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The Sanders Group and Subjacent Muldraugh Formation (Mississippian) in Indiana

By NED M. SMITH

DEPARTMENT OF NATURAL RESOURCES
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THE SANDERS GROUP AND SUBJACENT MULDRAUGH FORMATION (MISSISSIPPIAN) IN INDIANA

By Ned M. Smith

ABSTRACT

Lithologic similarities between the Salem Limestone and the subjacent Harrodsburg Limestone, redefined here, indicate a close relationship between these formations, which are assigned to a new rock unit, the Sanders Group (middle Mississippian). The Harrodsburg Limestone is redefined to exclude a dissimilar unit, the Ramp Creek Limestone Member, which is reassigned to the highest formation (Muldraugh) of the Borden Group; thus the Borden Group is modified by the addition of the Ramp Creek. The Ramp Creek is expanded to include subjacent rocks of similar lithologies that were formerly classed as parts of the Edwardsville Formation. The Leesville and Guthrie Creek Members are retained as parts of the Harrodsburg Limestone. The name Muldraugh Formation, excluding here the Leesville and Guthrie Creek Members of former usage in Kentucky, is introduced for the uppermost formation of the Borden Group in Indiana. The Muldraugh includes the Ramp Creek Limestone Member and the redefined Edwardsville Member and the Floyds Knob Limestone Member; the Floyds Knob and Edwardsville, formerly classified as formations, have widespread but thin carbonate rocks that are intercalated with calcareous, quartzose, and argillaceous rocks very similar lithologically to those of the revised Ramp Creek.

CHANGES IN MISSISSIPPIAN STRATIGRAPHY

The formations that are modified in this report from their authors' original concepts are (from lowest to highest) the Floyds Knob, Edwardsville, and Muldraugh Formations and the Harrodsburg Limestone. Some formational modifications involve the associated subformational and superformational rock units. The Salem Limestone, which overlies the Harrodsburg Limestone and is to be

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Associated with the Harrodsburg in the new Sanders Group, is not otherwise modified. The formations affected by the changes set forth in this report (table 1) lie between the top of the Carwood Formation of the Borden Group and the base of the St. Louis Limestone of the Blue River Group.

Authors of recent reports published by the Indiana Geological Survey (table 1) have followed the original definitions of the Harrodsburg and of the formations in the Borden. In general, these authors have not made unqualified use of Stockdale's (1929 and 1931) many subformational terms. I propose to continue the most useful of Stockdale's many unit names and to clarify the units so that they can be used without hesitancy or qualification. For some units I have followed the work and suggestions of Stockdale with only minor modifications. But some of Stockdale's units are, in present-day analysis, simple and similar parts of logical rock units that are lost in a profusion of complicated named units of all sorts. For this reason, solving problems related to the similarities of the Salem and Harrodsburg Limestones requires clarification, reassignment, or deletion of many of Stockdale's names so that all rock units ultimately selected are mappable.

Establishing the new Sanders Group resulted primarily from my extensive field and laboratory research of the Salem Limestone (Perry and others, 1954; Smith, 1955, 1957, 1962, and in preparation). This work involved rocks extending upward from the Salem into the lower part of the St. Louis Limestone and downward into the top fifth of the Borden Group.

The changes involving the top of the Borden Group, in addition to being modifications chiefly from the published works of Stockdale, are changes based on my work, knowledge, and interpretation of the Borden resulting from mapping for the report by Melhorn and Smith (1959) and for a report in progress on the geology and mineral resources of Lawrence County, Ind. This mapping has shown the need for the group that is introduced and for changes in the upper part of the Borden Group.

