THE STRATIGRAPHY OF THE MISSISSIPPIAN FORMATIONS OF IOWA

BY

FRANCIS M. VAN TUYL
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THE STRATIGRAPHY OF THE MISSISSIPPIAN FORMATIONS OF IOWA

CHAPTER I

THE MISSISSIPPIAN SYSTEM IN IOWA

Introduction

As a result of the development of a cooperative plan of study and correlation of the Mississippian formations of the Mississippi Valley by the several state geological surveys of the area and the U. S. Geological Survey in 1913, the writer was requested by Doctor Kay of the Iowa Geological Survey to undertake a stratigraphic study and revision of these formations in Iowa under the direction of Professor Stuart Weller of the University of Chicago.

Field work was carried on during the summers of 1913, 1914, 1915 and 1917. In addition the months of October to June, 1914-1915, were spent at Walker Museum, The University of Chicago, in a study and identification of fossil collections made during the progress of the field investigations.

For encouragement and helpful suggestions the writer is indebted to both Doctor Kay and Professor Weller. Doctor A. O. Thomas of the State University of Iowa has kindly assembled and prepared the material for the plates illustrating typical Mississippian fossils.

Distribution and Importance

The Mississippian formations constitute the bed rock in a diagonal belt twenty to sixty miles wide extending from the southeastern corner of the state northwestward through the central and north-central parts into southern Minnesota. There are also a number of small patches and linear areas of these rocks to the west and southwest of this belt as a result of the erosion of the Pennsylvanian rocks by the larger streams. Drill records indicate their presence beneath younger deposits over the entire southern and southwestern parts of the state. There is evidence that they likewise formerly extended some distance northeast of the present belt of exposures as will be brought out on a later page.
Occasional small outliers of Pennsylvanian strata appear in the main Mississippian area.

The system is of considerable economic as well as scientific importance. It contains valuable deposits of clay, building stone, road material and cement rock. In addition it involves the type sections of several formations of the lower portion of the standard Mississippian column which are known the world over for their profusion of excellently preserved fossil remains.

**Topography**

The state of Iowa lies entirely in the Prairie Plains physiographic province. The elevation of the surface of the area in which the Mississippian formations are the highest consolidated rock ranges from a little more than 500 feet in the valley of Mississippi river below Keokuk in southeastern Iowa to about 1300 feet in the north-central part.

The Mississippian belt lies in the path of the continental glaciers and partakes of the characteristics of a glaciated region. In the southeastern and central parts of the state where the glacial deposits are of early Pleistocene age the topography is of the mature type. However, the relief is not great except adjacent to Mississippi river. Exposures of the consolidated rocks are numerous along the larger streams and their tributaries. In northern Iowa, on the other hand, the surface is underlain by glacial deposits belonging to the late Pleistocene. The topography is youthful and the relief slight. The drift is thicker and rock exposures are less common.

**Drainage**

The area in Iowa in which the Mississippian rocks are exposed lies entirely within the drainage basin of Mississippi river, which crosses the belt along the southeastern boundary of the state. The runoff is through four southeasterly trending tributaries of the "Father of Waters", namely: Cedar river, which parallels the Mississippian belt on the northeast; Iowa river, which crosses the belt in central Iowa; Skunk river, which crosses it in southeastern Iowa; and finally Des Moines river, which parallels the belt on the southwest. The postglacial
drainage lines do not conform to the preglacial ones at many points along the stream courses. For this reason the distribution of outcrops along the valleys is often erratic. The more typical exposures are usually at those points where the streams have been diverted from their preglacial courses and have been compelled to cut new valleys through the drift and the indurated rocks below.

Character and General Relations

Relation to the Type Section.—The Mississippian succession was formerly regarded as a subdivision of the Carboniferous system, which was made to include the Mississippian at the base, the Pennsylvanian in the middle and the Permian at the top. At the present time there is a tendency to elevate each of these to the status of a distinct system.

The standard section of the Mississippian system is in the Mississippi valley, extending from southeastern Iowa into southern Illinois and southeastern Missouri.

Subdivisions.—The following classification of the Mississippian formations of the standard section, after Weller, incorporates several revisions necessitated by recent work and may be regarded as representing the latest word on the subject.1 2

All of the forma tional units of the Iowa Series are represented in Iowa. The type sections of the Burlington and Keokuk formations are at the cities of these names in southeastern Iowa, while the Warsaw beds derive their name from the town of Warsaw, Illinois, on the east bank of Mississippi river, nearly opposite Keokuk, Iowa. The Spergen, St. Louis and Ste. Genevieve formations are represented in Iowa by marginal deposits only.

None of the Chester formations is represented in the state, and it is probable that the Chester seas never extended this far north.

Thickness and Lithological Character.—The thickness and lithologic character of the forma tional units in southeastern Iowa, where the system attains its most complete development in the state, are indicated in the accompanying generalized

---

1 Illinois State Geol. Survey, Bull. 41, p. 80; 1920.
2 Jour. Geol., vol. XXVIII, p. 281; 1920.
## Classification of the Mississippian Formations of the Mississippi Valley
*(After Weller)*

<table>
<thead>
<tr>
<th>Chester Series</th>
<th>Upper Chester</th>
<th>Middle Chester</th>
<th>Lower Chester</th>
<th>Meramec</th>
<th>Osage</th>
<th>Kinderhook</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mississippian</td>
<td>Kinkaid</td>
<td>Glen Dean</td>
<td>Paint Creek</td>
<td>Ste. Genevieve</td>
<td>Keokuk</td>
<td>Various local formations in Mississippi Valley</td>
</tr>
<tr>
<td></td>
<td>Degonia</td>
<td>Hardinesburg</td>
<td>Yankeetown</td>
<td>St. Louis</td>
<td>Burlington</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clore</td>
<td>Golconda</td>
<td>Renault</td>
<td>Spergen</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Palestine</td>
<td>Cypress</td>
<td>Aux Vases</td>
<td>Warsaw</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Menard</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Waltersburg</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Vienna</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Tar Springs</td>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

*columnar section (fig. 1). In central and north-central Iowa the character and succession of the formations is somewhat different as will be pointed out in later pages.***

### Stratigraphic Relations

The Mississippian system succeeds the Devonian in Iowa. Along the northeastern boundary of the belt of outcrops of Mississippian strata the Kinderhook is in contact with the Cedar Valley limestone except in western Butler, northeastern Franklin, southwestern Cerro Gordo, northeastern Hancock and southeastern Winnebago counties, where it rests upon the overlying Lime Creek shales. However, exposures showing the contact of the two systems are very rare, owing to the drift cover-
ing and to the tendency of the basal Kinderhook shales to weather in such a way as to conceal the underlying strata.

The relation of the Mississippian system to the overlying

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>GROUP</th>
<th>FORMATION</th>
<th>SECTION</th>
<th>THICKNESS</th>
<th>LITHOLOGIC CHARACTER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ST. LOUIS (PELLA)</td>
<td></td>
<td>40-60</td>
<td>Fine-grained gray limestone chiefly, lower division locally brownish and dolomitic, in places brecciated.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SPERGEN (BELFAST)</td>
<td>0-35</td>
<td></td>
<td>Crinoidal limestone grading into arenaceous dolomite.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MARSH (BELFAST)</td>
<td>20-65</td>
<td></td>
<td>Interbedded shales and gray fossiliferous limestone. Gecodes in lower part.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KEBOKUK</td>
<td>63</td>
<td></td>
<td>Gray to bluish gray crinoidal limestone interbedded with shale in upper part. Cherty in lower part.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BURLINGTON</td>
<td>71</td>
<td></td>
<td>Gray, crinoidal, cherty limestone interbedded with limestone, cherty magnesian limestone,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KINDERHOOK</td>
<td>300±</td>
<td></td>
<td>A thick body of shale in lower part succeeded by interbedded limestone and sandstone. A bed ofoolitic limestone appears near the top.</td>
</tr>
</tbody>
</table>

Fig. 1.—Generalized columnar section of the Mississippian system in southeastern Iowa.
rocks is much more diversified, owing (1) to variation in the original distribution of the Mississippian formations, (2) to the profound erosion which followed the retreat of the Mississippian seas and preceded the Pennsylvanian transgression and (3) to the erosion which ensued between Pennsylvanian and Cretaceous time.

In southeastern Iowa and in Webster county the border of the main body of Pennsylvanian strata rests on the St. Louis and Pella formations but occasional outliers of the "Coal Measures" to the northeast rest on older beds ranging down to the Kinderhook. In central and north-central Iowa the Pennsylvanian beds are in contact with the Kinderhook almost everywhere along the boundary of the two systems except in Webster county as noted above, and in western Humboldt and western Kosseuth counties, where the Cretaceous sediments succeed the Kinderhook.

The stratigraphic relations of the Mississippian formations among themselves are somewhat complex as a result of the oscillation of the strand line during deposition. The Burlington, Keokuk, Warsaw and Spergen formations are confined to the southeastern part of the state. The St. Louis limestone overlaps these deposits and rests directly upon the Kinderhook in

![Diagram of stratigraphic relations of Mississippian formations in Iowa at the close of Ste. Genevieve time. The dip of the pre-St. Louis formations is exaggerated.](image)
north-central Iowa. The Ste. Genevieve deposits extend to this section of the state also. In the Fort Dodge area they are found above the St. Louis rocks. The accompanying diagram (fig. 2) expresses the approximate stratigraphic relations of the forma­tional units of the Mississippian of Iowa as they appeared at the close of Ste. Genevieve time.

Regional Structure

The diagonal belt in which the Mississippian formations are the highest consolidated rocks is on the flank of a large gently dipping geosyncline the axis of which plunges to the southwest through southwestern Iowa into northwestern Missouri and northeastern Kansas. The reader is referred to Norton’s map showing the elevation of the Saint Peter sandstone in Iowa, and to Van Tuyl’s structure contour map of the Western Interior geosyncline for details regarding the character and extent of this basin and its influence upon the distribution of the outcrops of the Paleozoic systems. The probable age of this basin and its influence on the present distribution of the Mississippian deposits is discussed on page 349 of this report.

Previous Work

Owen was among the first geologists to study the forma­tions in Iowa which are now referred to the Mississippian sys­tem. He grouped the beds into ten units chiefly upon the basis of their lithologic character. Several of these units correspond to formations recognized in the modern classification. He placed them in the Subcarboniferous period.

The foundation for all later work on the Mississippian of Iowa was laid by Hall, whose classification and nomenclature of the formations, published in 1858, paved the way for succeeding investigations. The formations recognized by him in ascending order were as follows: Burlington limestone, Cherty limestone of Keokuk rapids, Keokuk limestone, Geoede bed, Warsaw formation and the St. Louis Limestone. The strata directly

3 Iowa Geol. Survey, vo l. XXI (pocket) : 1912.
below the Burlington limestone were regarded by him as Chemung in age. The Carboniferous age of these was later demonstrated by Meek and Worthen who named them the Kinderhook beds because of their typical development near the town of that name in Illinois. White later recognized the beds below the Burlington limestone at Burlington as Kinderhook and described other exposures of this group in central and northern Iowa. He also further enhanced our knowledge of the overlying formations. His classification differs from that of Hall in that he grouped the cherty limestone, Keokuk limestone and Geode bed all as Keokuk and the Warsaw formation and St. Louis limestone inclusive as St. Louis. Keyes' classification of 1893 recognizes three major divisions of the Mississippian in Iowa, namely: the Kinderhook, the Augusta and the St. Louis. The Augusta is made to include the Lower and Upper Burlington limestone, the Keokuk limestone, the Geode bed and the Warsaw shales and limestone.

The same author in the reports on the geology of Lee and Des Moines counties contributed several new points on the stratigraphy of the formations in the southeastern part of the state. He designated the cherty limestones of Hall the Montrose cherts and again included all formations from the Burlington limestone to the base of the St. Louis in his Augusta series. The advisability of the use of this term, however, is questioned by Weller, who points out that the name Osage as proposed by Williams for deposits of the same age along Osage river in Missouri has priority.

In Gordon’s report on the Geology of Van Buren county the Montrose cherts of Keyes are referred to the Burlington, and the Keokuk limestone, Geode shales and Warsaw shales and limestones collectively to the Keokuk group. The overlying St. Louis is subdivided into arenaceous-magnesian beds at the base, brecciated limestone in the middle and compact and granular limestone at the top.

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8 Geol. of Iowa, vol. I, p. 192; 1870.
12 U.S. Geol. Survey Bull. 80, p. 169; 1891.
### Classifications of Mississippian Formations of Iowa

<table>
<thead>
<tr>
<th>Hall 1858</th>
<th>White 1870</th>
<th>Keyes 1895</th>
<th>Gordon 1895</th>
<th>Bain 1896</th>
<th>Present Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>St. Louis</td>
<td>St. Louis</td>
<td>St. Louis</td>
<td>St. Louis</td>
<td>Pella</td>
<td>Ste. Genevieve (Pella)</td>
</tr>
<tr>
<td>Warsaw</td>
<td>Sonora</td>
<td>Geode bed</td>
<td>Warsaw</td>
<td>Verdi</td>
<td>St. Louis (Upper (Verdi))</td>
</tr>
<tr>
<td>Geode bed</td>
<td>Keokuk</td>
<td>Keokuk</td>
<td>Geode shales</td>
<td>Springvale</td>
<td>Lower (Croton)</td>
</tr>
<tr>
<td>Keokuk</td>
<td>Augusta</td>
<td>Keokuk</td>
<td>Augusta</td>
<td></td>
<td>Spergen (Belfast)</td>
</tr>
<tr>
<td>Cherty limestone</td>
<td></td>
<td>Monrose chert</td>
<td>Burlington</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burlington</td>
<td>Burlington</td>
<td>Burlington</td>
<td>Kinderhook</td>
<td>Kinderhook</td>
<td></td>
</tr>
<tr>
<td>Chemung</td>
<td>Kinderhook</td>
<td>Kinderhook</td>
<td>Kinderhook</td>
<td>Kinderhook</td>
<td></td>
</tr>
</tbody>
</table>
H. F. Bain, in his description of the geology of Keokuk\textsuperscript{14} and Washington\textsuperscript{15} counties adopted the Augusta series of Keyes for the Burlington and Keokuk limestones, which he believed to be incapable of differentiation in that part of the state. He subdivided the St. Louis of earlier workers into three units which he designated the Springvale at the base, the Verdi in the middle and the Pella at the top. Additional data regarding the Mississippian deposits of Iowa have appeared in numerous other county reports and in scientific articles published in many journals and proceedings of learned societies. Reference is made to the more important of these elsewhere in this volume.

On the accompanying chart an attempt is made to show the evolution of the present classification of the formations in Iowa.

\textsuperscript{14} Iowa Geol. Survey, vol. IV, pp. 257-311; 1895.
\textsuperscript{15} Iowa Geol. Survey, vol. V, pp. 113-173; 1898.
CHAPTER II

THE KINDERHOOK GROUP

Definition

The name Kinderhook group was applied by Meek and Worthen\(^\text{16}\) in 1861 to the strata between the black slate and the base of the Burlington limestone at Kinderhook, Pike county, Illinois. Similar beds at Burlington were referred to the same group. They regarded the Kinderhook as basal Carboniferous in age. Five years later Worthen\(^\text{17}\) further defined the group and pointed out that the so-called “Chumung group” as described by Hall\(^\text{18}\) at Burlington, Iowa, was of Kinderhook age.

In northeastern Missouri the group is represented by the following section, according to Weller:\(^\text{19}\)

\[
\begin{array}{ll}
\text{Osage group} & \\
4. & \text{Burlington limestone} \\
\text{Kinderhook group} & \\
3. & \text{Fine-grained, compact buff limestone} & \ldots & 10-15 \\
2. & "Vermicular sandstone and shale" (Hamblil sandstone) \ldots & 70 \\
1. & \text{Compact blue-gray limestone with lithographic texture (Louisiana limestone)} & \ldots & 60
\end{array}
\]

He states\(^\text{20}\) that “in central Missouri the entire Kinderhook is represented in the Chouteau limestone, about 100 feet in thickness”.

In southwestern Missouri and in Jefferson county, twenty-five miles south of St. Louis, it exhibits still other variations. Weller remarks that “in no case can any formational unit be traced continuously throughout the entire basin”.

Areal Distribution

The Kinderhook group is the bed rock over a larger area

than any other division of the Mississippian of Iowa. With the exception of a small outlier of shale in Muscatine county which may possibly be of this age the group forms the highest consolidated rock over a continuous belt extending from Lee county in the extreme southeastern corner of the state northeastward and thence northward along the valley of Mississippi river to Louisa county, from which area it runs northwestward in the form of a broad irregular band to the north-central part of the state and doubtless continues across the boundary into Minnesota. However, no outcrops of the formation appear north of Humboldt county, owing to the heavy drift cover in that direction.

This Kinderhook area is bordered on the northeast by Middle and Upper Devonian limestones and shales. On the southwest, however, the boundary is much more complicated, owing to the disconformable relationship of the Kinderhook with several younger formations. In southeastern Iowa it is bordered by the Burlington limestone, presumably as far northwest as Poweshiek county, although the exact extent of the latter formation to the northwest beneath the drift is unknown. From this point to Humboldt county the Pennsylvanian rocks form the southwest boundary. In Hardin and Grundy counties the Kinderhook belt is scarcely half its normal width, owing to a tongue-like extension of Pennsylvanian deposits to the northeast. Beginning in Humboldt county, Cretaceous deposits form the west boundary, the trend of which shifts from northwest to nearly due north and thence to northeast in Kossuth county near the north boundary of the state.

Lithologic Character

In southeastern Iowa the Kinderhook group is represented chiefly by clastic deposits with shale predominating over sandstone. Near and at the top of the group several limestone beds, one of which is oölitic, are present. The proportion of limestone in the upper part gradually increases to the northwest. In central Iowa there is a continuous bed of limestone more than sixty feet thick at the top of the series. In north-central Iowa there is an even greater development of limestone in the
upper part of the formation with a corresponding reduction in thickness of the underlying clastic strata.

**Thickness**

The thickness of the Kinderhook in Iowa has been determined only by the study of deep well logs. The individual exposures are all of limited vertical and lateral extent and the strata are so gently tilted that traverses from contact to contact are not practicable.

At the city of Keokuk where the group is entirely beneath the surface its thickness is given by Norton as 270 feet. In a deep well drilled at Burlington the upper limit of the group was not definitely determined but the full thickness is probably between 300 and 350 feet. A deep well at Mount Pleasant, in Henry county, passed through 360 feet of Kinderhook, according to Norton.

A prospect hole at Marshalltown, in central Iowa, which started at the top of the Kinderhook, encountered the Devonian limestone at 320 feet. In the vicinity of Iowa Falls, in Hardin county, the total thickness, as determined by the study of surface exposures in conjunction with the log of a well, is about 300 feet. There is some evidence of a thinning of the group to the southwest of the outcrop belt. For example, Norton gives its thickness as 125 feet at Pella, in Marion county, and as 160 feet at Des Moines, in Polk county.

**Subdivisions**

Owing to the lithologic and faunal variations in the Kinderhook beds in passing from southeastern Iowa to the north-central part of the state it is not possible to subdivide the group into formational units of more than local application.

In Lee, Des Moines and Louisa counties no formation names have been applied. The Washington county succession has been subdivided by Bain into the Maple Mill shale at the base, the English River gritstone in the middle and the Wassonville limestone at the top. Still farther northwest in Marshall county,

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22 Idem, p. 647.
23 Idem, pp. 970 and 893.
Beyer used the names LeGrand beds and Marshalltown shales for the upper exposed part of the group.

During the present investigation it was found advisable to subdivide the Kinderhook group of north-central Iowa into six distinct formations which, from the base upward, are designated the Sheffield shale, the Chapin beds, the Mayne Creek formation, the Eagle City beds, the Iowa Falls dolomite and the Alden limestone.

