposed along State Highway No. 62, immediately northeast of the village of Edwardsville. NE. ¼ NE. ¼ Sec. 1, T. 3 S., R. 5 E. The contact with the Borden is indicated by the man's hand.

stratigraphic unit was recognized by Malott. Extensive study has revealed a persistent shaly to siliceous zone, weathering buff to yellow, immediately above this limestone layer, and between it and the overlying "typical" Harrodsburg limestone of the upper division. Below this waterfall-forming layer is the variable "bastard" rock, previously described. Other crinoidal lenses locally cause waterfalls, and may easily be confused at first with the main limestone member.

The name *Leesville Limestone member* is here proposed for the unit described above. The name is taken from the village of Leesville at the eastern edge of Lawrence County. The Leesville section (b) shows this member in its typical occurrence. Here it is a heavy, coarse-grained, blue-gray, crystalline and crinoidal limestone, six feet thick. At the time of this writing, it is exposed on both sides of the road, and near the top of the abandoned quarry immediately south of the road. It is

responsible for numerous waterfalls in nearby ravines. In this type section it is plainly delimited both above and below. Above it is the seven foot zone of calcareous shale to shaly limestone, which weathers light yellow. Above this is massive limestone of the Upper Harrodsburg. Directly below the Leesville limestone at this section, is variable, calcareous rock, quite siliceous, about 22 feet thick. The Leesville limestone ranges from one and one-half to as much as eight feet in thickness. Between four and five feet is an average thickness. Throughout the entire outcrop belt, its stratigraphic boundaries are persistently similar to those of the type section. That it is not as discernible in some places is due to improper exposure of the overlying unit and greater abundance of confusing crinoidal lenses below. The member is especially pronounced and valuable in southern Floyd and southeastern Harrison counties. Here it serves as an excellent key horizon for stratigraphic and structural studies, especially since the base of the Harrodsburg is indefinite.

Guthrie Creek member is the name proposed for the shaly to siliceous limestone unit lying immediately above the Leesville limestone. It is overlain by the Upper Harrodsburg limestone. The name is taken from Guthrie Creek, along which, in southeastern Lawrence County, the member is often exposed. In its typical occurrence, it is seen in the heretofore listed Leesville section (b) located adjacent to Guthrie Creek. Here as previously stated, it is seven feet thick; it is quite shaly, and has a number of large geodes. In other exposures it is often less shaly and is more sandy. Buff to light yellow is the characteristic color of the weathered rock in all exposures. Where unweathered, the rock is blue-gray and does not display, so well, its shaly nature. In most places this member is more shaly and weathers less yellow than the rock beneath the Leesville limestone. It ranges in thickness from two to 10 feet, with an average of about five feet.

For the main part of the variable, siliceous limestone with crinoid lenses, which lies between the Borden sandstone or shale below and the Leesville limestone above, the name *Ramp Creek member* is proposed. This is taken from Ramp Creek of southeastern Monroe County. In numerous tributary ravines, this member, and the underlying and overlying rocks are excellently exposed. A good type section is revealed in a headwater ravine which crosses the secondary road, and which runs southeast from near the eastern margin of NW. ¼ NW. ¼ sec. 35, T. 8 N., R. 1 W., one mile northeast of the village of Sanders. Here the following strata are exposed, the upper part along the road, and the main portion in the ravine:

	Feet
Upper Harrodsburg limestone	3
Lower Harrodsburg:	
Buff, siliceous, somewhat shaly limestone, with crinoidal patches (Guthrie Creek member)	2½
Massive, light gray, crinoidal limestone (Leesville limestone)	3½
Variable, impure limestone, mostly gray to yellow, siliceous and brittle; irregular crinoidal lenses up to eight inches thick; streaks of chert; geodes	15

Slabby, coarse, crinoidal limestone..... 3
Somewhat variable, more massive crinoidal limestone, with stylolites 3
Borden, sandy shale.

The lower 21 feet compose the Ramp Creek member. This exposure, and the exposures of the three sections (a, b, c) previously listed, show the general nature of the Ramp Creek member (see fig. 2). They demonstrate the distinctive variability. The predominance of brittle, siliceous limestone which weathers yellow; the presence of irregularly distributed crinoidal lenses, varying in thickness and often disappearing

Fig. 3—A sharp Harrodsburg-Borden contact made by a basal crinoidal limestone lens. The Borden rock is here a very shaly sandstone. This exposure is in the bank of a small stream, near the southwest corner sec. 22, T. 8 N., R. 1 W., about one and one-half miles southeast of the village of Clear Creek.

laterally, passing into the siliceous phases; and the prevalence of geodes and chert, are all characteristic of this member. The sharply defined crinoidal lenses furnish incentive for a unique, separate study. In some localities, as immediately north of Bloomington, these lenses are abundant; in others, as at Leesville, they are rare. In many places a crinoid layer marks the contact with the underlying Borden (see fig. 3); in others, such a layer is absent. The thickness range of the Ramp Creek member is 16 to 28 feet; the average thickness, about 22 feet.

The Lower Harrodsburg averages about 32 feet in thickness; the minimum is 25 feet; the maximum, 40 feet. The following table shows the approximate thicknesses of the Lower Harrodsburg members at or near a number of places:

Locality	Guthrie Creek member	Leesville limestone	Ramp Creek member	Total thickness
Mt. Tabor.....	2	2	24	28
Bloomington.....	6	5	16	27
Smithville.....	3	3	20	26
Patton Cave.....	2	3	25	30
Harrodsburg.....	3	5	23	31
Leesville.....	7	6	22	35
Borden.....	7	5	21	33
Georgetown.....	5	3	27	35
Edwardsville...	5	2	28	35
Rosewood.....	5	6	30?	41?
Evans Landing...	4	8	31?	43?
West Point, Ky..	5	10	25?	40?

Upper Harrodsburg. 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 yellow color upon weathering. Much of it is crystalline, and much is quite fossiliferous. Stylolites are common. Chert is far less abundant than in the Lower Harrodsburg. Shaly partings are not infrequent.

Of unusual interest is a zone at the top consisting almost entirely of comminuted bryozoa, commonly from four to 10 feet in thickness. This may be of a bioherm nature. The thickness of Upper Harrodsburg ranges from 30 to 50 feet, the common thickness being about 35 feet.

As previously stated, this paper is not offering a detailed treatment of the Upper Harrodsburg, and does not suggest the subdivisions of it. More intensive study is necessary to reveal its probable stratigraphic units. However, the fact has been clearly revealed that the Upper Harrodsburg is a distinct division, worthy of separate consideration from the Lower Harrodsburg.[9]

[9] The writer is especially indebted to Professors E. R. Cumings and C. A. Malott, of the Department of Geology, Indiana University, for valuable suggestions and assistance.