The changes set forth in this report have been discussed with my colleagues, chiefly Gary R. Gates, Duncan J. McGregor, Wilton N. Melhorn, Arthur P. Pinsak, and Jack A. Sunderman. Unanimity of opinion does not exist, particularly as to how much of the Harrodsburg of earlier authors should be grouped with the Salem.
The Sanders Group is defined in this report as including all rocks (table 1) above the base of the Leesville Member (of the Harrodsburg Limestone) of Stockdale (1929, p. 239-240) and below the top of the Salem Limestone of Cumings (1901, p. 232-233). The Sanders Group rests on rocks of the Borden Group, as modified later in this report, and is overlain by the Blue River Group. Thus the Sanders Group contains the Salem Limestone and the upper part of the Harrodsburg Limestone of Hopkins and Siebenthal (1987, p. 296-298).

Lithologic unity of formations included—Since Hopkins and Siebenthal (1987, p. 296-298) first defined the Harrodsburg Limestone, various geologists (Butts, 1922, p. 117-120; Stockdale, 1930, p. 236-1931, p. 397, 311; and 1939, p. 73 and 234; Pinnak, 1957, p. 38-29, 40-41) have noted in Indiana the lithologic dissimilarities between the upper and lower parts of the Harrodsburg and the similarities between the upper part of the Harrodsburg and the Salem. The Harrodsburg Limestone of this report (p. 11), that is, the upper part of the Harrodsburg of Hopkins and Siebenthal, and the Salem Limestone are fossil-calcarenites in which the chief ingredients are bryozoans and echinoderms of various sizes and abundances (fig. 1). These two formations in general are so similar in appearance that in some places they are separable only with difficulty, but they are separable. The revised Harrodsburg Limestone displays less crossbedding, current lineation, and other structures of sedimentation than the Salem does; the Harrodsburg was deposited in an environment possessed of less physical energy than the Salem was; and the Harrodsburg contains more geodes than the Salem does. The Salem Limestone contains oolithically coated fossil grains and specimens of the foraminifer Endothyra baileyi Hall (see Cumings and others, 1906, p. 1201, for description of this species), commonly in profusion. In contrast, the Harrodsburg lacks oolithically coated fossils and contains only a rare specimen of Endothyra in its topmost few feet in some places. In general, the Salem is finer grained than the Harrodsburg. Many thin exposures, lacking oolithically coated fossils and specimens of Endothyra, are difficult to identify as either the Harrodsburg or the Salem. It is important for this report only to recognize that these units are practical, mappable, and tabular rock units framed almost entirely of fossil debris bound together by carbonate material of both mechanical and chemical origin. In most places the Harrodsburg and the Salem are distinct because their similar ingredients were deposited or modified differently and because the Salem contains a vastly greater number of specimens of Endothyra than the Harrodsburg does.
I can demonstrate by use of microscopes that there is an almost infinite series of lithologies within the Salem Limestone. For field use there are more than 20 recognizable lithologies, facies, or lithofacies in lenticular, intertonguing, or gradational relationship to each other. In contrast with the revised Harrodsburg, which contains members or lithofacies of sufficient lateral extent to be useful in mapping, the many subformational units in the Salem of Indiana are not worthy of elevation to formal status because they do not have lateral extents useful in mapping.

Boundaries and mapping:--The revisions of lower and middle Mississippian rock units of Indiana made herein provide boundaries that are easily recognized and mapped. The practicality of the Sanders Group was demonstrated on a regional geologic map (Wier and Gray, 1941) published recently. The unnamed map unit M2 shown on that map matches the Sanders as herein defined.

The base of the Sanders Group is at the base of a bryozoan-calcarenite underlying a shale parting or as much as 10 feet of siliceous, dirty, or shaly calcilutite. This lowest bryozoan-calcarenite may be from 1 to 10 feet thick and may be a single bed.
The Sanders Group extends upward to the base of the Blue River Group; the relationship between these two groups is the well-known relationship between the Salem Limestone and the superjacent St. Louis Limestone. The base of the St. Louis Limestone is marked (Smith, in preparation) by a 1- to 4-foot bed of gray or light-gray cryptocrystalline limestone, by thin-bedded blue-gray microcrystalline limestone, or by at least an inch of calcareous shale. Care must be taken not to draw the top of the Sanders, and therefore the top of the Salem, at the top of the dimension-stone quarry beds. The commercially valuable dimension stone within the Salem extends in only a few places to the top of the formation and group.