**Stratigraphic Relations**

The stratigraphic relations of the Kinderhook beds with the underlying Devonian deposits are not well understood since the contact is everywhere concealed except possibly in Muscatine county where dark shales of questionable age rest upon Cedar Valley limestone. However, the evidence points to the presence of a disconformity between the Devonian and Mississippian systems in Iowa. In the southeastern and central parts of the state the relation of basal Kinderhook and Cedar Valley outcrops is such as to indicate that these groups are in contact while in north-central Iowa the Kinderhook is known to rest upon the younger Lime Creek formations of the Devonian.

The formations in contact with the Kinderhook above are of variable age. In southeastern Iowa there appears to be a transition into the Burlington limestone but to the northwest where there is a pinching out of the Burlington, Keokuk, Warsaw and Spergen formations the Kinderhook is succeeded directly by the St. Louis limestone. As a result of the erosion of the overlying Mississippian deposits prior to the advance of the Lower Pennsylvanian seas deposits of Pennsylvanian age rest upon the Kinderhook in the form of occasional outliers in northeastern Washington county while for a considerable distance along the southwestern boundary of the Kinderhook in central and north-central Iowa the main body of the Pennsylvanian overlies the basal Mississippian deposits. At the northwestern extremity of the Mississippian belt the Dakota member of the Cretaceous system rests upon the Kinderhook beds.

**Areal Description by Counties**

**GENERAL STATEMENT**

Previous to the present investigation the Kinderhook beds
have received careful study only in the southeastern part of the state, especially near the city of Burlington in Des Moines county. The character of the group to the northwest has been discussed in a general way in several county reports, but no detailed examination of the succession of beds has been made.

It is now known that the Kinderhook strata of north-central Iowa, central Iowa and southeastern Iowa are very different both lithologically and faunally. For this reason the areas are described separately.

KINDERHOOK OF SOUTHEASTERN IOWA

Lee County.—Regarding the Kinderhook of Lee county, Keyes\(^2\) has this to say:

"Although this member of the Lower Carboniferous is such an important formation in Des Moines county, immediately to the north, and in northeastern Missouri to the south, it lies almost entirely below the river level in Lee. It has only been recognized in a single place on the Skunk river near the Chicago, Burlington and Kansas City railroad bridge over that stream."

Des Moines County.—The area over which the Kinderhook beds form the surface rock in Des Moines county is confined to the valley of Mississippi river and the lower courses of its larger tributaries in the eastern part of the county.

The most representative and complete section of the Kinderhook in this county as well as in the whole of southeastern Iowa is in the Mississippi river bluff at Burlington. The Prospect Hill exposure is especially favorable for field study. A review of the literature on the Kinderhook of this area is given by Weller\(^5\) in his report on "The Succession of Fossil Faunas in the Kinderhook Beds at Burlington, Iowa." After a discussion of the descriptions of the strata by earlier investigators he adopted the following classification based upon the lithology and fossil content of the beds:

<table>
<thead>
<tr>
<th>Section of Kinderhook beds at Burlington (After Weller)</th>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Soft buff gritty limestone</td>
<td>3.5</td>
</tr>
<tr>
<td>6. White oolitic limestone</td>
<td>2.4</td>
</tr>
</tbody>
</table>

54 MISSISSIPPIAN STRATA OF IOWA

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.</td>
<td>Fine-grained yellow sandstone</td>
<td>6-7</td>
</tr>
<tr>
<td>4.</td>
<td>Fine-grained, compact, fragmental gray limestone</td>
<td>12-18</td>
</tr>
<tr>
<td>3.</td>
<td>Thin band of hard impure limestone filled with Chonetes; in some places associated with a thin oolite band</td>
<td>$\frac{1}{4}$-$\frac{3}{4}$</td>
</tr>
<tr>
<td>2.</td>
<td>Soft friable argillaceous sandstone, in some places harder and bluish in color, filled with fossils in the upper part, the most abundant of which is Chonopectus fisheri</td>
<td>25</td>
</tr>
<tr>
<td>1.</td>
<td>Soft blue argillaceous shale (exposed)</td>
<td>60</td>
</tr>
</tbody>
</table>

In the present investigation, Weller's subdivisions have been adopted without modification. A more detailed description of the beds at Prospect Hill than has hitherto been given follows:

Section of Kinderhook beds at Prospect Hill, Burlington

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.</td>
<td>Limestone, soft, buff to brownish, dolomitic; with casts of fossils; grading up into the Lower Burlington limestone</td>
<td>5</td>
</tr>
<tr>
<td>6.</td>
<td>Limestone, white, oolitic, scaling off obliquely on weathered surfaces</td>
<td>3</td>
</tr>
<tr>
<td>5.</td>
<td>Sandstone, soft, fine-grained, drab weathering buff; shaly in upper part; some seams filled with casts of fossil shells; bearing occasional plant remains</td>
<td>6</td>
</tr>
<tr>
<td>4.</td>
<td>Limestone, upper one to two feet brownish and dolomitic. Lower layers consisting of dense gray lithographic-like limestone mottled with small patches of brownish dolomite which in some instances follow small fractures. Small calcite geodes occur in the dolomite areas, and occasional small pockets of sphalerite appear in both the limestone and dolomite</td>
<td>10</td>
</tr>
<tr>
<td>3.</td>
<td>Limestone. Lower half coarse-grained and filled with Chonetes. Upper half oolitic. Upper surface very undulating, although there is a transition from the oolite into the limestone above. Contact with bed below in places irregular</td>
<td>2/3</td>
</tr>
<tr>
<td>2.</td>
<td>Sandstone, fine-grained, soft, drab weathering buff, massive; with occasional thin intercalated layers of shale; upper two feet filled with casts of fossils, most abundant of which is Chonopectus fisheri</td>
<td>22(\frac{1}{2})</td>
</tr>
<tr>
<td>1.</td>
<td>Shale, bluish, argillaceous, locally calcareous, drab, sparsely fossiliferous, grading into the bed above. The greatest thickness of this bed is in the old clay pit, where nineteen feet is shown. Between the bed of the pit and the level of Mississippi river, about fourteen feet more is concealed. The total thickness of this member at Burlington, as indicated by deep borings, is probably not less than three hundred feet. Exposed</td>
<td>19</td>
</tr>
</tbody>
</table>

Almost continuous exposures of the Kinderhook beds appear in the Mississippi river bluff for more than two miles to the southwest of the above section, but owing to the fact that the dip of the beds is slightly greater than the gradient of the stream, only the uppermost beds are exposed. In the Albert Kirschner quarries at Picnic Point, two miles southwest of Prospect Hill, beds 6 and 7 outcrop in the lower part of the openings. Bed 7 is only three feet in thickness and is represented almost entirely by brownish crinoidal limestone.

The same beds are exposed at the base of the section in the
Kemper quarries one mile south of the last named locality (NW.1/4 sec. 29, T. 69 N., R. 2 W.).

Other outcrops of the Kinderhook occur north of Prospect Hill. In the Main Street cut at North Hill, in Burlington, the succession involves the same beds as at Prospect Hill.

Similar exposures appear along Flint river at Starr Cave (NW.1/4 sec. 19, T. 70 N., R. 2 W.) two miles northwest of Burlington. The section here involves all the beds from the lower sandstone (bed 2) to the lower part of the Upper Burlington limestone.

**Fauna of the Kinderhook Beds at Burlington.**

Our knowledge of the faunas of the individual beds of the Kinderhook at Burlington has been greatly enhanced through the efforts of Weller\(^{26}\) to assign the species, which had been described from the group at this locality, to their respective stratigraphic horizons. The following faunal lists are his with occasional changes in nomenclature and with additions necessitated by the writer’s studies. The additions are indicated by asterisks.

**List of Fossils from bed 1 of the Kinderhook Group at Burlington**

**SPONGIAE**—
- Dictophyton sp. undet.

**CRINOIDEA**—
- Crinoid stems

**BRACHIOPODA**—
- Lingula sp. undet.
- Orbiculoidea sp. undet.
- Schizophoria sp. undet.
- Rhizodimella sp. cf. R. burlingtonensis (Hall)
- Productella sp. undet.
- Productus ovatus Hall
- Productus sp. undet.
- Eumetria altostris (White)

**PELECYPODA**—
- Aviculopecten sp. undet.

**GASTROPODA**—
- Platyphorisma sp. undet.
- Porcellia sp. undet.
- Conularia sp. undet.

**CEPHALOPODA**—
- Gomphoceras sp. undet.

**CRUSTACEA**—
- Palaeopalaemon newberryi Whitf.

**VERTEBRATA**—
- Coelacanthus welleri Eastman

**PLANTS**—
- Fragments of stems and leaves

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**List of Fossils from bed 2 of the Kinderhook Group at Burlington**

**CRINOIDEA**—
- Joints of crinoid stems

**VERMES**—
- Worm burrows

**BRACHIOPODA**—
- Lingula membranacea Win.
- Orbiculoidea capax (White)
- Schellwienella inaequalis (Hall)
- Chonetes illinoisensis Worthen

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\(^{26}\) Ibid., pp. 69 to 78.
Chonetes sp. cf. C. geniculatus White
Chonetes sp. undet.
Chonopectus fischeri (N. and P.)
Productus curtirostris Weller
Productus mesioconchus Weller
Productus coopereensis Swallow
Productus ovatus Hall
Productella nummularis (Win.)
Schizophoria sp.
Paryphelphynchus transversum Weller
Rhyynchonella sp. undet.
Eumetria altirostris (White)
Composita * corpulentia (Win.)
Spirifer subrotundus Hall
*Spirifer platynotus Weller
Spirifer triplicatus Hall
Syringothyris extenuatus (Hall)
Reticularia coopereensis (Swallow)

BRYOZOA—
Fenestrella sp. undet.

PELICYPODA—
Aviculopecten tenunicostus Win.
Aviculopecten caroli Win.
*Aviculopecten sp.
Pterinopecten cf. P. laetus Hall
*Pterinopecten cf. P. coopereensis (Shum.)
Perinopecten * sp. undet.
Leopteria spinalata (Win.)
Aviculo strigosa (White)
Pteronties whitei (Win.)
Mytilarca occidentalis (W. and W.)
Mytilarca frigistrata (W. and W.)
Goniophora jonesi (Win.)
Parallelodon oosteei (Win.)
Parallelodon rotyloides (Win.)
Grammysia plena Hall
Grammysia amygdalinus (Win.)
Edmondia burlingtonensis (W. and W.)
Edmondia quadrata (W. and W.)
Edmondia sequimarginalis Win.
Edmondia nitida Win.
Edmondia jegnus (Win.)
Sphenotus rigidus (W. and W.)
Sphenotus bicarinatus (Win.)
Sphenotus iowensis (Win.)

Sphenotus bicostatus Weller
Spathella ventricosa (W. and W.)
*Nucula iowensis W. and W.
Cardiopoma megambonata Win.
Schizodus iowensis Weller
Schizodus burlingtonensis Weller
Cypricardinia sulcifera (Win.)
Glossites elliptica (Win.)
Glossites? burlingtonensis Weller
Promacrus cuneatus Hall
Posidononychis ambiguus Win.

GASTROPODA—
Loxonema shumardana (Win.)
Loxonema oligospira Win.
Loxonema sp. undet.
Murchisonia quadricineta Win.
Strophastylus bivolve (W. and W.)
Sphaerodoma pinguis (Win.)
Naticopsis depressa Win.
Straparollus macromphalus Win.
Straparollus ammon (W. and W.)
Straparollus angulatus Weller
Platyechisma barrisi (Win.)
Platyechisma depressa Weller
Phaspheton paradoxus Win.
Bellerophon bilabiatus W. and W.
Bellerophon vinculatus W. and W.
Bellerophon panneus White
Bucanopsis deflectus Weller
Patelloimestum scriptiferus (White)
Porcellia crassinoda W. and W.
Porcellia obliquinoda White
Porcellia rectinoda Win.
Conularia byblis White

SCAPHOPODA—
Dentalium grandavum Win.

CEPHALOPODA—
Orthoceras whitneyi Win.
Orthoceras heterocinctum Win.
Orthoceras indianense Hall
Phragmoceras expansum Win.
Cyrtoceras uncinum Win.
Agonistes opinus (W. and W.)

The strongly Devonian aspect of this assemblage is commented upon by Weller.27 All the genera of the pelecypods, for example, except two are represented in the Devonian faunas of eastern New York. The cephalopods also have Devonian affinities. The brachiopods, on the other hand, are chiefly Carboniferous types. Weller states that “the strongly Carboniferous element among the brachiopods in the Chonopectus sandstone, is to be considered as a weightier evidence than the holdover pelecypods and cephalopods.”

27 Iowa Geol. Survey, vol. X, pp. 73, 74; 1900.
**List of Fossils from bed 3 of the Kinderhook Group at Burlington**

**BRACHIOPODA**
- *Schellwienella* sp.
- *Chonetes* gregarius Weller
- *Chonetes* cf. *C. geniculata* White
- *Chonopectus* fischeri (N. and P.)
- *Rhhipidomella* sp.
- *Rhynchonella* sp.
- *Paryphorhynchus* sp.
- *Spirifer* platynotus Weller
- *Spirifer* subrotundus Hall

**PELECYPODA**
- *Aviculoplecten iowensis* Miller
- *Pernoapecten* sp.
- *Paralleloodon leptogaster* (Win.)
- *Schizodus* sp.

**GASTROPODA**
- *Bellerophon* sp.
- *Straparollus* sp.

**List of Fossils from bed 4 of the Kinderhook Group at Burlington**

**BRACHIOPODA**
- *Chonetes* sp.
- *Chonetes* sp.
- *Chonopectus* fischeri (N. and P.)
- *Rhynchonella* unica Win.
- *Rhynchocyon* pustulosa (White)
- *Paryphorhynchus* striaticostatum (M. and W.)

**PELECYPODA**
- *Allorhynchus* heteropsis (Win.)
- *Allorhynchus* sp.

**List of Fossils from bed 5 of the Kinderhook Group at Burlington**

**BRACHIOPODA**
- *Leptaena* convexa Weller
- *Leptaena* inaequalis (Hall)
- *Chonetes* sp.
- *Productus* arcuatus Hall
- *Productus* parvulus Win.
- *Productus* blairi Miller
- *Pustula* morbilliana (Win.)
- *Camarophorella* lenticularis (W. and W.)
- *Cranaena* † allei (Win.)
- *Spirifer* biplicoides Weller
- *Spirifer* platynotus Weller
- *Brachythrypis* pecullaris (Shum.)
- *Syringothyris* sp.
- *Betricularia* cooperensis (Swallow)
- *Cyrtina* acutirestris (Shum.) †

**PELECYPODA**
- *Pterinopecten* nodocostus (W. and W.)
- *Pernoapecten* cooperensis (Shum.)
- *Lithophaga* cf. *L. minuta* Weller

**GASTROPODA**
- *Edmondia* nuptialis Win.
- *Edmondia* strigilata Win.
- *Sphenotis* cylindricus (Win.)
- *Spathella* phaselia Win.
- *Nucula* iowensis W. and W.
- *Palaeonello* microdonta (Win.)
- *Palaeonello* barrii (W. and W.)
- *Leda* saccata (Win.)
- *Dexiobia* ovata (Hall)
- *Dexiobia* halli Win.
- *Schizodus* trigonalis (Win.)
- *Cypriocardina* sulcifera (Win.)

**SCAPHOPODA**
- *Dentalium* grandaeum Win.

**VERTEBRATA**
- *Fish teeth.*

**List of Fossils from bed 6 of the Kinderhook Group at Burlington**

**ANTHOZOA**
- *Zaphrentis* sp. undet.

**BRACHIOPODA**
- *Leptaena* convexa Weller
- *Schellwienella* inflata (W. and W.)
- *Schellwienella* planumbona Weller
- *Schellwienella* inaequalis (Hall)

**PELECYPODA**
- *Schellwienella* cremulicostata Weller
- *Chonetes* logani N. and P.
- *Chonetes* burlingtonensis Weller
- *Chonetes* illinoensisis Wuerth
- *Chonetes* sp.
- *Pernoapecten* cooperensis (Shum.)
- *Productus* arcuatus Hall
- *Productus* ovatus Hall
- *Producta* concentrica (Hall)
List of Fossils from bed 7 of the Kinderhook Group at Burlington

<table>
<thead>
<tr>
<th>ANTHOZOA—</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>*Zaphrentis sp.</td>
<td></td>
</tr>
<tr>
<td>*Syringopora sp.</td>
<td></td>
</tr>
<tr>
<td>Leptopora typa Win.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CRINOIDEA—</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>*Several undetermined species</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BRYOZOA—</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>*Cystodictya sp.</td>
<td></td>
</tr>
<tr>
<td>*Fenestella sp.</td>
<td></td>
</tr>
<tr>
<td>*Ptilopora sp.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BRACHIOPODA—</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>*Leptaena convexa Weller</td>
<td></td>
</tr>
<tr>
<td>Schellwienella inflata (W. and W.)</td>
<td></td>
</tr>
<tr>
<td>Schellwienella inaequalis (Hall)</td>
<td></td>
</tr>
<tr>
<td>*Schellwienella sp.</td>
<td></td>
</tr>
<tr>
<td>*Chonetes logani N. and P.</td>
<td></td>
</tr>
<tr>
<td>*Chonetes illinoensis Worthen</td>
<td></td>
</tr>
<tr>
<td>*Choneus sp.</td>
<td></td>
</tr>
<tr>
<td>Productella concentrica (Hall)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GASTROPODA—</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>*Productus sampsoni Weller</td>
<td></td>
</tr>
<tr>
<td>*Productus sp.</td>
<td></td>
</tr>
<tr>
<td>*Rhipidomella thierei (White)</td>
<td></td>
</tr>
<tr>
<td>*Rhynechotetra caput-testudinis (White)</td>
<td></td>
</tr>
<tr>
<td>*Rhynechopora persinuata (Win.)</td>
<td></td>
</tr>
<tr>
<td>*Diestasla burlingtonensis (White)</td>
<td></td>
</tr>
<tr>
<td>*Spiferina solidirostris White</td>
<td></td>
</tr>
<tr>
<td>*Spifer cf. S. mundulus Bowley</td>
<td></td>
</tr>
<tr>
<td>*Spifer grimesi Hall</td>
<td></td>
</tr>
<tr>
<td>*Spifer forbesi N. and P.</td>
<td></td>
</tr>
<tr>
<td>*Spifer platynotus Weller</td>
<td></td>
</tr>
<tr>
<td>*Syringothyris sp.</td>
<td></td>
</tr>
<tr>
<td>*Reticularia cooperensis (Swallow)</td>
<td></td>
</tr>
<tr>
<td>Nucleospira barreti White</td>
<td></td>
</tr>
<tr>
<td>*Cliothyridina glenparkensis Weller</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CRUSTACEA—</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>*Grifithides f sp.</td>
<td></td>
</tr>
</tbody>
</table>

The vertical range of the Kinderhook species at Burlington is indicated in the following table:

<table>
<thead>
<tr>
<th>Table Showing Range of Species in Kinderhook Beds at Burlington</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizons</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Spongiae</td>
</tr>
<tr>
<td>Dictophytom sp. undet...............................</td>
</tr>
<tr>
<td>Anthozoa</td>
</tr>
<tr>
<td>Zaphrentis sp. undet...............................</td>
</tr>
<tr>
<td>Zaphrentis sp.......................................</td>
</tr>
<tr>
<td>Syringopora sp......................................</td>
</tr>
<tr>
<td>Leptopora typa Win..................................</td>
</tr>
<tr>
<td>Table Showing Range of Species in Kinderhook Beds at Burlington—Continued.</td>
</tr>
<tr>
<td>-------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Bryozoa</strong></td>
</tr>
<tr>
<td>Fenestella sp. undet.</td>
</tr>
<tr>
<td>Fenestella sp.</td>
</tr>
<tr>
<td>Ptilopora sp.</td>
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<tr>
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**Horizons**

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Kim, der lwo7c Beds at Burlington—Continued.
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<tr>
<td>Bellerophon vinctulus W. and W.</td>
<td>x</td>
</tr>
</tbody>
</table>
### Table Showing Range of Species in Kinderhook Beds at Burlington—Continued.