Type locality.—The name for the Sanders Group is taken from the small town of Sanders, Monroe County (fig. 2), which is in the SW 1/4 sec. 34, T. 8 N., R. 1 W. The town of Sanders is shown on the map prepared by Wier and Gray (1961) and on the Clear Creek, Ind., 1/2-minute topographic quadrangle published in 1956 by the U.S. Geological Survey. A type section has not been designated because vertical exposures of the complete group are rare, but the vicinity of the town of Sanders is designated as the type locality. The base of the Sanders Group, that is, its contact with the Ramp Creek Limestone Member at the top of the redefined subjacent Borden Group, can be seen in the tributaries of Ramp Creek within half a mile east and northeast of the town of Sanders. (See fig. 1 and p. 14 ff. for redefinitions of the Ramp Creek and the Borden.) The top of the group is exposed in the rock overburden of the abandoned dimension-stone quarry in the center of the SE 1/4 NW 1/4 sec. 33, T. 8 N., R. 1 W., which is 0.2 mile west-southwest of the Sanders School. The entire group can be seen by examining many natural outcrops and active and abandoned quarries within a radius of 1/2 miles of Sanders.

Part of the Sanders Group also is exposed in road cuts along the east side of Indiana Highway 37 and on both sides of Indiana Highway 46 in the northern and northeastern parts of Bloomington. These cuts are in a narrow strip near the west edge of sec. 21, in the NE 1/4 sec. 28, and in the SE 1/4 sec. 27, T. 9 N., R. 1 W., Monroe County. The top of the group is exposed in the road cut in the SE 1/4 NW 1/4 sec. 24, and the base is exposed in the road cut in the SE 1/4 SW 1/4 sec. 31, T. 9 N., R. 1 W.

Extent and thickness.—The Sanders Group is present continuously along its outcrop belt, which extends from the south tip of Harrison County (fig. 2) along the Ohio River 123 miles south of Indianapolis to within 3 or 4 miles of the common intersection of Fountain, Montgomery, and Parke Counties, about 60 miles northeast of Indianapolis. As is true of most rocks in Indiana, the Sanders Group is covered by soil, glacial debris, or other uncon-
KEY TO LOCALITIES

<table>
<thead>
<tr>
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<tr>
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Type sections

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</tr>
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<td>2 Harrodsburg Limestone</td>
<td>Hopkins and Shickshinny, 1897</td>
<td></td>
</tr>
<tr>
<td>3 Guthrie Creek Member</td>
<td>Stockdale, 1928</td>
<td></td>
</tr>
<tr>
<td>4 Louisville Member</td>
<td>Stockdale, 1928</td>
<td></td>
</tr>
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<td>5 Muldraugh Formation</td>
<td>Stockdale, 1929</td>
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</tr>
<tr>
<td>6 Edwardsville Member*</td>
<td>Stockdale, 1921</td>
<td></td>
</tr>
<tr>
<td>7 Floyds Knob Limestone Member*</td>
<td>Stockdale, 1931</td>
<td></td>
</tr>
<tr>
<td>8 Stewart Landing Facies</td>
<td>Stockdale, 1931</td>
<td></td>
</tr>
<tr>
<td>9 West Point Facies</td>
<td>Sutton, 1931</td>
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</tr>
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</table>

*New name used in this report.

Figure 2. Map showing locations of type sections and other localities mentioned in text.
solidated materials along most of its outcrop belt, and continuous, almost vertical exposures of the entire group are virtually unknown. Thus most outcrop thicknesses given for the group are inferred.

The Sanders Group is about 145 feet thick along the Ohio River at the south end of its outcrop belt in Indiana. It thins to about 110 feet in southern Washington County but thickens from at least 145 feet in central Washington County to its maximum thickness of about 165 feet in southern Monroe County. It gradually thins northward to central Putnam County, where 92 feet of the Sanders was penetrated in a core hole, but it is only about a third as thick where it passes northward out of Putnam County. The original thickness of the group is not known north of Putnam County because erosion during several different intervals has removed much of the evidence. There are indications, however, that it wedges out a few miles north of Putnam County because of nondeposition. (See Pinsak, 1957, p. 34, 44-45.) Southwest of its outcrop belt, the group in general thickens downdip to at least 400 feet near the center of the Illinois Basin (fig. 2). (See Pinsak, 1957, pl. 1.)

HARRODSBURG LIMESTONE

Restriction and redefinition.—It is necessary to redefine and restrict the Harrodsburg Limestone of Hopkins and Siebenthal (1897, p. 296-298) to achieve internal lithologic unity for the Sanders Group. The restriction here is slightly different (table 1) than that of Stockdale (1929, p. 1 and 72, pl. 6). The Harrodsburg Limestone is herein redefined, and actually re-restricted, to include the rocks between the base of the Leesville Member of Stockdale (1929, p. 239-240) and the base of the Salem Limestone of Cumings (1901, p. 232-233; also see Cumings and others, 1906, p. 1191 and the photographs that follow p. 1191). The Harrodsburg as here redefined is lithologically homogeneous and is formed chiefly of bryozoan-rich calcarenites and calcirudites in thick to massive beds.

The Harrodsburg in Indiana has been classified as a formation since 1897, and its upper boundary has been shown on many maps. The redefined lower boundary of the Harrodsburg, which coincides with the lower boundary of the Sanders Group, is the base of map unit M2, shown on the map by Wier and Gray (1961). I have mapped on a scale of 1:24,000 both boundaries of the newly restricted Harrodsburg across all of Lawrence County, Ind.

Members.—Several formal and informal unit names exist for rocks within the Harrodsburg and Salem Limestones of the Sanders Group. Some units and their names are useful (table 1), but I have found no
need for others. Some names, especially those associated with the Salem, are local names, trade names, or names ("bastard stone" of other authors) that have no useful or defined place in formal geologic literature.

The Leesville and Guthrie Creek Members Stockdale, 1929, p. 239-240) have long been used in discussions of the Harrodsburg Limestone. They are retained as formal members of the redefined formation because they are practical rock units useful in mapping and the names are associated with distinctive lithologies of the formation. Both units commonly consist of more than a single bed. The Ramp Creek Member of Stockdale (1929, p. 239-240), equal in stratigraphic importance with the Leesville and Guthrie Creek, is herein excluded from the Harrodsburg Limestone. The Ramp Creek is reassigned and redefined below (p. 15-16).

Publications (table 1) of the Indiana Geological Survey (Perry and others, 1954, pl. 1; McGregor, 1956, table 3) have used the terms Upper Harrodsburg limestone member and Lower Harrodsburg limestone member. Because these names are informal, capitalization of the words lower and upper should be discontinued. Stockdale (1939, pl. 1, p. 72, and pl. 9) separated the formation of Hopkins and Siebenthal into an "Upper Harrodsburg Division" and a "Lower Harrodsburg Division" for use in Indiana and referred (1939, pl. 1, p. 72-73, and pl. 6) to the upper division in Kentucky as the "Harrodsburg (restricted) limestone." He (1939, p. 72, 200 ff.) assigned the basal beds of the Harrodsburg in Kentucky to a rock unit that he named the Muldraugh Formation (table 1).

Stockdale earlier (1929, p. 239-240) had subdivided the lower part of the Harrodsburg into three units that he named (in ascending order) the Ramp Creek, Leesville, and Guthrie Creek Members. His 1939 (p. 72-73, pls. 6 and 25) restriction of the formation excluded these three members from his "Harrodsburg (restricted) limestone." In 1931 he had suggested (p. 310-311) the advisability either of considering the Lower Harrodsburg as a separate formation or of assigning the Ramp Creek Member to the subjacent Edwardsville Formation of the Borden Group and had suggested making the Leesville Member the base of the Harrodsburg Limestone. The part of the 1931 suggestion pertaining to assignment of the Ramp Creek to the Borden is followed in this report because certain lithologic affinities give a rock unit even more coherent than Stockdale's 1939 formally restricted Harrodsburg, which has not been used (table 1) by the Indiana Geological Survey.