<table>
<thead>
<tr>
<th>Species</th>
<th>Horizons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bellerophon panneus White</td>
<td>x</td>
</tr>
<tr>
<td>Bellerophon sp.</td>
<td>x</td>
</tr>
<tr>
<td>Bellerophon sp. undet.</td>
<td>x</td>
</tr>
<tr>
<td>Bucanopsis deflectus Weller</td>
<td>x</td>
</tr>
<tr>
<td>Bucanopsis perelegans (W. and W.)</td>
<td>x</td>
</tr>
<tr>
<td>Patellostium scriptiferus (White)</td>
<td>x</td>
</tr>
<tr>
<td>Straparollus macrocephalus Win</td>
<td>x</td>
</tr>
<tr>
<td>Straparollus ammon (W. and W.)</td>
<td>x</td>
</tr>
<tr>
<td>Straparollus angularis Weller</td>
<td>x</td>
</tr>
<tr>
<td>Straparollus obtusus (Hall)</td>
<td>x</td>
</tr>
<tr>
<td>Straparollus sp. undet.</td>
<td>x</td>
</tr>
<tr>
<td>Platychisma barrai (Win.)</td>
<td>x</td>
</tr>
<tr>
<td>Platychisma depressa Weller</td>
<td>x</td>
</tr>
<tr>
<td>Platychisma sp. undet.</td>
<td>x</td>
</tr>
<tr>
<td>Phanerothinae paradoxus Win</td>
<td>x</td>
</tr>
<tr>
<td>Naticopsis depressa Win</td>
<td>x</td>
</tr>
<tr>
<td>Lotonema shumardana (Win.)</td>
<td>x</td>
</tr>
<tr>
<td>Lotonema oligospira Win</td>
<td>x</td>
</tr>
<tr>
<td>Holopella subconica Win</td>
<td>x</td>
</tr>
<tr>
<td>Holopella mira Win</td>
<td>x</td>
</tr>
<tr>
<td>Lotonema undata (Win.)</td>
<td>x</td>
</tr>
<tr>
<td>Capulus paralius W. and W.</td>
<td>x</td>
</tr>
<tr>
<td>Capulus vomerium (Win.)</td>
<td>x</td>
</tr>
<tr>
<td>Capulus sp. undet</td>
<td>x</td>
</tr>
<tr>
<td>Strophostylus bivolve (W. and W.)</td>
<td>x</td>
</tr>
<tr>
<td>Sphaerodoma pinguis (Win.)</td>
<td>x</td>
</tr>
<tr>
<td>Conularia byblis White</td>
<td>x</td>
</tr>
<tr>
<td>Conularia sp. undet</td>
<td>x</td>
</tr>
<tr>
<td>Orthoceras whitei Win</td>
<td>x</td>
</tr>
<tr>
<td>Orthoceras heteroninum Win</td>
<td>x</td>
</tr>
<tr>
<td>Orthoceras indianaense Hall</td>
<td>x</td>
</tr>
<tr>
<td>Gomphoceras sp.</td>
<td>x</td>
</tr>
<tr>
<td>Phragmoceras expansum Win</td>
<td>x</td>
</tr>
<tr>
<td>Cyrtoceras unicorne Win</td>
<td>x</td>
</tr>
<tr>
<td>Gyrocerae burlingtonensis Owen</td>
<td>x</td>
</tr>
<tr>
<td>Agoniatites opimus (W. and W.)</td>
<td>x</td>
</tr>
</tbody>
</table>

### CEPHALOPODA

<table>
<thead>
<tr>
<th>Species</th>
<th>Horizons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthoceras whitei Win</td>
<td>x</td>
</tr>
<tr>
<td>Orthoceras heteroninum Win</td>
<td>x</td>
</tr>
<tr>
<td>Orthoceras indianaense Hall</td>
<td>x</td>
</tr>
<tr>
<td>Gomphoceras sp.</td>
<td>x</td>
</tr>
<tr>
<td>Phragmoceras expansum Win</td>
<td>x</td>
</tr>
<tr>
<td>Cyrtoceras unicorne Win</td>
<td>x</td>
</tr>
<tr>
<td>Gyrocerae burlingtonensis Owen</td>
<td>x</td>
</tr>
<tr>
<td>Agoniatites opimus (W. and W.)</td>
<td>x</td>
</tr>
</tbody>
</table>

### CRUSTACEA

<table>
<thead>
<tr>
<th>Species</th>
<th>Horizons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Griffithides † sp.</td>
<td>x</td>
</tr>
<tr>
<td>Psaleopalaemon newberryi Whitf. †</td>
<td>x</td>
</tr>
</tbody>
</table>

### VERTEBRATA

<table>
<thead>
<tr>
<th>Species</th>
<th>Horizons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coelacanthus welleri Eastman</td>
<td>x</td>
</tr>
</tbody>
</table>

### PLANTS

<table>
<thead>
<tr>
<th>Species</th>
<th>Horizons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fragments of stems and leaves</td>
<td>x x</td>
</tr>
</tbody>
</table>
It will be observed that the Upper Kinderhook beds carry a
typical Mississippian fauna, the Devonian aspect which charac­
terizes the collections from the lower beds being entirely lost.
The appearance of such forms as *Spirifer grimesi* and *Spirifer
forbesi* in the topmost bed of the Kinderhook together with the
lithologic character of this member at Burlington suggests a
transition into the limestone of the Lower Burlington. Such a
relationship is indicated also by the field relations of the two
formations. Attention is called to the Chouteau affinities of the
fossils of beds 6 and 7 of the Kinderhook beds at Burlington.

**Louisa County.**—In this county the Kinderhook succession is
much the same as at Burlington, but some of the individual
members of the series are more attenuated.

The best and most complete section exposed in the county is
described by J. A. Udden28 in his report on the geology of the
county. This appears “in and near Anderson’s Quarry on the
east bank of Smith creek, west of the center of the SW. 1/4 of
sec. 29, Tp. 73 N., R. 2 W.” The succession there as revised by
the writer is as follows:

*Section at Anderson quarry.*

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>8. Drift</td>
<td>5</td>
</tr>
</tbody>
</table>
| 7. Limestone, brownish and dolomitic below, but gray and cri­
  noidal above | 28 6 |

**KINDERHOOK.**

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
</table>
| 6. Limestone, yellowish to brownish, dolomitic; with geodic
cavities lined with calcite | 6 |
| 5. Limestone, light gray, oölitic | 3 |
| 4. Sandstone, ash-colored, fine-grained | 3 |
| 3. Limestone, irregularly bedded, brownish, dolomitic | 3 6 |
| 2. Sandstone, ash-gray, fine-grained | 9 6 |
| 1. Shale, bluish, argillaceous; progressively more calcareous be­
  low; with a carbonaceous seam about eight inches thick near
  the middle. Exposed in the east bank of the creek about
  forty rods north of the quarry | 20 |

The fauna of the Kinderhook beds at this locality is listed be­
low:

*Fauna of the Kinderhook Beds, Anderson Quarry Section.*

<table>
<thead>
<tr>
<th>Horizons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BRACHIOPODA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lingula sp.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Horizons</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthotetes sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Chonetes geniculatus White</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chonetes sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chonetes sp.</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Chonetes sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chonetes fischeri (N. &amp; P.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productus sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productus cf. P. curtirostris Win.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productus ovatus Hall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productus arcuatus Hall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productus blairi Miller</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productus sp.</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productus sp.</td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhipidomella thiemei (White)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schizophoria sp.</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhynchoconella sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paryphorhynchus transversum Weller</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spirifer biplicatus Hall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spirifer biplicoides Weller</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Spirifer platynotus Weller</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Spirifer subrotundus Hall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Spirifer sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brachythyriss burlingtonensis Weller</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reticularia cooperensis (Swallow)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ambocoelia parva Weller</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nucleospira barrisi White</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Composita corpulenta (Winchell)</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PELECYPODA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sphenotus iowensis (Win.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grammysia plena Hall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nucula iowensis W. &amp; W</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leda secaita (Win.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schizodus trigonalis (Win.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pernopecten cooperensis (Shum.)</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCAPHOPoda</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dentalium grandaerum Win</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GASTROPODA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bellerophon sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straparollus sp.</td>
<td></td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strophiostylus sp.</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orthonyx aristatus</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VERTEBRATA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fish teeth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In the Anderson quarry section, bed 1 is equivalent to the shale member (bed 1) at Burlington. Bed 2 is the attenuated equivalent of the Chonopectus sandstone (bed 2) and bed 3 is a thin dolomitic facies of bed 4. The thin limestone (bed 3) at Burlington is absent in Louisa county. The oolitic limestone (bed 6) and the overlying buff limestone (bed 7) at Burlington are equivalent to beds 5 and 6 in the above section.

The higher beds of the Kinderhook are again well exposed in the east bank of Smith creek near the bridge in the NW. 1/4 of sec. 31, T. 73 N., R. 2 W. The section given below is slightly modified after Udden.29

Section of Kinderhook beds, Smith creek.

BURLINGTON.

<table>
<thead>
<tr>
<th>Bed</th>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Limestone, brownish, crinoidal, bearing Lobocrinus pyriformis, a Pentremites and Productus burlingtonensis</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>Chert</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Limestone, buff, dolomitic, irregularly bedded, with casts of crinoid stems</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>Limestone, soft, gray weathering yellowish, with fragments of crinoid stems</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Limestone, gray, crinoidal, with seams of brownish dolomitic limestone, more irregularly bedded and cherty below</td>
<td>10</td>
</tr>
</tbody>
</table>

KINDERHOOK.

<table>
<thead>
<tr>
<th>Bed</th>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Limestone, brownish, soft, dolomitic, in two ledges, each three feet in thickness</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>Limestone, light gray, oolitic</td>
<td>2½</td>
</tr>
<tr>
<td>2</td>
<td>Sandstone, bluish, fine-grained, with a thin seam of shale near the middle</td>
<td>3½</td>
</tr>
<tr>
<td>1</td>
<td>Limestone, dark gray, fine-grained, imperfectly dolomitized, exposed</td>
<td>1½</td>
</tr>
</tbody>
</table>

The fauna of the Kinderhook beds in this section follows:

Fauna of Kinderhook Beds, in Bank of Smith Creek.

<table>
<thead>
<tr>
<th>Horizons</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anthozoa</strong></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Zaphrentis sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Syringopora sp.</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td><strong>Brachiopoda</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leptaena convexa Weller</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schellwienella planumbona Weller</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schellwienella inflata (W. and W.)</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schellwienella sp.</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Species</th>
<th>Horizons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Streptorhynchos † sp.</td>
<td>x</td>
</tr>
<tr>
<td>Orthotetes † sp.</td>
<td>x</td>
</tr>
<tr>
<td>Chonetes logani N. and P.</td>
<td></td>
</tr>
<tr>
<td>Chonetes burlingtonensis Weller</td>
<td>x</td>
</tr>
<tr>
<td>Chonetes multicosta Win.</td>
<td>x</td>
</tr>
<tr>
<td>Chonetes sp.</td>
<td>x</td>
</tr>
<tr>
<td>Chonetes sp.</td>
<td>x</td>
</tr>
<tr>
<td>Productus parvulus Win.</td>
<td>x</td>
</tr>
<tr>
<td>Productus arcuatus Hall</td>
<td>x</td>
</tr>
<tr>
<td>Productus sp.</td>
<td>x</td>
</tr>
<tr>
<td>Productus sp.</td>
<td>x</td>
</tr>
<tr>
<td>Rhipidomella thicemii (White).</td>
<td>x</td>
</tr>
<tr>
<td>Rhipidomella sp.</td>
<td>x</td>
</tr>
<tr>
<td>Schizophoria sp.</td>
<td>x</td>
</tr>
<tr>
<td>Allorrhynchos heterospis (Win.)</td>
<td>x</td>
</tr>
<tr>
<td>Rhyncotetra caput-testudinis (White)</td>
<td>x</td>
</tr>
<tr>
<td>Spiriferina solidirostris (White)</td>
<td>x</td>
</tr>
<tr>
<td>Spirifer platynotus Weller</td>
<td>x</td>
</tr>
<tr>
<td>Spirifer bicornicipes Weller</td>
<td>x</td>
</tr>
<tr>
<td>Brachythyris sp.</td>
<td>x</td>
</tr>
<tr>
<td>Nucleospira barrisi White</td>
<td>x</td>
</tr>
<tr>
<td>Athyris crassicardinalis White</td>
<td>x</td>
</tr>
</tbody>
</table>

**PELECYPODA**

- Cypricarina sulcifera (Win.)
- Worthena mississippiensis W. and W.
- Palaeonilo barrisi (W. and W.)
- Nucula iowensis W. and W.
- Edmondia equimarginalis Win.

**SCAPHOPODA**

- Dentalium grandaevum Win.

**GASTROPODA**

- Bucanopsis perelegans (W. and W.)
- Bellerophon sp.
- Murchisonia quadricincta Win.
- Straparollus obtusus (Hall)
- Straparollus sp.

**CEPHALOPODA**

- Orthoceras indianense Hall
- Orthoceras sp.

**TRILOBITA**

- Phillipsia † sp.

Several other exposures of the Kinderhook in Louisa county
have been described by J. A. Udden. The location and description of these are taken from his report.

Sections in the Bluffs and Creeks North and East of Morning Sun

Section on the first creek in the Mississippi bluffs north of the county line southwest of Oakville, in the SW. 1/4 of sec. 35, T. 73 N., R. 2 E. W. (After Udden.)

BURLINGTON. FEET

11. Disintegrated crinoidal limestone ........................................ 6
10. Chert .................................................................................. 1
9. Disintegrated crinoidal limestone .......................................... 3
8. Blue shale ............................................................................. 1
7. Hard white crinoidal limestone with chert in upper layers .... 8
6. Beds grading from a disintegrated yellow shaly residue below to a somewhat crumbling crinoidal limestone with much chert above ................................................................. 20

Kinderhook.
5. Yellow magnesian limestone with irregular bedding above and occasional quartzose concretions ................................. 7
4. Oolitic yellow or brown fossiliferous disintegrated limestone .... 2
3. Fine sandstone, like number 1 .................................................. 1½
2. Compact dark gray limestone, somewhat weathered, showing small cavities and veins filled with calcite ............................. 3
1. Bluish white fine sandstone, weathering yellow, with casts of gastropods and lamellibranchs .................................................. 8

Section on the Mississippi river bluffs on the second creek north of the county line in the east half of sec. 34, T. 78 N., R. 2 E. W. (After Udden.)

BURLINGTON. FEET

15. Blue shaly beds, weathering yellow, with some calcareous and cherty bands above ................................................................. 15½
14. Concealed .............................................................................. 1
13. Chert .................................................................................. 1
12. Brown limestone and chert ...................................................... 2½
11. Brown limestone, disintegrated ............................................... 1
10. Bluish shaly material, with quartz geodes below .................... 2
9. White crinoidal limestone, with quartz geodes in a shaly seam near base ................................................................. 8
8. Concealed .............................................................................. 1
7. White crinoidal limestone ......................................................... 4
6. Concealed .............................................................................. 1
5. Hard white and yellow crinoidal limestone, moderately fine-grained, with layers of chert .................................................. 10

Kinderhook.
4. Yellow rather fine-grained dolomitic crinoidal limestone, broken with many joints in upper part .......................................... 10
3. Oolitic limestone with Spirifer marionensis, Productella concentrica, Spirifer (undescr. sp.), Athyrus sp., Zaphrentis sp., and Orthoceras sp. ................................................................. 3
2. Bluish or rusty brownish weathered compact limestone, with arenaceous rock above ................................................................. 5
1. Bluish fine sandstone, weathering yellow, with teeth of Helodus and casts of brachiopods in upper part. Syringothyris extenuatus occurs near the top of the lowest member; also Spirifer biplicatus and Productus sp. ................................................................. 9

Beds 1, 2, 3, and the lower portion of 4 of this section are to be referred to the Kinderhook. All above belong to the Lower Burlington.

**Section in a creek one mile southeast of Ellicott Junction in the south part of sec. 29, T. 73 N., R. 2 W. (After Udden).**

<table>
<thead>
<tr>
<th>KINDERHOOK</th>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Yellow limestone, exhibiting oolitic structure below</td>
<td>10</td>
</tr>
<tr>
<td>4. Blue evenly bedded argillaceous sandstone</td>
<td>2</td>
</tr>
<tr>
<td>3. Fine-grained, concretionary yellow or brown limestone, disintegrated</td>
<td>4</td>
</tr>
<tr>
<td>2. Soft fine-grained sandstone, with <em>Helodus</em> teeth at base</td>
<td>2½</td>
</tr>
<tr>
<td>1. Blue soft sandy material, with wavy yellow stained bands containing <em>Chonopectus fischeri</em>, above</td>
<td>6</td>
</tr>
</tbody>
</table>

**Section on the east bank of a railroad cut at the edge of the upland, three miles north of Morning Sun (After Udden).**

<table>
<thead>
<tr>
<th>KINDERHOOK</th>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Disintegrated brownish magnesian limestone with <em>Athyris incrasatus</em> and <em>Chonetes Illinoisensis</em></td>
<td>3</td>
</tr>
<tr>
<td>4. Yellow weathered fine sandstone, with <em>Edmondia burlingtonensis</em>, <em>Spirifer bigeorgeus</em>, <em>Chonopectus fischeri</em>, <em>Paryphyma striato-costatum</em> (var), <em>Orthotetes inaequalis</em> ?, <em>Chonetes</em> sp., <em>Fenestella</em> sp.</td>
<td>3</td>
</tr>
<tr>
<td>3. Fine blue sandstone, with few fossils</td>
<td>10</td>
</tr>
<tr>
<td>2. Fine-grained blue sandstone, with casts of <em>Produbctus laevicostatus</em>, <em>Productus cooperensis</em>, <em>Athyris corpulente</em>, <em>Orthotetes inaequalis</em> ?, and other lamellibranchs in abundance</td>
<td>2</td>
</tr>
<tr>
<td>1. Blue shale</td>
<td>1</td>
</tr>
</tbody>
</table>

**Kinderhook Sections in Long Creek Basin**

"Following Long creek west we find bed rock for the first time near the east line of sec. 13, Tp. 74 N., R. 5 W. From this point the exposures are almost continuous along the south fork for two miles, but have a limited vertical range. The Kinderhook beds gradually disappear under the overlying limestones. The Buffington fork is rocky a mile from its mouth, and has a few scattered exposures farther west. The north or main branch runs through a valley in which the Burlington limestone is frequently exposed in the bluffs or on the small tributaries. But with few exceptions these rocky cliffs are less than twenty feet in height."

**Section on a small tributary of Long creek, south of the center of the SE. 1/4 of sec. 13, T. 74 N., R. 5 W. (After Udden).**

<table>
<thead>
<tr>
<th>KINDERHOOK</th>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Brownish gray compact siliceous rock, possibly changed locally from a dolomitic limestone by infiltration</td>
<td>8</td>
</tr>
<tr>
<td>3. Not exposed</td>
<td>2</td>
</tr>
<tr>
<td>2. Blue soft fine sandstone, with <em>Orthotetes inaequalis</em>, <em>Chonopectus fischeri</em>, <em>Avenulopecten caroli</em>, <em>Productus levicostus</em>, <em>Ehipidomella</em></td>
<td></td>
</tr>
</tbody>
</table>
KINDERHOOK ON IOWA RIVER

burlingtonensis, Macrodon cochlearis, Orthoceras whitei, Conularia (micronema 1), Edmondia sp. .............................................................. 4
1. Soft shale (seen farther east) ........................................................... 4

Section in the west bluff of Long creek, south of the center of the NW. ¼ of sec. 13, T. 74 N., R. 5 W. (After Udden).

KINDERHOOK. FEET
5. Irregularly bedded, compact brown or gray dolomite; some brachiopods with a few crinoid fragments ........................................ 10
4. Rather harder than that below, brown earthy stone ...................... 2
3. Soft rather uniform bluish gray, light colored fine sandstone, with lamellibranchs and teeth of Helodus near top ........................... 5
2. Alternating layers of fine loose sandstone .................................... 5
1. Green clayey shale ........................................................................ 3

Section on the west bank of Long creek one-fourth mile south of the mouth of Johnny creek, near the center of the south line of sec. 12, T. 74, R. 5 W. (After Udden).