The Leesville Member of Stockdale is in many areas a marker bed separated from the rest of the Harrodsburg by the Guthrie Creek Member, which can be recognized readily (fig. 1). Where the Guthrie Creek Member is absent, the Leesville is difficult to separate from the overlying beds of limestone. It is the first 1-
11-foot thick relatively pure calcarenite found within about 10 feet below the base of the Upper Harrodsburg Division of Stockdale. The Leesville Member has more bryozoan debris than the subjacent rocks but less than the overlying rocks, and in comparison with the subjacent rocks, it is equally resistant to erosion but is not siliceous. The Leesville Member of Stockdale is allied lithologically to younger Harrodsburg beds rather than to the older echinodermal limestones of the Ramp Creek Member, the Stewarts Landing Facies of the Edwardsville Formation of Stockdale (1931, p. 228), or the bioturbated parts of the Edwardsville and Floyds Knob Formations of Stockdale. Stockdale assigned contiguous parts of bioherms to his Floyds Knob and Edwardsville Formations; he used (1931, pl. 6) a line bearing question marks and extending from the top of the Floyds Knob to show this separation.

The unit at the top of Stockdale's Lower Harrodsburg Division is the Guthrie Creek Member, which may be absent, may represent as a parting of calcareous shale, or may consist of as much as 10 feet of siliceous, dirty, or shaly calcilutite. The Guthrie Creek in some places is very fossiliferous and may contain thin lenses of carbonate rocks that are very rich in bryozoans. The lithologic affinities of the Guthrie Creek are not so clear as those of the Leesville, but this member chiefly resembles the material found at the top of the Harrodsburg (the Somerset Shale of Butts, 1922, p. 89, 104-107) at many Indiana localities rather than the calcareous silicilutites or shaly impure calcilutites of the lower strata. The base of the Leesville Member in most places is well exposed and is easy to recognize in the field.

Also included in the Harrodsburg is the Indiana equivalent of the Somerset Shale that Butts defined (1922, p. 89, 104-107) as near the top of his Warsaw Formation in Kentucky. He (1922, p. 113) also suggested that the Salem be considered a member of the Warsaw. Stockdale (1939, p. 226, pls. 6 and 25) traced the Somerset Member, as he called it, from Somerset, Ky. (fig. 2), to the vicinity of Harrodsburg, Ind., and considered that it constituted the lowest part of the Salem Limestone. Cumings (1910, p. 232-233; also see Cumings and others, 1906, p. 1191 and the photographs that follow), however, did not include rocks later assigned to the Somerset in the Salem. In Indiana the Somerset, although not present everywhere, is a calcareous, dolomitic, and (or) quartzose lutite containing thin beds and lenses of bryozoan-rich lutite that are silicified in places. The term shale is correct in reference to Somerset-equivalent rocks in Indiana only if used to define its fissile nature in some localities. The rock is variable in bedding structure and in grain size, and therefore the term shale is not always appropriate. Lithologically the Somerset of Stockdale is more reminiscent of rock in the Guthrie Creek Member than it is.
of any rock in the Salem. The term Somerset serves no useful purpose in Indiana even though the rocks in some places, especially south of Salem, mark the top of the Harrodsburg.

MULDRAUGH FORMATION

REDEFINITION OF THE MULDRAUGH FORMATION AND BORDEN GROUP

The original definition of the Harrodsburg Limestone was changed to give this formation and the Sanders Group internal lithologic unity. The Ramp Creek Member of Stockdale, excluded above from the redefined Harrodsburg, is here assigned to the Borden Group because it forms part of a sequence of alternating carbonate and noncarbonate rock units (fig. 1). The parts of this sequence are lithologically so similar that they are joined into a unit of formational rank. Stockdale (1939, p. 72, 200-201) assigned the majority of the rocks in this sequence in Kentucky (table 1) to the Muldraugh Formation, which included the Leesville and Guthrie Creek Members.

I have incorporated (table 1) into the Muldraugh Formation all rocks between the base of the rock unit which Stockdale (1931, p. 193-196) named the Floyds Knob Formation and the top of the Ramp Creek, including the Edwardsville Formation of Stockdale. This redefinition of the Muldraugh reduces the rank of the units which Stockdale (1931, p. 76, 193-196, 220) called the Floyds Knob and Edwardsville to the status of member, reassigns the Ramp Creek to the Muldraugh Formation, and expands the Borden Group upward to include the Ramp Creek (that is, to the base of the Sanders Group).

The Muldraugh Formation was originally named and defined by Stockdale (1939, p. 72, 200-201) from exposures along a secondary road which ascends the Muldraugh Escarpment south of Phillipsburg, Marion County, Ky. (fig. 2). The name was taken from the escarpment (Stockdale, 1939, p. 201), not from the village of Muldraugh along U. S. Highway 31 West, within the Fort Knox Military Reservation in Meade County, Ky. (fig. 3), although the area around the village would have been a satisfactory type locality.

The Muldraugh Formation in Kentucky as defined by Stockdale is essentially an argillaceous cherty carbonate rock unit within the

Borden Group; as defined, the formation extends (table 1) from the top of the Floyds Knob Formation of Stockdale (1931, p. 193-196) to the base of the Harrodsburg as restricted by Stockdale in 1939 (p. 1, 72). It originally was divided by Stockdale (1939, p. 75) at the Indiana-Kentucky boundary into an "Edwardsville division" and a "Lower Harrodsburg division" as well as into several lateral facies.

Just as I have mapped both boundaries of the newly restricted Harrodsburg Limestone, I have also mapped on a scale of 1:24,000 the Muldraugh Formation in Lawrence County, Ind.

MEMBERS OF THE MULDRAUGH FORMATION

The Muldraugh, the top mappable formation of the Borden Group in Indiana, characteristically consists of siliceous, cherty, and echinodermal limestones; siltstones; and shales (fig. 1). The siltstones and shales generally are calcareous, and most lithologies bear geodes. Stockdale (1931, p. 76, and 1939, p. 74-76) assigned these lithologic types to several named units. The carbonate rocks of the Floyds Knob (Stockdale, 1939, p. 205), of bioherms extending well up into the former Edwardsville Formation, of the West Point Facies (Stockdale, 1939, p. 202-203), of the Stewarts Landing Facies (Stockdale, 1931, p. 226-236), and of the Ramp Creek are basically similar in lithology.

The rock units formerly called the Floyds Knob and Edwardsville Formations are here assigned member status in the Muldraugh Formation, and the first named unit is further modified by addition of the term Limestone. The Floyds Knob Limestone Member of the Muldraugh Formation is not mappable in Indiana over wide areas. The Edwardsville Member of the Muldraugh Formation, although mappable over wide areas, is so entrapped between and gradational into the predominantly carbonate members of this formation that it is best considered as a part of a heterogeneous formation. The third member of the Muldraugh, the Ramp Creek, also is not mappable over wide areas.