KINDERHOOK. FEET
5. Gray compact limestone .................................................................... 8
4. Concealed .......................................................................................... 13
3. Brownish gray gritty rock .............................................................. 3
2. Blue soft fine sandstone, with casts of Bellerophon bilabiatus, Straparolus macromphalus, Spirifer subrotundatus, Orthoceras whitei, Closites elliptica, Straparolus sp., Modiomorpha sp., Bellerophon (two species) ................................................. 3
1. Blue arenaceous soft rock, with shale below ..................................... 12

Sections on Clifton Creek and Iowa River

"North of Long creek basin the drift rapidly increases in thickness and the bed rock is rarely exposed. It has been observed only in sections 22 and 27, Tp. 75 N., R. V. W., and in ...
various gastropods; also *Athyris corpulenta*, *Pseudoceras curvirostrum*, *Productella nummularia*, *Orthoceras inaequis*, *Edmondia burlingtonensis*, *Eumetria altirostris*, *Porcellia obliquinoda*, *Grammysia plena*, *Bellerophon* (undescr?) and a *Platyschisma*

**Correlation of the Kinderhook Beds of Louisa County**

Only the upper portion of the basal shale is exposed in this county though the lower beds have been penetrated by the drill at several localities. Its total thickness is reported to be as much as 180 feet. The sandstone bed above, which is correlated with the *Chonopectus* sandstone of the Kinderhook beds at Burlington, is very similar in character to the equivalent bed at Burlington and bears essentially the same fossils, though its thickness is less than half as great.

Bed 3 of the Burlington section has not been recognized in any of the Kinderhook exposures of Louisa county. This is not surprising since it has a thickness of only eight inches at Burlington.

Beds 4 and 5 of the Kinderhook at Burlington are present in Louisa county but are more attenuated and less typically developed. For example, the lithographic limestone (bed 4), which is ten feet thick at Burlington, is represented in this area by only three and one-half feet of brownish dolomitic limestone.

The oölitic limestone and the overlying brownish dolomitic limestone of the Louisa county sections are easily identified as beds 6 and 7 of the Burlington section. They have essentially the same development in the two areas.

**Muscatine County.**—No strata of Kinderhook age are known positively to exist in Muscatine county. However, the Sweetland Creek beds of Udden\(^1\) which were referred by him to the Upper Devonian may possibly be an outlier of the basal Kinderhook as suggested by Weller.\(^2\) This deposit consists of interbedded dark shale, green shale and argillaceous magnesian limestone with a maximum thickness of about forty-eight feet. It is disconformable with Cedar Valley limestone of Devonian age below and with Pennsylvanian sandstone above.

Udden\(^3\) lists the following fossils from the Sweetland Creek beds:

---

KINDERHOOK AT MAPLE HILL

Lingula cf. melie Hall
Lingula cf. nuda Hall
Lingula subspatulata M. and W. ?
Lingula sp. undet.
Gastropod
Spathiocaris emersoni Clarke
Solenocaris strigata Meek
Ptyctodus calceolus M. and W.
Rhynchodus cf. excavatus Newb.
Synthetodus
Impressions of plants.

Weller34 calls attention to the fact that Ptyctodus calceolus occurs in beds known to be basal Kinderhook at several localities in Missouri and that a Spathiocaris is represented both in the Upper Devonian black shale of southern Illinois and in a basal Kinderhook shale in southwestern Missouri. Further study of the Sweetland Creek beds by Dr. A. O. Thomas and the writer failed to bring to light additional species sufficiently diagnostic to fix the age of the formation more definitely. The problem is the more difficult because there are no known exposures of the basal Kinderhook in southeastern Iowa which can be compared with the Sweetland Creek beds.

Washington County.—The area underlain by the Kinderhook in Washington county is confined to its northeastern and extreme northern parts. The best exposures appear in the valley of English river, though occasional small outcrops occur along the tributaries of this stream and on Goose creek and Whiskey run.

Probably the most complete section of the Kinderhook in this county is the exposure at Maple Mill on the south bank of English river, a short distance south of the center of section 8 of Lime Creek township. This has been described by Bain35 as follows:

Section of Kinderhook beds at Maple Mill (After Bain).

4. Limestone, ferruginous, arenaceous in places, fine-grained, red, containing numerous casts of fossils, and with thin chert layers two to eight inches thick, also fossiliferous .... 10
3. Sandstone, or gritstone, very fine-grained, white to buff, very fossiliferous ................................................................. 18
2. Limestone, fine-grained, non-fossiliferous ..................... 1/6
1. Shale, argillaceous, dark blue to drab, almost black in places 12

The writer’s section of the Kinderhook at Maple Mill differs only in detail from that of Bain.

It will be noted that beds 1 and 2 of Bain’s section are now concealed and that his bed number 3 is divided into three members (beds 2, 3, and 4) in the writer’s section. The shale exposed at the time of Bain’s visit was correlated by him with the basal shale (bed 1) of the Kinderhook section at Burlington, although he was not able to secure fossils to substantiate this correlation. This division of the Kinderhook has been designated by Bain the Maple Mill shale from the fact that it is well developed at this locality. He reports 36 that the same shale outcrops along the bank of English river southeast of Kalona (Tp. 77 N., R. 7 W., sec. 16) where it has an exposed thickness of twelve feet.

The sandstone member of Bain’s section (bed 3) was named by him, the English River gritstone, and was regarded as the equivalent of the *Chonopectus* sandstone which occupies a similar position above the basal shale at Burlington. The fauna of this member has been studied by Weller. 37 In correlating it with the beds at Burlington he says:

“This fauna of the English River Grit is essentially that of the *Chonopectus* bed at Burlington, but with certain modifications. *Chonopectus fischeri*, although present in the fauna, is not one of the most abundant species; in fact, although most of the species at Maple Mill can be identified with Burlington forms, many of those that are common at Burlington are rare on English river, and vice versa, rare species at Burlington are in several instances more common on English river.”

The writer has little to add to the above correlations further.

---

than to suggest that the *Chonopectus* sandstone of Burlington is represented only by the lower thirteen feet of Bain's bed 3, corresponding to bed 2 of the revised section. Following this interpretation, the thin dolomitic limestone member (bed 3) and the sandstone above (bed 4), represent the attenuated representatives of the “Lithographic limestone” (bed 4) and the upper sandstone (bed 5) of the Burlington section. The marked thinning of these beds in Louisa county is in conformity with this view. It must be admitted, however, that the faunas of the uppermost beds are not sufficient to make this correlation certain.

The fauna of bed 2 of the revised section at Maple Mill is as follows:

**List of fossils from bed 2, Maple Mill section, Washington county.**

<table>
<thead>
<tr>
<th>VERMES—</th>
<th></th>
<th>BRACHIODONATA—</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Scalearituba missouriensis</em> Weller</td>
<td></td>
<td><em>Schellwienella</em> sp.</td>
<td></td>
</tr>
<tr>
<td><em>Chonetes</em> sp.</td>
<td></td>
<td><em>Productella zannularis</em> (Win.)</td>
<td></td>
</tr>
<tr>
<td><em>Productella concentrica</em> (Hall)</td>
<td></td>
<td><em>Productus mesicostalis</em> Weller</td>
<td></td>
</tr>
<tr>
<td><em>Productus ovatus</em> Hall</td>
<td></td>
<td><em>Productus arcusat Hall</em></td>
<td></td>
</tr>
<tr>
<td><em>Productus curtirostris</em> Win.</td>
<td></td>
<td><em>Schizophoria</em> sp.</td>
<td></td>
</tr>
<tr>
<td><em>Parryphorhynchus transversum</em> Weller</td>
<td></td>
<td><em>Allorhynchus heteropsis</em> (Win.)</td>
<td></td>
</tr>
<tr>
<td><em>Spirifer clavus</em> Hall</td>
<td></td>
<td><em>Spirifer maplenessis</em> Weller</td>
<td></td>
</tr>
<tr>
<td><em>Syringothyris extenuatius</em> (Hall)</td>
<td></td>
<td><em>Eumetrica altostris</em> (White)</td>
<td></td>
</tr>
<tr>
<td><em>Composita corpulenta</em> (Win.)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SCAPHOPODA—</th>
<th></th>
<th>GASTROPODA—</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Dentalium grandaeum</em> Win.</td>
<td></td>
<td><em>Porcella obliquinoda</em> White</td>
<td></td>
</tr>
<tr>
<td><em>Bellerophon bilabiatus</em> W. and W.</td>
<td></td>
<td><em>Bellerophon vinculatus</em> W. and W.</td>
<td></td>
</tr>
<tr>
<td><em>Bellerophon sp.</em></td>
<td></td>
<td><em>Euphemus</em> sp.</td>
<td></td>
</tr>
<tr>
<td><em>Straparollus amphoa</em> (W. and W.)</td>
<td></td>
<td><em>Straparollus</em> sp.</td>
<td></td>
</tr>
<tr>
<td><em>Naticopsis depressus</em> Win.</td>
<td></td>
<td><em>Straparollus expansum</em> Win.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PELECYPODA—</th>
<th></th>
<th>CEPHALOPODA—</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Edmondia jejunis</em> (Win.)</td>
<td></td>
<td><em>Orthoceras whitei</em> Win.</td>
<td></td>
</tr>
<tr>
<td><em>Sphenotus iovensis</em> (Win.)</td>
<td></td>
<td><em>Orthoceras heterocinctum</em> Win.</td>
<td></td>
</tr>
<tr>
<td><em>Sphenotus</em> sp.</td>
<td></td>
<td><em>Phragmoceras expansum</em> Win.</td>
<td></td>
</tr>
<tr>
<td><em>Grammysia plena</em> Hall</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Grammysia amygdalina</em> (Win.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Palaeoneilo microdonta</em> (Win.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Parallelopecte cochlearis</em> (Win.)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The brownish dolomitic limestone (bed 3) has not yielded fossils sufficiently well preserved to be specifically identified, but a few species have been collected from the fine sandstone of bed 4 above. These are listed below.
List of fossils from bed 4, Maple Mill section, Washington county.

**BRACHIOPODA**
- Schellwienella sp.
- Chonetes
- Schizosphoria chouteauensis Weller
- Spirifer platynotus Weller

**PELECYPODA**
- Pernopecten cooperensis (Shum.)
- Nucleospira barrisi White

The brownish dolomitic limestone capping the section at Maple Mill represented by bed 4 of Bain’s section and bed 6 of the revised one is the topmost member of the Kinderhook in Washington county. This member attains its typical development at the old Wassonville mill one and one-half miles west of the above described exposure. Hence the name Wassonville limestone as applied by Bain.

**Section at Wassonville Mill.**

| 15. Drift | 15.00 |
| 14. Shale, brownish, dolomitic, much weathered | 2.00 |
| 13. Limestone, soft, yellowish, dolomitic; showing fine, close stratification on weathered surface; bearing a few silicified fragments of crinoid stems | 5.00 |
| 12. Chert, white, nonfossiliferous; in the form of lenses and nodules | 3.00 |
| 11. Limestone, buff, dolomitic, thin-bedded | 6.00 |
| 10. Band of soft white fossiliferous chert nodules | 3.00 |
| 9. Limestone, massive, yellowish, dolomitic | 3.00 |
| 8. Band of soft white fossiliferous chert nodules | 3.00 |
| 7. Limestone, massive, yellowish, dolomitic | 7.00 |
| 6. Band of white fossiliferous chert nodules | 5.00 |
| 5. Limestone, soft, massive, yellowish, dolomitic | 2.00 |
| 4. Limestone, soft, massive, brownish, dolomitic | 2.00 |
| 3. Limestone, tough, brownish, dolomitic, weathering into thin, nodular layers | 2.00 |
| 2. Sandstone, ash-colored, fine-grained; exposed | 4.00 |
| 1. Concealed to level of water in river | 5.00 |

Beds 5 to 15 of the above section are exposed in a quarry back of the mill, while beds 1 to 4 are shown in the river bank just below. The dolomitic limestone layers are nearly barren of identifiable fossils, but certain of the nodular chert bands, especially beds 8 and 10, contain many excellently preserved specimens. The following fossils were collected from the cherts:

**List of fossils from beds 8 and 10 of Wassonville Mill section, Washington county.**

**BRACHIOPODA**
- Schellwienella crassnestata White
- Chonetes logani N. and P.
- Chonetes multicostata Win.
- Productus arcuatus Hall
- Camarotoechia chouteauensis Weller

**PELECYPODA**
- Spiriferina solidirostris White
- Spirifer platynotus Weller
- Sphenotus cylindricus (Win.)
- Leda sp.
- Paralleloodon parvus (W. and W.)

---

Another excellent exposure of the Wassonville limestone is shown in an abandoned quarry on the opposite side of the river at the head of the big bend (Tp. 77 N., R. 8 W., sec. 6, SE.1/4). The succession of beds at this place is indicated below.

Section of Wassonville limestone at the head of the big bend.

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.</td>
<td>Drift</td>
</tr>
<tr>
<td>7.</td>
<td>Limestone, brownish, dolomitic, soft</td>
</tr>
<tr>
<td>6.</td>
<td>Chert, in the form of a band of nodules</td>
</tr>
<tr>
<td>5.</td>
<td>Limestone, brownish yellow, dolomitic, massive</td>
</tr>
<tr>
<td>4.</td>
<td>Chert, in the form of a band of nodules</td>
</tr>
<tr>
<td>3.</td>
<td>Limestone, yellowish, massive, dolomitic</td>
</tr>
<tr>
<td>2.</td>
<td>Chert, in the form of a discontinuous band, slightly coarser-grained than that in the beds above</td>
</tr>
<tr>
<td>1.</td>
<td>Limestone, yellowish to brownish, massive, soft, dolomitic; bearing a few poorly preserved fossils similar to those in the chert just above. Exposed</td>
</tr>
</tbody>
</table>

The Wassonville limestone is again well exposed in an abandoned railway quarry three miles northeast of Wellman. Bain describes this section as follows:

"In the old Burlington, Cedar Rapids and Northern railway quarry (Tp. 77 N., R. 8 W. Sec. 16) the limestone layers are exposed twenty feet thick, with the base twenty feet above the bridge on Smith creek. The stone is of the usual earthy magnesian character, and runs in ledges two to four feet thick, separated by thin layers of chert. The Augusta (Burlington) is reported to occur immediately above the top of the quarry, though it is not now exposed."

The contact relations of the Wassonville limestone with the overlying Burlington limestone are not certainly known, since no section showing the actual contact of the two formations is now exposed in the region. Bain refers to a possible contact section on Smith creek as follows:

"Southeast of Wellman the creek soon cuts through the Augusta into the Kinderhook. In section 19 (Tp. 77 N., R. 8

W.) the latter was encountered in the base of a quarry on a level with the stream”.

At the time of the writer’s visit in the summer of 1915, this section was no longer exposed.

The correlation of the Wassonville limestone with the Kinderhook at Burlington is attended with some difficulty, owing in part to lack of lithologic similarity and in part to faunal differences. Thus, we have at least thirty-five feet of yellowish cherty dolomite at the top of the Kinderhook in this region, while at Burlington the only bed which resembles this lithologically is a zone five feet in thickness at the very top of the section (bed 7). Again, there are many undescribed species of pelecypods and gastropods in the Wassonville limestone which have not been found in the uppermost Kinderhook beds at Burlington. Upon the basis of the brachiopod faunas of the two regions, however, it is possible to say with a reasonable degree of certainty that the Wassonville represents beds 6 and 7, and possibly part of bed 5, of the Burlington section. All of the brachiopods of the Wassonville, with the exception of Spirifer platygnus, which ranges from bed 2 to bed 7, at Burlington, are confined to the three uppermost beds at the latter locality.

The marked thinning of the lower members of the Kinderhook is continued from Louisa county into Washington. The extent of the attenuation of the basal shale in this region is not known, but evidently it is considerable, for a deep boring at Sigourney in Keokuk county, which borders Washington on the west, shows this member to be only 198 feet thick as compared to a thickness of 300 feet at Burlington. The sandstone above this (English River gritstone) is only a little more than one-half as thick as at Burlington, and the limestone and sandstone beds directly above are much less than one-half as thick as their probable equivalents in the latter region.

The higher members of the Kinderhook, on the other hand, are distinctly thicker in Washington county than the beds of the same horizon both in Louisa county and at Burlington. It is safe to say that the Wassonville limestone is represented by not more than ten to twelve feet of strata at Burlington. A thickening of the higher limestone beds, which carry a Chouteau fauna, and a thinning of the lower clastic ones is a persistent feature
of the Kinderhook as it is traced from southeastern Iowa northwestward to the northern part of the state.

The belt of Kinderhook rocks extending northwest from Washington county does not appear again at the surface, except for a small exposure in Iowa county, until Marshall and Tama counties are reached.

Poweshiek County.—With reference to the Kinderhook of Poweshiek county Stookey\(^4\) says:

"No rocks of this stage appear at the surface in Poweshiek county. All that area where they form the country rock is covered to a depth of from two hundred to four hundred feet with glacial deposits, through which the streams have nowhere cut. All that is positively known of rocks of this age in this county is obtained from the meager records of wells that have been sunk here and there into the rocks.

The Grinnell wells show a body of limestone and shale more than three hundred fifty feet in thickness next below the drift that is regarded as chiefly representing this stage. Wells in the vicinity of Brooklyn penetrate similar deposits. In the northwest quarter of section 12, Bear Creek township, the Talbott and Thompson well shows the following as reported by W. W. Shannon of Brooklyn:

<table>
<thead>
<tr>
<th></th>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pleistocene deposits</td>
<td>355</td>
</tr>
<tr>
<td>Shale</td>
<td>175</td>
</tr>
<tr>
<td>Limestone and shale (water)</td>
<td>76</td>
</tr>
</tbody>
</table>

In section 16, Bear Creek township, on the Newkirk farm the well is reported as follows:

<table>
<thead>
<tr>
<th></th>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow and blue clay</td>
<td>350</td>
</tr>
<tr>
<td>Soapstone</td>
<td>75</td>
</tr>
<tr>
<td>Limestone, honeycombed</td>
<td>125</td>
</tr>
</tbody>
</table>

The nearest surface exposure of Kinderhook rocks to the east is at Amana in Iowa county, near the Iowa river. Along the same river in Marshall and Tama counties to the north exposures are found that have been described in detail in the reports by Beyer and Savage. It is not possible to map accurately the limits of this terrane in Poweshiek county, but it is safe to say that the area to the north and east of the divide between the Iowa river basin and that of the North Skunk has as its country rock the Kinderhook deposits."

\(^4\) Iowa Geol. Survey, vol. XX, pp. 254, 255.
Iowa County.—The Kinderhook of Iowa county is described by Stookey as follows:

"At Amana in the bank of Price creek is an exposure of limestone, the only one within the limits of the county. The area of exposure is limited to one or two square rods. The rock is brown to buff in color, irregularly and thinly bedded, and cherty. Both the chert and limestone are fossiliferous. *Spirifer biplicatus* and two or three species of *Productus* are among the fossils. This is the only exposure of Kinderhook rocks in Iowa county. The discovery of rocks of this age so far to the eastward is a matter of surprise, and carries the margin of the Kinderhook terrane much farther to the northeastward than was believed to be the case. It is a general law of outcrop in Iowa that the margins of the terranes run in a northwest-southeast direction. It seems a proper inference that the rocks underlying the drift to the west and south belong to the Kinderhook stage.

Everywhere in the central and northwestern parts of the county the glacial deposits overlie a dark shale of considerable thickness, evidently the upper member of the Kinderhook stage. This deposit is referred to by well drillers as 'soapstone', and is dreaded by them as it is barren of water, and often, according to their reports, as much as three hundred feet in thickness. In the southwest part of Benton county the drill strikes the same shale, though its thickness is not so great in that county."

Jasper County.—Referring to the Kinderhook beds in this county, Williams says:

"In Jasper county the area underlain by the Kinderhook rocks cannot be definitely outlined as these materials are deeply buried beneath the glacial deposits. The area outlined as Kinderhook on the map is determined by projecting the line of the strike from outcrops in Marshall county."

KINDERHOOK OF CENTRAL IOWA

General statement.—The area underlain by the Kinderhook in this section of the state comprises roughly the eastern half of Marshall county, the whole of Tama county, with the exception of a small triangular area in the extreme northeast corner which is underlain by the Devonian and the southwestern two-
thirds of Grundy county, excepting a small area of Pennsylvanian in the western part.

The Kinderhook of this area shows a marked variation both lithologically and faunally from the series as it is developed elsewhere in the state, and this has rendered difficult the exact correlation of the beds. Owen, as a result of his study of the formations, referred the beds in question to the Subcarboniferous. Still later Whitney described the deposits in this part of the state and referred them to the Carboniferous upon the basis of their fauna. In his Geology of Iowa, Volume II, page 312; 1870, White describes the exposures near LeGrand and refers the beds to the Kinderhook formation. Wachsmuth and Springer later devoted some space to the strata in this area in connection with their description of the numerous species of crinoids and blastoids from LeGrand, Iowa.

More recent reports on the area are Beyer’s Geology of Marshall county and Savage’s Geology of Tama county.

The lower beds of the Kinderhook formation are not exposed in central Iowa, though we have some knowledge of their character as a result of Norton’s description of the cuttings of a deep well at Marshalltown which was published by Beyer.

The upper portion of the record is as follows:

<table>
<thead>
<tr>
<th></th>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone, light gray, in fine sand, with many angular fragments of limpid quartz at 68 feet</td>
<td>70</td>
</tr>
<tr>
<td>Limestone, light yellow, compact, earthy lustre, three samples</td>
<td>45</td>
</tr>
<tr>
<td>Limestone, brown, crystalline, cherty at 115 feet</td>
<td>30</td>
</tr>
<tr>
<td>Shale, soft, light green, calcareous</td>
<td>175</td>
</tr>
<tr>
<td>Limestone ↑ no samples (Devonian)</td>
<td>145</td>
</tr>
</tbody>
</table>

It will be observed that the beds above the limestone identified as Devonian are composed of 175 feet of shale, overlain by 145 feet of limestone. The shale beds were referred provisionally by Beyer to the basal Kinderhook and the writer has no reason to question this correlation. The overlying limestones belong to the formations designated as the LeGrand beds by Beyer because of their exposure in the quarries near the town.

44 Geological Survey Wisconsin, Iowa and Minnesota, pp. 98-102; 1852.
of this name. It is possible also that the Marshalltown shales of Beyer are represented in the upper part of the section.

**Marshall County.**—The Kinderhook area of Marshall county occupies approximately its eastern half, the western part being underlain by the "Coal Measures."

The most important exposures of the series in this county are in the quarries near LeGrand in the northern part of LeGrand township, though outcrops of lesser importance appear at Rockton in Marion township, and near Marshalltown in Linn township.

**LeGrand Beds.**—A number of years ago several quarries were worked a short distance north and northwest of LeGrand by the LeGrand Quarry Company. The sections are somewhat similar in all of these, but the succession is most complete and can be most satisfactorily studied in the two east quarries. Lower beds are exposed in these than in any other outcrops in the county.

The succession in the east quarry, north of Iowa river, in the extreme northwest corner of section 1 of LeGrand township, is as follows:

<table>
<thead>
<tr>
<th>Section in the east quarry.</th>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drift</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Limestone, soft, buff, magnesian, much weathered; somewhat nodular; no fossils noted</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>5. Limestone, brownish, subcrystalline to crinoidal; some layers in upper half slightly oolitic</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>4. Limestone, gray, magnesian, weathering buff; upper part thin bedded; lower half more massive when fresh but weathering into thin layers; with a rather persistent three inch chert band six and one-half feet below the top; interbedded with a few seams and layers of brownish, crinoidal limestone ranging from one inch to twelve inches in thickness; thin seams of oolitic limestone appear in the lower part of the upper four feet of the bed. With some thin fossiliferous seams</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>3. Limestone, ash-colored to buff, magnesian; subcrystalline; cleaving into thin layers; locally grading in part into brownish, crinoidal limestone; the main crinoid zone; surface of layers in places showing faint ripple marks; with stylolytic seams</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>2. Limestone, buff to yellowish, magnesian; with nodular lenses and discontinuous seams of dense gray chert weathering whitish; in upper part are two discontinuous seams of brownish crinoidal limestone which have a maximum thickness of one foot. The uppermost of these bears pebbles and angular fragments of limestone similar in character to that in the layer just below, but no certain evidence of a disconformity at this level is to be found</td>
<td>25</td>
<td>6</td>
</tr>
<tr>
<td>1. Limestone, light gray, oolitic, very fossiliferous. Exposed</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>
List of fossils from bed 1 of east quarry.

ANTHOZOA—
Zaphrentis sp.

BRACHIOPODA—
Chonetes logani N. and P.
Chonetes sp.
Schellwienella inflata (W. and W.)
Schellwienella planumbona Weller
Schellwienella sp.
Productus sp.
Productellla sp.
Rhipidomella sp.
Dielasma sp.
Camarotoechia sp.
Spirifer platynotus Weller
Spirifer cf. S. platynotus Weller
Spirifer sp.
Syringothis sp.
Cliothyridina tenuilineata (Rowley)
Composita opposita (W. and W.)

GASTROPODA—
Straparollus obtusus (Hall)

List of fossils from bed 2 of east quarry.

BRACHIOPODA—
Leptaena cf. L. analoga (Phillips)
Chonetes multicosta Weller
Productellla sp.
Productus ovatus Hall
Productus arcuatus Hall
Orthotetes ? sp.

,List of fossils from bed 3 of east quarry.

BRACHIOPODA—
Orthotetes ? sp.
Productellla ? sp.
Chonetes multicosta Weller
Leptaena analoga (Phillips)
Camarotoechia sp.
Spirifer legrandensis Weller
Spirifer calvini Weller
Spirifer sp.
Syringothis ? sp.
Reticularia cf. R. cooperensis (Swallow)

List of fossils from bed 5 of east quarry.

ANTHOZOA—
Zaphrentis sp.

BRACHIOPODA—
Productus sp.
Productus sp.
Orthotetes ? sp.
Rhipidomella sp.
Composita sp.
Spiriferina solidirostris White
Spirifer platynotus Weller
Spirifer sp.
Spirifer sp.

GASTROPODA—

BRYOZOA—
Fenestella sp.

CEPHALOPODA—
Orthoceras sp.

Lower layers were formerly exposed in this section. Thus Beyer\(^5\) reports a thickness of fifteen feet for the oolite bed (bed 1 of above section) and describes an underlying fine-grained bluish sandstone with an exposed thickness of ten feet.

Collections were made in the quarries south of the river from the same horizon as bed 5 of the preceding section. The forms have been identified as follows:

---
List of fossils from quarries south of Iowa River.

**ANTHOZOA**
- Zaphrentis sp.
- Delthyris clarksvillensis (Winchell)†
- Spirifer platynotus Weller

**CRINOIDEA**
- Platycrinus sp.
- Spirifer sp.

**BRACHIOPODA**
- Orthotetes sp.
- Productus sp.
- Rhipidomella cf. R. dubia (Hall)
- Composita sp.
- Spiriferina solidirostris White
- Spirifer sp.
- Spirifer sp.
- Spirifer sp.
- Spirifer sp.
- Spirifer sp.
- Eumetria sp.
- Spiriferina sp.
- Camarotoechia sp.
- Spirifer sp.
- Spirifer sp.
- Spirifer sp.
- Spirifer sp.

**GASTROPODA**
- Spiriferina sp.
- Strapatollus (two species)

At the point where the Minneapolis and St. Louis railway crosses Timber creek, three and three-fourths miles west of Le­Grand, beds corresponding in age to those at the top of the above described east quarry section are well exposed in an abandoned quarry. However, certain of the layers are much more oölitic here.

**Timber creek section.**

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>8. Drift ..................................................</td>
<td></td>
</tr>
<tr>
<td>7. Limestone, compact, gray, magnesian, weathering yellowish, thin bedded, nonfossiliferous; cherty in middle part</td>
<td>6</td>
</tr>
<tr>
<td>6. Limestone, brownish, medium-grained, slightly crinoidal, thin bedded; with a median layer of compact gray magnesian limestone three inches thick</td>
<td>2</td>
</tr>
<tr>
<td>5. Limestone, brownish, rather coarse-grained, crinoidal, fossiliferous; locally grading laterally into oolith</td>
<td>0</td>
</tr>
<tr>
<td>4. Limestone, gray, oölitic, weathering to thin layers</td>
<td>5</td>
</tr>
<tr>
<td>3. Limestone, medium-grained, bluish when fresh but weathering brownish</td>
<td>0</td>
</tr>
<tr>
<td>2. Limestone, bluish, compact, magnesian, weathering buff; with occasional seams of bluish unaltered limestone; rather massive</td>
<td>7</td>
</tr>
<tr>
<td>1. Limestone, bluish when fresh but weathering to a gray color, oölitic</td>
<td>4</td>
</tr>
</tbody>
</table>

Collections were made from beds 1, 5, and 6.

List of fossils from bed 1 of Timber creek section.

- Camarotoechia sp.
- Rhipidomella sp.
- Eumetria sp.
- Spirifer sp.
- Spirifer sp.
- Spirifer sp.
- Spirifer sp.
- Spirifer sp.

List of fossils from beds 5 and 6 of Timber creek section.

- Camarotoechia sp.
- Rhipidomella sp.
- Streptorhynchus sp.
- Spirifer sp.
- Cliothyridina sp.
- Composita sp.
- Dentalium grandaevum Win.

The latter beds are believed to represent a portion of bed 5 of the east quarry section.
Beyer\textsuperscript{51} reports that the topmost beds at LeGrand are again exposed in the old quarries at Rockton near the central part of Marion township. The section there is described by him as follows:

\textit{Section of LeGrand beds at Rockton (After Beyer).}

\begin{tabular}{ll}
\hline
6. Loess and soil & 1.3  \\
5. Till, yellow (Iowan) & 2.4  \\
4. Till, reddish brown, sometimes blue below (Kansan) & 0.3  \\
3. Limestone, brown, subcrystalline, rubbly & 3.5  \\
2. Limestone, oölite, heavy bedded & 5  \\
1. Limestone, gray-brown, beds thinner and slightly argillaceous & 2  \\
\hline
\end{tabular}

The strata of the above described sections have been designated the LeGrand beds by Beyer.\textsuperscript{52} The limestone above the basal oölite has yielded many species of Echinodermata in the LeGrand area. These have been described by Wachsmuth and Springer, by Miller and Gurley and by Worthen. The list follows:

\textit{List of echinoderms described from the LeGrand beds.}

\textbf{Cystoidea—}

Agelacrinus legrandensis Miller and Gurley

\textbf{Blastoidea—}

Orophocrinus conicus W. and Sp.  
Orophocrinus fusiformis W. and Sp.

\textbf{Crinoidea—}

Rhodocrinus kirbyi W. and Sp.
Rhodocrinus nanus M. and W.
Magistocrinus nobilis W. and Sp.
Batoicrinus macbridei W. and Sp.
Batoicrinus poculum Miller and Gurley
Aerocrinus immaturus W. and Sp.
Aerocrinus parvibasis W. and Sp.
Cactocrinus ornatissimus W. and Sp.
Cactocrinus nodobrachiatus W. and Sp.
Cactocrinus proboscidialis (Hall)
Cactocrinus arnoldi W. and Sp.
Platyicrinus symmetricus W. and Sp.
Platyicrinus agassizi W. and Sp.
Dichocrinus inornatus W. and Sp.
Dichocrinus delicatus W. and Sp.
Dichocrinus cinetus Miller and Gurley

\textbf{Echinoidae—}

Eutaxocrinus fletcheri Worthen
Taxocrinus intermedius W. and Sp.
Gozoicrinus sculptilis Miller and Gurley
Cyathocrinus marshallensis Worthen
Poteriocrinus genea Miller and Gurley
Poteriocrinus hammondii Miller and Gurley
Poteriocrinus legrandensis Miller and Gurley
Poteriocrinus maccabei Miller and Gurley
Poteriocrinus maccabei var. decipitus Miller and Gurley
Poteriocrinus scopae Miller and Gurley
Scaphiocrinus elegantulus W. and Sp.
Scaphiocrinus globosus W. and Sp.
Scaphiocrinus notatus Miller and Gurley
Graphiocrinus longicirrifer W. and Sp.

\textsuperscript{52} Idem, p. 221 ff.
Marshalltown Shales.—Beyer\textsuperscript{53} reports the occurrence of about fifteen feet of argillo-calcareous beds, named by him the Marshalltown shales, above the LeGrand beds in an exposure near the flouring mills at Marshalltown. He describes them as follows:

"They consist of ash blue to deep blue shales interbedded with argillaceous limestones. Chert nodules are present in the upper calcareous layers. After diligent search no trace of organic remains could be found."

At the time of the writer’s visit these beds were largely concealed. Only three feet of soft browish dolomitic limestone overlain by three feet of residual soil was exposed.

Tama County.—Savage\textsuperscript{54} describes the Kinderhook of Tama county as follows:

"As these rocks are exposed in Tama county they present three different facies. The lowest phase is a yellow, fine-grained sandstone which bears but few fossils and which is seen in but a few of the outcrops in the area. Overlying this sandstone is a stratum of light colored, oolitic limestone which occurs in thick, massive layers. This phase is very fossiliferous throughout and is quite uniformly developed and constantly present wherever in the county the rocks of this horizon are exposed. The upper phase is a brown magnesian limestone which in some layers changes to a yellowish brown, fine-grained sandstone. The layers of this upper phase carry quite a number of fossils, usually in the form of casts or moulds. Near the upper part the magnesian character gives way to thinly bedded limestone which, in the uppermost layers exposed, carries a large quantity of the comminuted fragments of the stems of crinoids."

These beds are the equivalent of the LeGrand beds of Marshall county. A typical exposure of them appears in an old quarry near the east side of section 17, Indian Village township. The following description is after Savage.

\textit{Section of Kinderhook beds, section 17, Indian Village township (After Savage).}

\begin{tabular}{ll}
\hline
\textbf{FEET} & \textbf{INCHES} \\
\hline
14. Yellowish brown loess & 2 \\
13. Brown clay containing numerous crystalline pebbles & 6 \\
12. Bed of grayish brown, impure limestone which breaks up & \\
\hline
\end{tabular}

\textsuperscript{54} Iowa Geol. Survey, vol. XIII, p. 213 ff.; 1903.
into narrow layers and irregular pieces when exposed to the action of the weather. Fossils rare ........................................... 3
11. Band composed largely of nodules of chert ............................................. 3
10. Impure limestone, brown in color, with few fossils; species of Chonetes, Rhyynchonella, and Spirifer were found.................................................. 1
9. Band of chert nodules .............................................................................. 3
8. Thick, heavy layer of brown magnesian limestone containing casts of Chonetes and Rhyynchonella .......................................................... 2 6
7. Layer composed mostly of nodules of chert .............................................. 4
6. Layer of brown magnesian limestone with casts of Zaphrentis, Chonetes and Rhyynchonella .......................................................... 10
5. Brown limestone with numerous chert nodules intermingled, containing casts of a species of Productus .................................................. 10
4. Massive layers of brown magnesian limestone in which there is a considerable quantity of sand ................................................................. 4 8
3. Heavy layer of oolite which weathers into small irregular blocks and bits, containing in abundance Orthocetes crenatus, a species of Rhyynchonella, Spirifer extenuatus, Spirifer biplicatus and Strasporollus latus ................................................... 5 8
2. Massive beds of oolite in two layers similar to number 3 above and carrying similar fossils, the lower part somewhat talus covered .......................................................... 8 6
1. Yellowish sandstone with some clay, containing few fossils; not well exposed. To level of road .................................................. 8

Numerous crinoids and fish remains are reported to have been found by the quarrymen in the seams separating the layers of magnesian limestone. At the time C. A. White visited this quarry in 1869 a greater thickness of yellow sandstone was exposed below the oolite bed. At present none of the sandstone outcrops.

In another quarry situated near the southwest corner of section 8 of the same township a greater thickness of strata is preserved above the oolite. Savage’s description of this exposure is given below:

**Exposure in section 8, Indian Village township (After Savage).**

<table>
<thead>
<tr>
<th>FEET INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>15. Gray, crinoidal limestone which weathers into thin pieces...</td>
</tr>
<tr>
<td>14. Crinoidal limestone, gray in color, with numerous fossil fragments</td>
</tr>
<tr>
<td>13. Fissile limestone in thin layers, few fossils</td>
</tr>
<tr>
<td>12. Brown magnesian limestone with layer of chert nodules two inches in thickness at top</td>
</tr>
<tr>
<td>11. Bed of rather soft, friable sandstone, much water seamed and containing numerous chert nodules; fossils few</td>
</tr>
<tr>
<td>10. Arenaceous-magnesian limestone, fine-grained and quite hard, brown in color, layers 8 to 12 inches in thickness, containing casts of a species of Chonetes, Productus, Rhyynchonella and Spirifer</td>
</tr>
<tr>
<td>9. Bed of incoherent brown fine-grained sand</td>
</tr>
<tr>
<td>8. Band made up of chert nodules</td>
</tr>
<tr>
<td>7. Impure arenaceous-magnesian limestone, few fossils</td>
</tr>
<tr>
<td>6. Bed composed largely of nodules of chert carrying a layer of sand 3 inches in thickness</td>
</tr>
</tbody>
</table>
5. Magnesian limestone containing some fine-grained yellow sand .......................... 1 8
4. Bed similar to number 5 above ................................................................. 1 6
3. Layer of massive oölite weathering into small bits and bearing numerous fossils, among which appear Orthotetes oreni-stria, Spirifer biplicatus, Spirifer cf. extenuatus, and Straparol-lus latus .......................................................... 7
2. Layer similar to number 3 above in lithological characters and fossils contents ........................................ 4 6
1. Layer of light gray oölite similar to numbers 2 and 3 above 3

At the “Devils Anvil”, near the southeast corner of section 7, Indian Village township, Savage measured the following section on the east side of the hill.

Section at “Devils Anvil” (After Savage).

9. Reddish brown clay, containing numerous small pebbles ......... 3
8. Bed of crinoidal limestone which weathers into thin layers 1 to 4 inches in thickness .......................................................... 7
7. Layer of crinoidal limestone bearing a band of chert nodules near the middle .................................................. 2
6. Bed made up of irregular layers of brown colored magnesian limestone 1 to 4 inches in thickness, and containing numerous nodules of chert 6 to 12 inches in long diameter and 3 to 6 inches in the short direction. Casts of fossils not rare; among them appear species of Rhynchoella, Zaphrentis, Chonetes and Productus .......................................................... 10
5. Impure magnesian limestone, brown in color, containing but few fossils, and showing numerous cavities which appear to have been formed by the dissolving action of percolating waters .......................................................... 4
4. Bed of fine-grained brown colored sandstone in layers 9 to 18 inches in thickness, a part of the layers containing some magnesian limestone, and all of them bearing numerous chert nodules .......................................................... 8
3. Band of chert nodules on the surface of which appear casts of fossils, among them Orthotetes and Productus .......... 1/3
2. Bed of impure sandstone which appears massive in places and at other places weathers into irregular layers 2 to 4 inches in thickness .......................................................... 4
1. Bed of light gray oölite containing numerous fossil fragments among which are Orthotetes oreni-stria, Spirifer biplicatus, and Straparollus latus .......................................................... 6

The oölite bed at the base of the exposure is the same as that of the two preceding sections. The overlying layers have a greater thickness than elsewhere in the county. At the north end of the exposure there are several small bryozoan reefs in the upper four feet of bed 8. These reefs consist of compact gray limestone filled with bryozoans and flanked on the sides by brownish crinoidal limestone.