I have tested and found deficiencies in some of the names (West Point and Stewarts Landing Facies) available for the calcareous beds, formerly assigned to the Edwardsville as facies or as biothermal phases by Stockdale, that continue from the Floyds Knob the vertical and lateral transition from the clayey and quartzose rocks of the older parts of the Borden to the fossil-calcareous rocks of the Sanders. Both West Point Facies (Stockdale, 1939, p. 202-204) and Stewarts Landing Facies (Stockdale, 1931, p. 226-236) are names that were defined to express the concept of transition and would serve nicely if expanded to include the Ramp Creek;
indeed, the West Point may have originally (Sutton, 1931, p. 281, called the West Point a member of the Warsaw Limestone) encompassed the Ramp Creek. But the name West Point was preoccupied when it was originally used in Kentucky (Wilmarth, 1938, p. 2310). Thus one must choose between the names Ramp Creek and Stewarts Landing, and either unit needs modification to include the beds of the other because the Ramp Creek represents a stratigraphically higher and a geographically widespread continuation of some of the lithologic sequence assigned to the Stewarts Landing Facies by Stockdale. Stewarts Landing has been abandoned as a geographic name, and therefore I hesitate to redefine the term drastically. In its original concept the Stewarts Landing Facies of the Edwardsville Formation of Stockdale was the southern Indiana name for the whole formation. To use the term Stewarts Landing would require that the original concept of Stewarts Landing as a local facies name for all the original Edwardsville be restricted to a member, excluding a particular lithology, of the redefined Muldraugh Formation. Such a change in concept would be confusing. Thus the name Ramp Creek is retained because Ramp Creek is a well-known and mapped stream in the vicinity of Sanders, Monroe County, Ind. (fig. 2); stratigraphically, nomenclaturally, and conceptually the name is easily modified. The name Ramp Creek Member is herein changed to Ramp Creek Limestone Member, and the unit is expanded to include the entire unit of siliceous, cherty, and echinodermal limestones interbedded with calcareous shales and siltstones found in the top of the Muldraugh Formation chiefly above the Edwardsville Member and below the Leesville Member of the Harrodsburg Limestone. In some places the carbonates in the Ramp Creek lens out; thus the Edwardsville and the Ramp Creek also are found laterally adjacent to each other.

The Ramp Creek and Floyds Knob Limestone Members are exposed in many places in Harrison County, and the intervening Edwardsville Member and the upper and lower boundaries of the Muldraugh Formation (Stockdale, 1931, p. 114, 167, 228, and 233-235) are also exposed in some places. Northward from Harrison County the Ramp Creek Limestone Member thins, and the Edwardsville Member becomes thicker. In and north of southern Monroe County the Floyds Knob Limestone Member thickens as bioherms, which are commonly contiguous with, indistinguishable from, and herein included within that unit (fig. 1), become prominent. Although Stockdale placed the carbonate rocks and other sediments of bioherms in his Edwardsville Formation, he did not, in his 1931 publication, for many places indicate a firm formational boundary between carbonates in his Floyds Knob and his Edwardsville bioherms. In some places the Edwardsville Member contains thin beds and lenses of limestone or of calcareous siltstone and shale.
that are not contiguous with the Floyds Knob or Ramp Creek Members. It seems best to include these materials in the Edwardsville, although they are probably lateral, but in places disconnected, extensions of bioherms or are local deposits of material washed from bioherms. The Edwardsville Member is believed to be present everywhere north of Harrison County (fig. 2). In some exposures, and perhaps in the subsurface, one cannot find the less calcareous siltstones of the Edwardsville or select a reasonable boundary between the Floyds Knob and Ramp Creek Limestone Members of the Muldraugh.

Thus the Floyds Knob is chiefly a unit of limestones in the bottom of the Muldraugh Formation, and the Edwardsville is chiefly a unit of clayey and quartzose rocks in the Muldraugh above, and in places laterally adjacent to, the Floyds Knob.

A study of Stockdale’s reports (1931 and 1939) and of the rocks in the field shows that the upper part of the Borden Group consists of several closely related parts. These parts, when considered in relation to other Mississippian rocks, demonstrate that rhythmic changes in sedimentation took place during early and middle Mississippian time in Indiana. The rocks show, in the outcrop belt of the Borden in south-central Indiana (fig. 1), the change from the dominantly silty and clayey environment of Borden rocks of pre-Muldraugh age to the calcareous environment of the Sanders and Blue River Groups. There are alternations within the carbonate rocks of the Sanders and Blue River Groups of Indiana. The rocks include evidence of a time when some of these several environments existed in some places alternately or contemporaneously. Rocks that show the transition and alternation of lithologies from the Borden to the Sanders (fig. 1) are reassigned to the Borden Group and are herein considered as a rock unit for which the name Muldraugh Formation is adapted (table 1) for use in Indiana from Stockdale’s usage in Kentucky.