The reef limestone is structureless but weathers to irregular flakes. The reefs are roughly lenticular in shape and range in size from masses two to three feet long and one foot high to
others as much as six feet long and two to three feet high. In some places there is a slight interfingering of the reef material with the limestone on the sides.

The fauna of the reef zone is as follows:

<table>
<thead>
<tr>
<th>Blastoida</th>
<th>Bryozoa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orophocrinus conicus W. and Sp.</td>
<td>Leiolema wachsmuthi Ulrich</td>
</tr>
<tr>
<td>Camarotoechia sp.</td>
<td>Rhombopora sp.</td>
</tr>
<tr>
<td>Leptaea analoga (Phillips)</td>
<td>Streblo trypa sp.</td>
</tr>
<tr>
<td>Spiroter calvini Weller</td>
<td>Taeniocysta cf. T. ramulosa var.</td>
</tr>
<tr>
<td>Spirifer legrandensis Weller?</td>
<td>Burlingtonensis Ulrich</td>
</tr>
<tr>
<td>Reticularia cooperensis (Swallow)</td>
<td>Undetermined (several species)</td>
</tr>
</tbody>
</table>

Numerous other exposures of the oolite bed and the overlying layers of magnesian limestone appear along the south bank of Iowa river northeast of LeGrand station and at several points along the bluffs of Sugar creek, a tributary from the north.

**Grundy County.**—Regarding the Kinderhook of Grundy county, Arey\(^5^5\) says:

"While there is little superficial demonstration of the fact within the limits of the county, there is no doubt that by far the greater portion of the county is underlain with rock of the Kinderhook series. As has been stated elsewhere already, the only actual rock exposures are on Wolf creek near Beaman and Conrad. At the latter place, an abandoned quarry gives the only opportunity for an examination of rock in place where a section can be secured."

A section of the quarry at Conrad given by Beyer\(^5^6\) in his Hardin county report is as follows:

<table>
<thead>
<tr>
<th>Section of Kinderhook beds at Conrad.</th>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Drift (modified Kansan probably)</td>
<td>5</td>
</tr>
<tr>
<td>4. Limestone, residual, consists chiefly of cherty concretions imbedded in a matrix of greenish clay streaked and mottled with ferruginous and marly material</td>
<td>3</td>
</tr>
<tr>
<td>3. Limestone, slightly oölitic, composed essentially of a shelly breccia almost identical with No. 1 in the Eagle City section</td>
<td>2</td>
</tr>
<tr>
<td>2. Limestone, hard, subcrystalline, containing numerous brachiopod casts</td>
<td></td>
</tr>
<tr>
<td>1. Limestone, typical oölite in heavy beds; a <strong>Straparollus</strong> and a turreted form of gastropod were noted, also numerous brachiopod casts</td>
<td>5</td>
</tr>
</tbody>
</table>

A number of species were collected from this exposure by the author, viz:

---

\(^5^5\) *Iowa Geol. Survey*, vol. XX, p. 77; 1910.

Zaphrentis sp.  
Schellwienella inflata (W. and W.)  
Camarotoechia sp.  
Rhipidomella thiemei (White)  
Dielasma ? sp.  
Spirifer platynotus Weller  
Conocardium sp.  
Straparollus obtusus (Hall)  
Lexonema ?

Correlation of Kinderhook of Central Iowa

The age of the shales overlying the Devonian limestone in central Iowa is not definitely known but they are believed to belong to the Kinderhook. If they are Kinderhook they undoubtedly belong to the middle or lower or both middle and lower portions of this formation as developed farther south as suggested by the fauna of the overlying LeGrand beds.

The strata now known as the LeGrand beds in Tama and Marshall counties were correlated with the Kinderhook beds at Burlington, Iowa, by White. However, he believed that the middle part of the Burlington Kinderhook was not represented in this part of the state. The oolite bed (bed 6) at Burlington was regarded as the equivalent of the oolite bed near or at the base of the exposures in Tama county, while the underlying sandstone in this county was believed to be the equivalent of the basal shales (bed 1) in the southern section. He noted the similarity of the crinoidal limestones in the upper part of the LeGrand beds to the Burlington limestone in the type section but correlated them nevertheless with the topmost bed of the Kinderhook (bed 7) at Burlington.

Wachsmuth and Springer in their report on the echinoderms from LeGrand agree that the lower part of the series belongs to the Kinderhook but remark that the occurrence of Cactocrinus proboscidialis, a characteristic lower Burlington fossil, in the topmost beds renders their correlation with that formation probable.

At the time Beyer examined the beds he submitted a series of fossils, some of which were taken from the uppermost strata, to Professor Calvin, who found them all to be distinctly Kinderhook in character.

Savage discusses the correlation of the beds in his report on the geology of Tama county. He points out the marked differ-
ence between the faunas of beds 6 and 7 at Burlington and those of the beds correlated with them by White but states that a larger proportion of the fossils of the oolite layers is similar to those found in bed 6 than to those of any other member of the Burlington section.

Numerous collections were made from the LeGrand beds during the writer's field studies. The identification of these has strengthened the correlation of the formation with the uppermost beds of the Kinderhook at Burlington, though the presence of a large number of species, many of which are undescribed, in the northern section, which are absent from the beds at Burlington makes exact correlation difficult. Most of the brachiopods specifically identified from the LeGrand beds, which are common to the two localities, are confined to beds 6 and 7 at Burlington though a few species range down into lower beds and an occasional one occurs in the Lower Burlington of the type section.

The crinoid element of the fauna is remarkable in that none of the species has been found in the Kinderhook elsewhere in Iowa. However, *Cactocrinus proboscidialis* occurs in the Lower Burlington limestone. Wachsmuth and Springer have described another species, *Dichocrinus delicatus*, as common to the Lower Burlington limestone at Burlington and the Kinderhook beds of Marshall county. The exact horizon of the latter is not given but probably it came from the upper part of the LeGrand.

The LeGrand beds are tentatively correlated with the Upper Kinderhook of southeastern Iowa. The uppermost layers at LeGrand very probably represent a transition into the Lower Burlington limestone.

The marked difference in thickness of the LeGrand beds as compared to the Upper Kinderhook at Burlington is worthy of note. If we assume their equivalence we must explain this great discrepancy in thickness as due either to more favorable conditions for the deposition of limestone in the northern area or to the presence of a disconformity between the Kinderhook and Lower Burlington formations in southeastern Iowa. Inasmuch as a study of this contact over wide areas in Des Moines and Louisa counties has revealed no evidence of a break in sedi-
mentation, the theory of original differences in deposition is favored. The continued thickening of the Kinderhook limestones northward from Marshall county as indicated by the exposures in Hardin county also lends weight to this view.

The age of the Marshalltown shales is not definitely known owing to the fact that their contact with the LeGrand beds is not exposed and that no diagnostic fossils have as yet been collected from these strata. If the uppermost limestones of the LeGrand beds are regarded as transition layers between the Kinderhook and Lower Burlington formations then these shales may represent the near shore facies of the basal beds of the Lower Burlington.

KINDERHOOK OF NORTH-CENTRAL IOWA

General statement.—The Kinderhook has a much more widespread distribution in north-central Iowa than in any other part of the state, but the beds are effectually concealed over a large part of the area by a thick mantle of glacial drift. Beginning at the southern part of this province we find that, to the best of our knowledge, the Kinderhook constitutes the surface rock in Hardin county in its extreme southeastern corner, in its central part and in the northern part. It underlies small areas in the north-central part of Hamilton county and in the southwestern part of Butler county; the whole of Franklin county, with the exception of a small area occupied by the Lime Creek beds in the northeast corner; all of Wright county except small areas in the southeastern and southwestern parts; the northern half of Humboldt county; a very narrow linear area in the extreme eastern part of Pocahontas county; all of Kossuth county except the area occupied by the Cretaceous in the western and northwestern parts; the whole of Hancock county barring a small area of Lime Creek in the northeast corner; and the greater part of Winnebago county.

Prior to the present investigation the Kinderhook beds of this part of the state were imperfectly understood and it must be admitted that the exact character and extent of several of the formations is even now not definitely known, owing to the fact that the drift mantle is thick and the outcrops are few and usually small.
The Kinderhook of northern Iowa is somewhat related to that of the central part of the state but possesses little in common with that of southeastern Iowa. The thickness is approximately the same (350 feet), but lithologically and faunally the series is very different. The group is divided into six distinct formations, upon the basis of individual exposures and the log of a well at Iowa Falls.

- The Alden limestone
- The Iowa Falls dolomite
- The Eagle City beds
- The Mayne Creek beds
- The Chapin beds
- The Sheffield beds

**The Sheffield beds.**—This basal member of the Kinderhook has a thickness of about sixty feet. The main mass of the formation, representing approximately the lower two-thirds, consists of bluish plastic shale intercalated with which are thin layers of fine-grained sandstone and brownish impure limestone, but the upper third is more calcareous. It is brownish and dolomitic and locally bears a lenticular bed of gray oolitic limestone which, at those localities where it is typically developed, is about six feet in thickness. Fossils are scarce and poorly preserved except in the upper part of the formation, where a few species with Chouteau affinities occur.

It is possible that the lower shaly portion of the Sheffield beds will ultimately be referred to a distinct formation of either Kinderhook or Upper Devonian age. The paucity of recognizable fossils in the lower shales and intercalated sandy layers renders their exact correlation impossible at present. However, the absence of any evidence of a disconformity between these strata and the fossiliferous layers above favors the reference of the entire succession to one formation.

The formation takes its name from the town of Sheffield in northern Franklin county in the vicinity of which it is well exposed.

**The Chapin beds.**—These have a thickness of perhaps twenty to thirty feet and consist of a massive limestone, the lower part of which is altered to dolomite at some localities, followed by fine-grained yellow sandstone. They are best exposed in a small quarry near the town of Chapin in Franklin county. At

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60* See footnote 76, page 116.
this locality the beds are very fossiliferous, having yielded about thirty-five species.

The Mayne Creek Beds.—This formation consists chiefly of soft brownish dolomitic limestone, which at several horizons is arenaceous. It has a thickness of about sixty-eight feet. Occasional chert nodules in the formation yield well preserved fossils. It is best exposed at a locality on Mayne creek in Geneva township of Franklin county.

The Eagle City Beds.—This division is made up of alternating beds of brownish dolomite and gray limestone. Some of the limestone beds are oolitic. It is best exposed in the banks of Iowa river at Eagle City in Hardin county and in the lower part of the gorge at Iowa Falls. The limestone horizons contain brachiopods of Upper Kinderhook age. Its thickness is seventy-five feet.

The Iowa Falls Dolomite.—This member is typically developed in the gorge of Iowa river at Iowa Falls in Hardin county where it has a maximum thickness of not less than fifty feet. Its contact with the underlying formation is very undulating, but this is believed to have resulted from uneven dolomitization rather than from disconformity. The formation is heavily bedded, except at the very top where the layers are comparatively thin. It is brownish in color, and contains but few fossils.

The Alden Limestone.—This is a light gray thin-bedded slightly oolitic limestone which is well exposed at the town of Alden in Hardin county. It has a maximum exposed thickness of about thirty-two feet. The contained fossils are very poorly preserved and the exact age of the formation is open to question. It is referred tentatively to the Kinderhook. The contact of this formation with the underlying dolomite has been observed at only one locality. This is at the old Ivanhoe quarries along Iowa river midway between Alden and Iowa Falls. It is there very irregular, and there is evidence of a distinct disconformity between the two formations.

Hardin County.—The greater part of the surface of Hardin county is underlain by Pennsylvanian strata, but the erosion of
these overlying deposits has brought the Kinderhook to the surface over small areas in the southeastern and central parts of the county, and over a broad area in its northern part.

The most important exposures, by far, are along Iowa river between Alden and Eagle City. Indeed, the exposures between these two points furnish the most complete and representative section of the Kinderhook in the northern part of the state.

So far as the writer is aware no strata older than the Eagle City formation are exposed within the limits of Hardin county. Our knowledge of the character and thickness of the lower beds of the Kinderhook in this region has been considerably enhanced by the record of the city well at Iowa Falls. This well is located near the head of Rock Run gorge. The log of the strata passed through as given by Beyer is as follows:

<table>
<thead>
<tr>
<th>Bed</th>
<th>Thickness</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Drift and weathered material</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>Limestone, light gray, compact</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>Limestone, brown, dolomitic, sub crystalline</td>
<td>29</td>
</tr>
<tr>
<td>4</td>
<td>Limestone, gray-blue, magnesium, cleavage fragments of calcite not uncommon; compact; grading downward into a light colored and less magnesium limestone</td>
<td>16</td>
</tr>
<tr>
<td>5</td>
<td>Limestone, gray, semi-oölitic in texture</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>Limestone, gray-brown, dolomitic and porous; drillings of a gray compact limestone abundant</td>
<td>11</td>
</tr>
<tr>
<td>7</td>
<td>Limestone, brown, dolomitic, with considerable light-colored chert</td>
<td>37</td>
</tr>
<tr>
<td>8</td>
<td>Dolomite, gray-brown</td>
<td>7</td>
</tr>
<tr>
<td>9</td>
<td>Dolomite, yellowish brown, sugary</td>
<td>7</td>
</tr>
<tr>
<td>10</td>
<td>Sandstone, gray-blue, shaly</td>
<td>7</td>
</tr>
<tr>
<td>11</td>
<td>Sandstone, white, friable and very fine-grained</td>
<td>10</td>
</tr>
<tr>
<td>12</td>
<td>Sandstone, gray, fine-grained and compact; slightly argillaceous and noncalcareous</td>
<td>14</td>
</tr>
<tr>
<td>13</td>
<td>Limestone, blue-gray to yellowish gray, compact; slightly argillaceous and exhibits an almost earthy fracture</td>
<td>6</td>
</tr>
<tr>
<td>14</td>
<td>Shale, plastic, even-textured, light gray-blue, and slightly calcareous above</td>
<td>62</td>
</tr>
<tr>
<td>15</td>
<td>Limestone, hard, compact (penetrated)</td>
<td>2</td>
</tr>
</tbody>
</table>

Bed 15 of this section is believed to represent Devonian limestone; bed 14, the Sheffield shale; beds 13 and 12, the Chapin formation; beds 11 to 7, the Mayne Creek formation; and beds 6 to 2, the Eagle City formation.

The Eagle City beds.—The outcrops of this formation in Hardin country are confined to the valley of Iowa river, the

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most complete exposure of the formation being at Eagle City in
the extreme southwestern corner of Aetna township. At the
east end of the bridge over Iowa river at this place, the follow­
ing section is shown in an abandoned quarry:

<table>
<thead>
<tr>
<th>Section of Eagle City formation at Eagle City.</th>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Drift ......................................................</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>4. Dolomite, thin-bedded at top but more massive below, brown­</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>ish, soft ....................................................</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Limestone, gray, oölitic, compact ...............</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>2. Dolomite, yellow to brownish, thin-bedded, soft ..........</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>1. Limestone, gray, oölitic ................................</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

All of these beds are distinctly lower than any observed at
Iowa Falls. The fossils collected from bed 1 are as follows:

List of fossils from bed 1 of the bridge section at Eagle City.

<table>
<thead>
<tr>
<th>BRACHIOPODA—</th>
<th>GASTROPODA—</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leptaena analoga (Phillips)</td>
<td>Eumactria cf. E. verneuliana (Hall)</td>
</tr>
<tr>
<td>Orthotetes (?) several species</td>
<td>Bryozoa—</td>
</tr>
<tr>
<td>Schellwienella inflata (W. and W.)</td>
<td>Chaetetes † sp.</td>
</tr>
<tr>
<td>Productus sp.</td>
<td>Rhombopora † sp.</td>
</tr>
<tr>
<td>Diecasma † sp.</td>
<td>Fenestella sp.</td>
</tr>
<tr>
<td>Spirifer cf. S. legrandensis Weller</td>
<td>GASTROPODA—</td>
</tr>
<tr>
<td>Reticularia cooperensis (Swallow)</td>
<td>Orthonychia sp.</td>
</tr>
<tr>
<td>Straparollus † sp.</td>
<td></td>
</tr>
</tbody>
</table>

The following species were collected from bed 3:

List of fossils from bed 3 of the bridge section at Eagle City.

| Productus ovatus Hall | Camarotoechia chouteauensis |
| Orthotetes † sp. | Weller |
| Spirifer cf. S. legrandensis Weller |

Bed 4 yielded the fossils listed below:

List of fossils from bed 4 of the bridge section at Eagle City.

| Leptaena analoga (Phillips) | Spirifer cf. S. legrandensis Weller |
| Schellwienella (several species) | Spirifer sp. |
| Camarotoechia sp. | Reticularia cooperensis (Swallow) |
| Schizophoria sp. | Bryozoan sp. |
| Spiriferina subicrassa White † |

A few rods upstream from the above described quarry, lower
beds are exposed in the river bank, viz:

| Limestone (No. 1 of above section) | 2 ½ |
| Dolomite, soft, yellowish | 12 |
| Limestone, dense, yellowish and irregularly bedded. Exposed above water | 1 |
Regarding the Kinderhook exposures along Iowa river below Eagle City, Beyer\textsuperscript{62} has this to say:

"Beyond Eagle City the beds disappear rapidly, and the surface outcrops of the Kinderhook beds are almost entirely obscured by glacial debris and coal measure talus. At Hardin City, Steamboat Rock, and at one or two points between, number 4 of the Eagle City section is visible and rises some six or eight feet above the water level. In all cases it is greatly weathered and shattered, making its identity difficult to establish. Between Steamboat Rock and Eldora, the Lower Carboniferous passes entirely below the stream channel, but rises again immediately south of the wagon road bridge at Eldora. Going down stream from the Eldora bridge, a weathered dolomite appears in the stream bed and also in the right bank about sixty rods below the road crossing. The ledges rise eight feet above the water and appear to be identical, both lithologically and faunally, with the upper member at Iowa Falls.\textsuperscript{63} \textit{Straparollus} casts and a cystophyllloid coral were found. These beds appear more or less interruptedly from this point to Union, forming low benches on one or both sides of the river. At Xenia and again between Gifford and Union, the white limestone member is visible. The maximum exposure is south of Gifford, near a small stream which enters the Iowa from the west. The beds exposed to view are:

\begin{center}
\textit{Section of Kinderhook beds south of Gifford (After Beyer).}
\end{center}

\begin{tabular}{ll}
4. Drift and wash & 0-8 \\
3. Limestone, light gray; white when weathered & 0-3 \\
2. Dolomite, yellowish brown, much shattered and unevenly bedded & 6-8 \\
1. Dolomite, red-brown, heavy, but unevenly bedded, exposed & 4-6 \\
\end{tabular}

Numbers 1 and 2 are, in a sense, complementary. Where one thins the other thickens, and the two aggregate twelve feet exposed. Not the slightest trace of organic remains could be found. Southward and southeastward the beds are cut out within one hundred yards by the coal measure shales, only to come into view again a quarter of a mile down the branch on the terrace of the Iowa."

Other exposures of brownish dolomitic limestone of Eagle City age appear at intervals in the banks of Iowa river above Eagle City all the way to Iowa Falls.

Near the east line of the northwest quarter of section 20,


\textsuperscript{63} In the writer's opinion these beds are probably older than the upper beds at Iowa Falls. They may be correlated tentatively with the Eagle City.
Hardin township, at the mouth of a small creek in the north bank and near the point where the river turns south, twenty-two feet of thinly and irregularly bedded yellowish dolomite outcrops. The rock evidently was once an oolitic limestone, in part at least, as indicated by the fact that small remnants of imperfectly dolomitized gray oolite were observed in the dolomite. No fossils were noted here.

One-half mile above this point in the southeast one-fourth of the southeast quarter of section 18, Hardin township, another good exposure of these beds is afforded in the quarry of the Ellsworth Stone Company.

**Section in the quarry of the Ellsworth Stone Company.**

| FEET |
|-----------------|-----------------|
| 6. Drift | 2—3 |
| **IOWA FALLS DOLOMITE.** | |
| 5. Dolomite, soft, brownish, thin-bedded above but massive below. Resting on the irregular surface of the bed below. A two foot zone five feet below the top is rich in simple corals, and bears numerous specimens of *Straparollus obtusus*. The dolomite is granular and slightly vesicular. Probably formed by the alteration of a medium-grained limestone. Thin slaty seams occur in the basal part | 20 |
| **EAGLE CITY BEDS.** | |
| 4. Limestone, gray, oolitic, more compact and in thicker layers than in bluff at Iowa Falls. The upper part is locally dolomitized and discolored yellowish | 2—5 |
| 3. Limestone, light gray, lithographic, the upper three and one-half feet interbedded with layers and discontinuous seams of coarser dark gray dolomite | 12 |
| 2. Dolomite, fine-grained, soft, gray weathering yellowish, rather thinly bedded. With many small pockets and seams of calcite. In some places parts of the bed are filled with masses and streaks of pyrite, which in some instances is associated with the calcite | 6 |
| 1. Dolomite, dark gray when fresh, dense, massive. Exposed | 7 |

Beds 1 to 4 of this section are referred to the Eagle City, but probably they represent a higher horizon of that formation than is represented at the type locality described above. Bed 5, on the other hand, belongs to the lower part of the Iowa Falls dolomite. The contact of this formation with the limestone below is undulating in such a way as to suggest a disconformity at this level, but the phenomenon probably is due to uneven dolomitization, in which case it should be classed as a pseudo-disconformity.

Another excellent opportunity for studying the Kinderhook is furnished in the gorge of Iowa river below the dam at Iowa
Falls, two miles above the Ellsworth quarry. The river has cut through an anticlinal flexure here, exposing in the west bank about seventy feet of strata, the lower twenty-five feet of which belongs to the Eagle City. The section is as follows:

**Section in gorge at Iowa Falls**

**IOWA FALLS DOLOMITE.**

<table>
<thead>
<tr>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Dolomite, yellowish to brownish, massive below but thin-bedded at the top; slightly vesicular. The lower beds tending to recede in the cliff. Contact with bed below very undulating, as a result of uneven dolomitization.</td>
</tr>
</tbody>
</table>

**EAGLE CITY FORMATION.**

<table>
<thead>
<tr>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Limestone, gray, lithographic, contact with bed above wavy owing to dolomitization along an irregular line; bearing Camarotoechia subglobosa.</td>
</tr>
<tr>
<td>4. Limestone, dark gray, dolomitic, in a single layer with regular contacts.</td>
</tr>
<tr>
<td>3. Limestone, gray, compact, faintly oolitic below but distinctly so above; flaking off parallel to surface of bluff. This and bed above receding.</td>
</tr>
<tr>
<td>2. Limestone, gray, lithographic, in thin layers but in places assuming a massive appearance. No fossils noted. With layers of darker gray dolomitic limestone interbedded at the top. Weathering whitish.</td>
</tr>
<tr>
<td>1. Limestone, dark gray, dolomitic, dense, brittle; in layers of medium thickness. Exposed.</td>
</tr>
</tbody>
</table>

At the dam, bed 5 is seven feet thick and is not dolomitized. Further down stream it thins abruptly and is dolomitized locally.

Bed 3 of the above section contains occasional fossils, several of which are undescribed. A list of those collected is given below:

**List of fossils from Eagle City formation at Iowa Falls.**

- Syringopora ? sp.
- Camarotoechia subglobosa Weller ?
- Schizodus (several species)
- Camarotoechia sp.
- Eumetria sp.
- Straparollus obtusus (Hall)
- Pelecypods (several undetermined species)
- Conocardium sp.
- Conocardium sp.

**THE IOWA FALLS DOLOMITE.**—This division of the Kinderhook attains its typical development only in the vicinity of Iowa Falls where it caps the section in the west bank of the gorge of Iowa river at the point where it cuts through the anticline. The character of the formation in this exposure has been considered in the above-described section. In general it consists of yellowish to brownish slightly vesicular beds of dolomite, massive in the lower part, but thin-bedded at the top. The lower beds at many places recede slightly in the cliff.
At a point in the west bank about one hundred yards below the axis of the anticline, this dolomite may be seen in irregular contact with the Eagle City formation. It has here a thickness of forty-four feet, but higher beds undoubtedly have been eroded. The upper six feet is thin-beded.

A good exposure of this member also appears a short distance upstream in the cliff at the west end of the Washington street bridge. It has an exposed thickness of forty-four feet six inches at this point, the contact with the lower beds being situated two or three feet below the water level. The upper five feet is thin-beded.

In Wild Cat Glen, on the west side of the river, not far from the last mentioned exposure, the thin-beded member at the top of the Iowa Falls is eight feet six inches thick, and bears a number of fossils in the form of molds. These are listed below:

<table>
<thead>
<tr>
<th>ANTHOZOA—</th>
<th>BRACHIOPODA—</th>
<th>GASTROPODA—</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zaphrentis sp.</td>
<td>Orthotetes f sp.</td>
<td>Orthopectes sp.</td>
</tr>
<tr>
<td>Spirifer sp.</td>
<td>Dicelasma sp.</td>
<td>Camarotoechia cf.</td>
</tr>
<tr>
<td>Ambocoelia sp.</td>
<td>Camarotoechia f sp.</td>
<td>Camarotoechia sp.</td>
</tr>
<tr>
<td></td>
<td>Spiriferina solidirostris White</td>
<td>Holopectes subconica Win.</td>
</tr>
</tbody>
</table>

Approximately one and one-half miles west of the gorge sections, the Iowa Falls dolomite is again well exposed in a high cliff on the south side of Iowa river in the northwest quarter of section 14, Hardin township. The following succession was measured:

Section of Iowa Falls dolomite in Hardin township.  

<table>
<thead>
<tr>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Drift .................................................</td>
</tr>
<tr>
<td>3. Dolomite, thin-beded, brownish .................................. 9</td>
</tr>
<tr>
<td>2. Dolomite, brownish, massive, soft, showing concretionary structure ........................................ 26</td>
</tr>
<tr>
<td>1. Dolomite, soft, brownish, thin-beded with thin discontinuous bands of chert. Exposed ........................................... 10</td>
</tr>
</tbody>
</table>

Three hundred yards upstream, in the opposite bank, Des Moines shales and sandstones replace these beds of dolomite. They appear to rest on the irregular surface of bed 1 of the preceding section and to extend down almost to the water level in places. They doubtless fill an old channel cut into the dolomite in pre-Pennsylvanian time.
One-half mile southwest of this point a small exposure of the Iowa Falls dolomite appears at the east end of the railroad bridge, a short distance south of the center of section 15 of Hardin township. It consists of fifteen feet of brownish dolomite in the form of thin even layers in the basal part, massive beds in the middle, and thin, nodular layers at the top. No fossils were found.

Sixty rods above the railroad bridge in the southwest quarter of section 15, the Iowa Falls dolomite may be seen in disconformable relation with the Alden limestone. The contact line is very uneven and undulating. At the south end of the exposure it is at places below the level of the water of the river and at other places is above that level. Toward the north end it rises. The maximum exposed thickness of the dolomite is six feet. It is thin-bedded and nodular in places, and tends to recede in the low bluff. The overlying gray slightly oölitic Alden limestone has a maximum exposed thickness of eighteen feet. Lenticular masses of shale, some of which are of large size, appear here and there along the contact.

Another excellent contact section of the Iowa Falls dolomite with the Alden limestone is shown a short distance upstream in the old Ivanhoe quarries. This exposure is described under the discussion of the Alden limestone.

The Alden Limestone.—This member of the Kinderhook is typically exposed in the south bank of Iowa river just below the wagon bridge at the town of Alden in Alden township. It consists of light gray, slightly oölitic, subcrystalline limestone in thin layers which locally are cross-bedded. Many of the layers are less than one inch in thickness, and layers exceeding three inches are rare. The total thickness of beds exposed in this section is about seventeen feet. Careful search was made for fossils, but no identifiable specimens were found.

A second exposure of the Alden limestone of considerable interest is found in the quarry of the Hale Roberts Stone Company, just northeast of Alden between the wagon road and the Chicago and North Western railway in the southeast quarter of section 18, Alden township. This shows lower layers than are exposed in the river bank at Alden. About thirty-two feet of limestone is exposed, of which the upper half is like that ex-
posed along the river. It is light gray in color, thin-bedded and slightly oölitic. The lower part is a darker gray when fresh and some is slightly bluish. It is in thicker layers and is less oölitic than that above and evidence of cross-bedding is shown at several horizons. Some of the layers near the bottom are as much as a foot in thickness. Occasional fissures, widened by solution, have been filled with clay. One set of these trends nearly north-south and another set nearly east-west. The drift at the top is thin, usually being only a foot or two in thickness.

At the old Ivanhoe quarries in the southeast quarter of section 16 of Alden township, this formation is shown in contact with the Iowa Falls dolomite. The section at that place is as follows:

Section in Ivanhoe quarries.

1. Dolomite, brownish, cavernous and vesicular; in places concretionary; contact with bed above very irregular and undulating, locally marked by lenses of fine sandstone and shale one foot or more in thickness. Some of these bear small fragments of carbonized wood. Exposed .............................................................. 6

2. Limestone, light gray, faintly oölitic, some layers slightly crinoidal, especially in the lower part. The upper half weathers to thin layers, but the lower part is more massive and tends to show a darker tint when fresh. Locally slightly mashed and showing slickensided structure along small irregular fractures ...................................................... 18

Bed 1 of this section represents the Iowa Falls dolomite. Bed 2 is the Alden limestone which was formerly quarried. No fossils sufficiently well preserved to be identified were found.

In the northwest quarter of section 2, Tipton township, a limestone similar to the Alden in lithologic character outcrops on the west bank of the South Fork of Iowa river just below the wagon bridge. Four feet of slightly mashed gray medium-grained limestone, some layers of which are finely crinoidal, is exposed here. No fossils were found.

Franklin County.—With the exception of a small area in its extreme northeastern part where the Upper Devonian forms the surface rock, the Kinderhook underlies the whole of Franklin county. In the western part of the county it is buried by Wisconsin drift, but to the east, beyond the border of this drift sheet, it is exposed at many localities in the banks of the larger streams.
The Kinderhook of this area comprises the three basal formations: the Sheffield beds, the Chapin beds and the Mayne Creek formation.

The Sheffield beds.—The lower part of this member is well exposed in a clay pit at the brick plant one-half mile south of the town of Sheffield, near the center of section 9, Ross township. The section at this point as described by Williams is as follows:

| Shale, buff to yellow, slightly magnesite, containing irregular concretions of lime carbonate and thin bands of limestone at top; nonfossiliferous | 3 |
|---------------------------------------------------------------|
| Shale, yellow, pink to red, plastic | 6 |
| Shale, nonfossiliferous, plastic, blue, with some carbonaceous matter and occasional thin seams of seilite | 6 |

A well drilled at the plant encountered firm limestone (Upper Devonian?) about twenty feet below the bottom of the pit. Williams refers the shale in this exposure to the Hackberry shale member of the Upper Devonian, and it is so represented on his geological map of Franklin county. But its correlation with similar bodies of shale exposed in the eastern part of the county and referred to the Kinderhook appears to the writer to be the more reasonable one. Unfortunately the shaly character of the basal Kinderhook in this region has caused its contact relations with the Upper Devonian to be obscured.

The greatest exposed thickness of the Sheffield shale observed in Franklin county is shown about three-fourths mile southeast of the clay pit mentioned above, in the south bank of Bailey creek just east of the road along the west side of section 10, Ross township, and in a road cut above.

Forty-four feet of argillaceous shale, gray when dry but bluish when wet and containing thin bands and flakes of brownish dolomitic limestone in the lower part, is present in the bluff. In the road cut near the top of the bluff this is overlain conformably by twelve feet of soft brownish dolomitic shale which bears the following fossils:

<table>
<thead>
<tr>
<th>Orthotetes † sp.</th>
<th>Spirifer sp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camaroteochia chouteausensis Weller</td>
<td>Cleothyrindina prouti (Swallow)</td>
</tr>
</tbody>
</table>

---

This assemblage of fossils is characteristic of the topmost member of the Sheffield shale wherever it outcrops in northern Iowa.

The work of Prof. A. O. Thomas has shown the presence of an outlier of the Sheffield formation in sections 7, 8, 17, and 18 of West Fork township which had been mapped previously by Williams as Upper Devonian. The total thickness of the formation in this region, according to Thomas, who has studied certain well records, is sixty feet. Along the north-south road near the northeast corner of section 17, West Fork township, a good opportunity is afforded for studying these beds.

**Section of Sheffield beds, section 17, West Fork township.**

<table>
<thead>
<tr>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Drift ...............</td>
</tr>
<tr>
<td>2. Shale, brownish and dolomitic in upper part, but gray and slightly gritty below. A thin seam of chert eleven feet below the top bears <em>Clithyridina prouti</em>, <em>Productus blairi</em>, <em>Camarotoechia chouteauensis</em>, and a <em>Spirifer</em> resembling <em>Spirifer whitneyi</em></td>
</tr>
<tr>
<td>1. Shale, bluish, argillaceous, no fossils noted</td>
</tr>
</tbody>
</table>

The fossils of bed 2 are characteristic of the upper fossiliferous part of the Sheffield.

In an abandoned quarry in the southeast quarter of section 7, higher beds of the Sheffield are exposed. The section here is as follows:

**Section of Sheffield beds, section 7, West Fork township.**

<table>
<thead>
<tr>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Drift ...............</td>
</tr>
<tr>
<td>2. Shale, dolomitic, yellowish, thin-bedded; bearing thin flakes of chert</td>
</tr>
<tr>
<td>1. Limestone, gray, in thin layers filled with fragments of brachiopods, crinoids, and other fossils. Locally cross-bedded on a small scale. Many fragments of fossils are silicified and stand in relief on weathered surfaces. Exposed</td>
</tr>
</tbody>
</table>

The following fossils were collected from beds 1 and 2:

- *Productus blairi* Miller
- *Camarotoechia* sp.
- *Spirifer* sp. (similar to *S. whitneyi*)
- *Clithyridina prouti* (Swallow)
- *Eumetria* ? sp.

About twenty rods south of this quarry along the east-west road on the north line of the northeast quarter of section 18, a small outcrop shows several feet of bluish argillaceous shale overlain by one foot of thin-bedded limestone rich in fragments of crinoids. This limestone bed is at a level twenty-seven feet
below the quarry described above. The following fossils were collected from it:

Productus sp.
Camarotoechia sp.

The upper fossiliferous beds of the Sheffield, including the oölitic limestone member, are again well exposed in an abandoned quarry located near the middle of the north line of section 14 of Geneva township. The section is described below.

Section of Sheffield beds, section 14, Geneva township.

<table>
<thead>
<tr>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Soil</td>
<td>1--2</td>
</tr>
<tr>
<td>3. Dolomite, yellowish, soft, thin-bedded, much weathered, earthy, stratification very imperfect</td>
<td>5</td>
</tr>
<tr>
<td>2. Dolomite, yellowish brown, massive when fresh but weathering to thin layers. Lower part filled with silicified fossils</td>
<td>2½</td>
</tr>
<tr>
<td>1. Limestone, gray to pinkish, oölitic, massive when fresh; cut by very even vertical joints with remarkably flat surfaces.</td>
<td>6½</td>
</tr>
</tbody>
</table>

On the opposite side of a small valley at this place there is a change in profile at a level about one foot below the bottom of the quarry. A shale bed is believed to underlie the oölite.

List of fossils from above exposure.

Schellwienella sp.         Spirifer sp.
Productus blairi Miller    Spirifer sp. (resembles S. whitneyi)
Productus arcuatus Hall    Cloothyridina prouti (Swallow)
Productus sp.              Fish spine.
Camarotoechia sp.          

One mile slightly north of west of the preceding exposure, in the southwest one-fourth of the southeast quarter of section 10, Geneva township, strata of a similar horizon appear in an abandoned quarry situated just east of the bridge over Mayne creek. The succession of beds here is indicated below:

Section of Sheffield beds in section 10, Geneva township.

<table>
<thead>
<tr>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Soil</td>
<td>1</td>
</tr>
<tr>
<td>2. Shale, brownish, dolomitic, with a band of chert nodules near the middle</td>
<td>11</td>
</tr>
<tr>
<td>1. Dolomite, yellowish brown, in one massive ledge. Soft and vesicular. Exposed</td>
<td>10</td>
</tr>
</tbody>
</table>

Silicified fossils are common. The beds are rent by rather widely spaced vertical joints. Fragments of oölitic limestone were noted in the rubble and doubtless came from a lower bed.
now concealed. A line of springs appears about ten feet below the base of bed 1.

List of fossils from above exposure.

- Chonetes sp.
- Streptorhynchus sp.
- Productus blairi Miller
- Camarotoechia chouteaunsis Weller
- Clothyridina prouti (Swallow)
- Spirifer sp. (resembles S. whitneyi)
- Fish plate.

The Chapin beds.—Following the Sheffield shale conformably appear the Chapin beds. These differ in character from place to place, but consist typically of shale at the base followed above by cross-bedded crinoidal and slightly oolithic limestone which is in turn overlain by brownish soft fine-grained sandstone. The two uppermost beds, however, in places pass laterally into soft brownish dolomitic limestone. All the beds are highly fossiliferous. The thickness of the Chapin is twenty to thirty feet.

The most representative exposure of these beds in Franklin county is at the type section, which is shown in an abandoned quarry one mile west of the town of Chapin in the southwest corner of the southwest quarter of section 29, Ross township. The succession of beds there is as follows:

Section of Chapin beds near Chapin.

<table>
<thead>
<tr>
<th>Bed</th>
<th>Description</th>
<th>Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Limestone, gray, subcrystalline, faintly oolitic, with interbedded layers of crinoidal limestone which weather brownish. In rather heavy, even layers when fresh but weathering into thinner layers. Exposed</td>
<td>6½</td>
</tr>
<tr>
<td>2.</td>
<td>Sandstone, very fine-grained, soft, gray when fresh but weathering yellowish; lower two feet massive, but upper four and one-half feet thin-bedded; filled with casts of fossils</td>
<td>6½</td>
</tr>
<tr>
<td>3.</td>
<td>Drift</td>
<td>2—3</td>
</tr>
</tbody>
</table>

In a smaller opening only a few rods away in the northeast corner of section 31, number 1 has an exposed thickness of seven feet.

Beds 1 and 2 are highly fossiliferous. The species collected are listed below.

List of fossils from bed 1 of the Chapin beds, near the southwest corner of section 29, Ross township.

**ANTHOZOA**
- Zaphrentis calceola (W. and W.)
- Zaphrentis sp.
- Amplexus sp.
- Syringopora sp.
- Leptopora typa Win.

**BLASTOIDEA**
- Schizoblastus roemeri (Shum.)
THE MAYNE CREEK BEDS.—This formation is typically developed along Mayne creek in Franklin county, hence its name. The type section is located in the north bluff of this creek in the northeast quarter of section 21, Reeve township. A revised description of the succession at this place is given below:

<table>
<thead>
<tr>
<th>Type section of the Mayne Creek formation.</th>
<th>1ST</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Drift</td>
<td>12</td>
</tr>
<tr>
<td>5. Dolomite, yellowish brown, soft, thin-bedded, with occasional thin lenses of chert</td>
<td>10</td>
</tr>
<tr>
<td>4. Dolomite, yellowish brown, soft, in rather heavy, irregular layers, becoming soft, pulverulent and saccharoidal where weathered; with thin discontinuous seams and nodules of fossiliferous chert which weathers chalky</td>
<td>16</td>
</tr>
<tr>
<td>3. Dolomite, yellowish, compact and tough; more resistant than the bed below</td>
<td>1</td>
</tr>
<tr>
<td>2. Dolomite, very soft, much weathered, brownish, flaking off obliquely; with occasional thin discontinuous seams of chert some of which are fossiliferous</td>
<td>10</td>
</tr>
<tr>
<td>1. Dolomite, compact, brownish, tough, with occasional small nodules of chert. A few imperfect casts and impressions of fossils were noted</td>
<td>4</td>
</tr>
</tbody>
</table>

A number of species of brachiopods, pelecypods and gastropods, several of which are undescribed, were collected from the chert seams of bed 2. These have been identified as follows:
List of fossils from the Mayne Creek formation in the northeast quarter of section 21, Reeve township.