The Floyds Knob Limestone Member is now the lowest member of the Muldraugh Formation; it is predominantly a carbonate rock unit and rests on the Carwood Formation. Overlying the Floyds Knob is the Edwardsville Member; it consists of calcareous shales, siltstones, and mudstones but also includes thin beds and lenses of limestone that are stratigraphically and mostly geographically remote from the named members that are dominantly carbonates. The highest member of the Muldraugh is the Ramp Creek; the top of the Ramp Creek Limestone Member is the top of the Muldraugh Formation and of the Borden Group. The Ramp Creek consists of
the sequence of variable impure quartzose or silicified calcilutites containing crinoidal beds resistant to erosion; these constitute the "beds of passage," the name Hopkins and Siebenthal (1897, p. 297) applied to the transition from the predominantly noncarbonate rocks of the Osage Series to the carbonate rocks of the Meramec Series.

Overlying the Borden Group is the Leesville Member of the Harrodsburg Limestone of the Sanders Group. The Leesville is a relatively pure calcarenite rich in bryozoans. The Guthrie Creek Member commonly is present as a shale or a siliceous, dirty, or shaly calcilutite between the Leesville and the rest of the Harrodsburg. The part of the Harrodsburg Limestone overlying the Guthrie Creek, or the Leesville in the absence of the Guthrie Creek, is not assigned a member name and commonly is not separable into useful subformational units. Characteristically the upper part of the Harrodsburg consists of bryozoan-calcarenites or bryozoan-calciudrites. A small rock unit quite similar to the Guthrie Creek is present in some places at the top of the Harrodsburg. The Salem Limestone, the uppermost of two formations in the Sanders Group, consists of heterogeneous fossil-calcarenites or fossil-calcilutites that characteristically are in massive beds. My extensive studies of the Salem Limestone demonstrate that it is neither practical nor correct to divide the Salem into subformational rock units.

The rock units described are tabular and are mappable. Many changes set forth in this report are within the framework of some of Stockdale's published (1931 and 1939) views. Those members of formations that are defined help clarify stratigraphic and geographic relations of all rock units. And the rock units herein defined possess lithologic unity because of internal homogeneity or repetition of dissimilar materials.

LITERATURE CITED


LITERATURE CITED


------in preparation, Petrography and economic geology of the Salem Limestone: Indiana Geol. Survey Bull. ___.


## DEVELOPMENT OF CLASSIFICATION OF ROCK UNITS

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*Kentucky West Central Region*  
*Indiana Southwest Region*  

Formations in type region  

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**Stockdale 1931, pl. 2**

**Stockdale 1939, pl. 6**

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**Formation**

- **St. Louis**
- **Salem Formation**
- **Salem Formation**
- **Salem Member**
- **Upper Harrodsburg**
- **Upper Harrodsburg Division**
- **Guthrie Creek Member**
- **Leeville Member**
- **Ramp Creek Member**
- **Edwardsville Division**
- **Floyds Knob Formation**
- **Carwood Formation**

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- **Stockdale 1931, pl. 2**
- **Stockdale 1939, pl. 6**

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- **Formation is divided into six facies, including Stewarts Landing Facies in Harrison County, Ind., and grades laterally. Also included is a "bioherm phase" in places in and north of Monroe County, Ind.**

- **The name West Point Facies was used for this formation in northern Kentucky.**

- **Relationship between epochal boundary and named strata in the Harrodsburg Limestone is not given.**

- **Boundary is variable and depends on the position of each lithologic facies.**