**ANTHozoA**
- Zaphrentis ? sp.

**BryozoA**
- Cystodictya sp.

**BrachioPodA**
- Chonetes multicosta Win.
- Orthotetes ? sp.
- Camarotoechia sp.
- Spiriferina solidirostris White
- Spirifer legrandensis Weller ?

**PelecyPoda**
- Leda saecata Win.
- Myalina sp.

**GastroPodA**
- Bellerophon sp.
- Bucanopsis sp.
- Meekopsira ? sp.
- Orthonychia sp.

**CrustaceA**
- Phillipsia ? sp.

Two miles northeast of the above described bluff section, near the northwest corner of the northeast quarter of section 23, Reeve township, a part of the Mayne Creek beds is exposed in an abandoned quarry on the property of Mr. Bert Jones. At the present time ten feet of thin-bedded, shelly brownish dolomitic limestone is shown in the quarry face. The upper half contains thin discontinuous bands of chert, and becomes cavernous where long exposed to weathering. Several specimens of a *Productus* and an *Orthotetes* were collected from the chert. A few small cavities lined with calcite were noted at one point in the middle part of the ledge.

East of the road, near the middle of the west side of section 18, Geneva township, there is a conspicuous outlier of Mayne Creek limestone. About twelve feet of brownish, dolomitic limestone is exposed at the top of the hill. The lower half is massive, cavernous and cherty, and weathers to a brownish pulverulent mass. The upper half is thin-bedded, and contains fossiliferous chert seams. The fossils collected from these seams are:

- Leptaea analoga (Phillips)
- Schizophoria chouteacensis Weller ?
- Reticularia cooperensis (Swallow)
- Composita ? sp.

The Mayne Creek formation appears again in a small abandoned quarry in the north bank of a small creek about fifty yards west of the road in the southeast one-fourth of the southeast quarter of section 9, Reeve township. Ten feet of soft, brownish, thin-bedded dolomite, with occasional bands and lenses of light gray chert are shown. Numerous poorly preserved fossils occur in the chert.

**Butler County.**—The Kinderhook beds constitute the highest
consolidated rock over a small area in the southwestern part of Butler county. The distribution of the formation as indicated in Arey's geological map of the county is only approximately correct. For example, the narrow area of Kinderhook represented in the northwestern part of Madison township and extending into the southwestern part of Pittsford township probably does not exist. Apparently the fact that Williams erroneously referred to the Kinderhook the Owen limestone which outcrops near the middle of the north-south line between section 18, Madison township, Butler county, and section 13, Geneva township, Franklin county, is responsible for the confusion. Again the occurrence of Sheffield shale three-fourths mile north of the town of Aplington in Monroe township as described below necessitates a shifting of the Kinderhook border in that region some distance to the northeast.

The Kinderhook formations represented in Butler county are the Sheffield, the Chapin and the Mayne Creek. The Sheffield covers by far the largest area.

THE SHEFFIELD BEDS.—The basal member of the Kinderhook series of this part of the state outcrops at a number of localities in Washington and Monroe townships.

In the right bank of Beaver creek east of the center of section 31, Washington township, there appears eight feet of bluish, plastic shale with thin intercalated layers of brownish dolomite. It is believed that these beds should be correlated with the lower shaly division of the Sheffield.

Near the middle of the north line of section 18, Washington township, about six feet of soft thin-bedded cherty dolomitic shale outcrops in a roadside gully. Silicified specimens of the following forms were collected at this locality:

<table>
<thead>
<tr>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shellwienella ? sp.</td>
</tr>
<tr>
<td>Productus blairi Miller</td>
</tr>
<tr>
<td>Camaratoxechia chouteanusensis Weller</td>
</tr>
<tr>
<td>Spirifer sp. (resembling S. whitneyi)</td>
</tr>
<tr>
<td>Cliothyridina prouti (Swallow)</td>
</tr>
</tbody>
</table>

These species indicate the topmost division of the Sheffield.

Beds carrying the same fauna are exposed in an abandoned quarry in section 28, Washington township, a few rods west of the railway bridge over Beaver creek. Five feet of brownish
arenaceous and dolomitic shale is shown here at the present time.

In Monroe township, this fossiliferous zone of the Sheffield may be studied to good advantage in the gullies along the north-south road in the northwest quarter of section 20, three-fourths of a mile north of the town of Aplington. Seven feet of soft brownish dolomite with a few imperfect casts and impressions of fossils is here overlain by four feet of soft brownish dolomitic shale which bears silicified specimens of the same species as listed above.

Arey\(^{67}\) reports the occurrence of Lime Creek beds in this vicinity but no trace of such beds could be found by the writer.

**The Chapin and Mayne Creek Beds.—** At two points in Washington township these formations appear in contact. The most complete exposure is found in an old quarry near the center of the west half of section 31, between Beaver creek and the Illinois Central railroad. This has been described by Arey\(^{68}\) and the following description is copied in part from his:

<table>
<thead>
<tr>
<th>Section in section 31, Washington township.</th>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Limestone, thin-bedded, yellow to drab, with bands and nodules of chert</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>4. Limestone, brown, sugary, dolomitic; with a five inch band of chert in the lower half</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>3. Chert, in the form of a series of lenses</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>2. Dolomite, massive, yellowish, finely arenaceous, fossiliferous</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>1. Dolomite, brownish, massive, tough; bearing casts and impressions of fossils. Exposed</td>
<td>1</td>
<td>6</td>
</tr>
</tbody>
</table>

Beds 1 and 2 of the above section bear a Chapin fauna and they are referred to that formation. The overlying cherty beds are correlated with the Mayne Creek. Near the southwest corner of the southwest quarter of section 28 there is an east-west ridge just north of Beaver creek. On the south side of this the following composite section is exposed:

| 3. Dolomite, soft, yellowish, thin-bedded; with occasional small lenses of chert. No identifiable fossils noted | 7 1/2 |
| 2. Sandstone, very fine, soft, yellowish, with occasional thin layers of brownish dolomite. A zone in lower part filled with casts of fossils | 7    |
| 1. Dolomite, tough, brownish. Fossils scarce | 4    |

\(^{67}\) Iowa Geol. Survey, vol. XX, p. 36.

\(^{68}\) Idem, p. 39.
The fauna of beds 1 and 2 suggests their Chapin age. Bed 3 is referred to the Mayne Creek. The species collected from bed 2 are listed below:

- Schizoblastus roemert Shumard
- Fenestella sp.
- Productus sp.
- Schellwienella " sp.
- Spirifer legrandensis Weller
- Spirifer platynotus Weller
- Syringothyris sp.
- Clothyridina tenuilineata (Rowley)
- Conocardium sp.

Another section in which appear beds believed to be of Mayne Creek age is in an old quarry in the southeast one-fourth of the northeast quarter of section 32 of Washington township. Eighteen feet of fine gray massive sandstone with several discontinuous seams of chert is exposed. Fragments of fossils occur in the cherts.

**Wright County.**—The Kinderhook formation is believed to form the bed rock over the greater part of Wright county though no exposures of rocks of this age are described by Macbride in his report on the geology of Hamilton and Wright counties.

**Humboldt County.**—The Kinderhook is nearly everywhere covered by glacial drift in Humboldt county. But in the vicinity of the towns of Humboldt and Rutland, oolitic limestones of this age appear at the surface over small areas. The largest of these appears in the east bank of the West Fork of Des Moines river in the southwest part of the town of Humboldt. At an abandoned lime kiln in this area, the limestone has an exposed thickness of twelve feet. The rock is gray in color, and the texture is typically oolitic. In the lower part of the section, the oölite grains are small and the matrix lithographic, but in the upper part the grains are coarser and the texture is more crystalline.

Macbride lists the following gastropods from the oölites of the Humboldt area:

- Loxonema yancellana Hall
- Straparollus macromphalus Winchell
- Straparollus obtusus (Hall)

The following additional forms have been collected and de-
scribed from this locality by Sardeson\(^1\) who remarks that "fossils are readily found in certain strata at Humboldt along the river's bank from Bicknell's Park to the dam . . . ."

\begin{align*}
\text{Euomphalus luxus White} & \quad \text{Mylina \? abstemia Sardeson} \\
\text{Loxonema difficile Sardeson} & \quad \text{Cyathophyllum glabrum Keyes}
\end{align*}

On the east side of the river just below the dam at Humboldt fifteen feet of oölite is exposed in the river bank. The texture of some of the upper layers is very finely oölitic and approaches that of a lithographic limestone, but elsewhere the grains are large except for occasional thin seams. Stratification is very imperfectly developed, and the rock shows many fractures. Slickensided structure is abundantly shown along the fissures.

In the northeast quarter of section 33, Rutland township, just east of the Humboldt cemetery, the oölite is well exposed in a small drainage ditch about four feet in depth. The upper one-third of the outcrop consists of coarse oölite, but in the lower two-thirds the grains are very fine and the rock is dense and rather brittle. Large pisolitic masses ranging from the size of a pea to three or four inches in diameter are common throughout. Many of these consist of a nodule of oölitic limestone coated with concentric layers, but a few show concentric structure throughout. No fossils were noted.

At the town of Rutland the oölite is exposed on the south side of the river both above and below the bridge. On the north side there are good exposures farther west, in the vicinity of the dam. The maximum thickness exposed on this side is ten feet and the rock is rather brittle. The lower half is not well stratified, and weathers to irregular polyhedrons. The oölite grains are small in this part. The upper half is evenly bedded, and the oölite grains are large.

Sardeson regards these beds as identical with those at Humboldt. He lists the following species from this locality:

\begin{align*}
\text{Cyathophyllum glabrum Keyes} & \quad \text{Murchisonia sp. undet.} \\
\text{Macrodon cf. cochlearis Win.}
\end{align*}

In the south bank of a small creek southwest of the creamery at Rutland, there is a very interesting section showing the St.

\(^1\) Am. Geologist, vol. XXX, p. 300 ff.; 1902.
Louis limestone in contact with the Kinderhook. The succession is as follows:

**Section near the creamery at Rutland.**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drift</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>St. Louis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Limestone, brecciated, dense, gray, imperfectly dolomitized; lower surface irregular and undulating</td>
<td>3</td>
</tr>
<tr>
<td>2.</td>
<td>Limestone, dense, gray, tough, in the form of one undulating layer which fills irregular depressions in the limestone beneath</td>
<td>½ to 1</td>
</tr>
<tr>
<td>Kinderhook</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Limestone, light gray; stratification very imperfect; finely oolitic except in middle part where there is a thin seam of coarse oolite</td>
<td>2 to 3½</td>
</tr>
</tbody>
</table>

At the mouth of this creek, in the southeast quarter of the northwest quarter of section 29, Rutland township, the contact of the Kinderhook and the St. Louis is again shown. At this point about four feet of the oolite is exposed above the bed of the creek. This is overlain by three feet of gray tough St. Louis dolomite which weathers yellowish. At one point in the exposure this dolomite grades laterally, in part, into unaltered gray brecciated limestone.

About seventy-five yards below this exposure the contact is shown in the river bank. Three feet of Kinderhook oolite is succeeded by a two to three foot layer of yellowish undulating limestone, and this again by four feet of dense gray thin-bedded unaltered limestone which locally is mashed into mounds of breccia. The Kinderhook at this locality also shows considerable fracturing and slight brecciation. Several other exposures between this point and the bridge show similar contact relationships. The gray limestone of the St. Louis is five and one-half feet thick at one point.

The relation of the Humboldt oolite to the Kinderhook formations of Hardin and Franklin counties has not been determined definitely owing to the absence of exposures of underlying formations in Humboldt and adjacent counties. The fauna and the lithologic character of the oolite are of little aid in correlating it with other Kinderhook formations. The fact that it is overlain by the St. Louis limestone at several localities indicates that it represents the topmost member of the Kinderhook group in this part of the state. It may be younger than the
Alden limestone of Hardin county, which has not been found in contact with the St. Louis, but the possibility of greater erosion of the Kinderhook in the Humboldt area than in the Iowa Falls area in pre-St. Louis time must be borne in mind. Inasmuch as the Humboldt oölite bears no resemblance, either lithologically or faunally, to the Iowa Falls or older formations, it is believed to represent either a more oölitic and more fossiliferous facies of the Alden limestone or a younger formation not preserved in Hardin county.

In the southwestern part of Humboldt county a limestone formation which is referred provisionally to the Kinderhook group outcrops at several localities. This was formerly correlated with the St. Louis limestone by Macbride who describes the exposures as follows:

"At various points in Weaver township, as in the northeast quarter of section 9, there are exposures of limestone rock which must be considered here. These are mostly in the form of quarries, originally sink-holes, which have been developed to meet the local demand for rubble stone. From the exposure in section 9, just mentioned, a large amount of rock has been taken. The quality seems to be excellent, and the bedding is such as to make comparatively light the labor of the quarrymen. The rock is a rather coarse-grained, crystalline, encrinital limestone, reminding one of rocks elsewhere referred to the Augusta stage, unlike any seen anywhere in the river exposures. Open sink-holes in this neighborhood show almost everywhere rock of the same character, so that it is probable that all the southwestern part of the county is underlain by similar strata, except where removed by pre-glacial erosion. In the town of Gilmore, for instance, a similar rock in the northeast part of the village comes to the surface of the ground, while a few rods west, the town well goes down sixty feet before encountering rock at all. Nevertheless, we may consider this peculiar encrinital limestone as the surface rock for all that part of Humboldt county lying south of the west fork, except the flood plains immediately adjacent to the stream. The same rock extends far into Pocahontas county, and is there exposed in precisely the same way. Thus in Clinton township, in Pocahontas county, one mile west of Gilmore, and one and one-half miles north, is a sink-hole quarry, which for years has been very extensively worked."

Fossils were collected from this limestone in the outcrops across the county line in Pocahontas county. The age of the

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formation is discussed in connection with the description of these exposures.

Pocahontas County.—The same limestone formation which outcrops in Weaver township, Humboldt county, forms the bed rock along a narrow belt in the extreme eastern parts of Garfield and Lake townships in Pocahontas county. To the west it passes under Cretaceous deposits. The Pocahontas county extension of this formation was also formerly referred to the St. Louis upon the basis of a few poorly preserved fossils.73

In the quarry of the Gilmore Portland Cement Company, one and one-half miles northwest of Gilmore City, the following beds are exposed:

Section in Gilmore Portland Cement Company’s quarry.

<table>
<thead>
<tr>
<th>FEET</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5.</td>
<td>Limestone, light gray, fine-grained, thin-bedded, rather soft: Exposed at the south end of the quarry</td>
<td>4½</td>
</tr>
<tr>
<td>4.</td>
<td>Limestone, compact, gray, dense, fine-grained, brittle, very faintly oolitic, massive</td>
<td>10</td>
</tr>
<tr>
<td>3.</td>
<td>Limestone, as in bed 2 but filled with cylindrical corals</td>
<td>2½</td>
</tr>
<tr>
<td>2.</td>
<td>Limestone, gray, oolitic, compact, brittle</td>
<td>4</td>
</tr>
<tr>
<td>1.</td>
<td>Limestone, gray, massive, slightly crinoidal, oolitic. Exposed</td>
<td>6</td>
</tr>
</tbody>
</table>

The beds dip gently in a southeasterly direction in the quarry face, the axis of a low anticline being shown in the northwest end of the quarry.

One-half mile northwest of the preceding section similar beds are shown in two adjoining sink-hole quarries:

Section in sink hole quarries.

<table>
<thead>
<tr>
<th>FEET</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td>Limestone, gray, compact, brittle, slightly oolitic</td>
<td>7</td>
</tr>
<tr>
<td>2.</td>
<td>Limestone, gray, crinoidal, massive, the matrix oolitic, crinoid fragments less pronounced and oolitic character more characteristic in lower half. Showing tendency towards cross bedding</td>
<td>8</td>
</tr>
<tr>
<td>1.</td>
<td>Limestone, gray, compact, fine-grained, slightly oolitic, thin-bedded and somewhat shaly below. Exposed</td>
<td>4½</td>
</tr>
</tbody>
</table>

The following fossils were collected from these exposures:

List of fossils from sink hole quarries two miles northwest of Gilmore City.

ANTHOZOA—
Zaphrentis sp.
Monotrypa sp.

BRACHIOPODA—
Streptorhynchus sp.
Orthotetes † sp.
Productas sp.
Camarotoechia sp.
Camarotoechia sp.
Spiriferina sp.
Spirifer sp.

GASTROPODA—
Spirifer † sp.
Spirifer sp.
Syringothyris † sp.
Eumetria sp.
Composita trinuclea (Hall)

---

All of the beds in these exposures belong to a horizon below the coral zone (bed 3) of the cement quarry. The total exposed thickness of the formation, therefore, is not less than thirty-six and one-half feet. A well record at the cement plant is reported to have shown a thickness of forty-one feet of this type of limestone, succeeded below by a brownish dolomitic limestone.

The lack of diagnostic fossils in the fauna listed above, most of the species being undescribed, together with the absence of exposures of associated formations of known age renders the exact correlation of the Gilmore City limestone impossible at present. Lithologically it resembles the Alden limestone of Hardin county more closely than any other formation in north-central Iowa, but unfortunately no identifiable fossils were found in the Alden limestone which could be compared with those collected near Gilmore City. The occurrence of brownish dolomitic limestone below the Gilmore City oolitic limestone as reported in the boring at the cement quarry reminds one of the similar succession in Hardin county where the brownish Iowa Falls dolomite underlies the oolitic Alden limestone. However, exact correlation must await the discovery of better preserved fossil remains in the Alden limestone than have hitherto been found.

The relation of the Gilmore City limestone to the Humboldt oolite could not be determined by field study since no exposure showing them in contact has been found. The inference is that the Humboldt oolite is the younger of the two formations.

*Cerro Gordo County.*—The Kinderhook series extends into the southwestern part of Cerro Gordo county. Calvin\(^4\) wrote as follows regarding the beds:

"Strata of the Kinderhook stage of the Lower Carboniferous series are exposed along Beaver Dam creek in section 36 of Pleasant Valley township. Where the county line road, on the south side of the section, crosses the creek, the Kinderhook beds are composed of soft, shaly, magnesian limestone; but in Franklin county, a short distance south of the road, beds that occupy a higher position are exposed in the sides of the valley, and these are firm enough to afford quarry stone suitable for bridge piers, foundations, and other rough masonry. An *Athyris* re-\(^4\) Iowa Geol. Surv., vol. VII, p. 170.
KiNDERHOOK OF NORTH-CENTRAL IOWA 115

sembling *Athyris proutii* Swallow, a *Productus* related to *P. punctatus*, and *Orthothetes* sp. are the characteristic fossils. The next exposures east of the Kinderhook outcrops are the Devonian beds already noted on Beaver creek. The contact of the Carboniferous with the Devonian was not observed, but the line of overlap lies between the two localities last named.

Kossuth, Hancock and Winnebago Counties.—The Kinderhook apparently extends over this area but it is deeply buried by drift. No exposures are referred to in the literature on these counties. The Cretaceous deposits of western Kossuth county are believed to rest upon the Kinderhook beds.

**Correlation of the Kinderhook of North-central Iowa**

The Kinderhook of north-central Iowa attains its most typical development in Franklin, Butler and Hardin counties. From a study of individual exposures and the log of a deep well at Iowa Falls in Hardin county the series has been subdivided into six distinct formations as follows:

The Alden limestone
The Iowa Falls dolomite
The Eagle City beds
The Mayne Creek beds
The Chapin beds
The Sheffield beds

The paucity of fossils in the lower shaly strata of the Sheffield beds renders their age uncertain. Further study may indicate their Upper Devonian affinities. The collections obtained from the limestone and dolomitic shale directly above the shales of doubtful age contain a few species of brachiopods and an occasional fish remain. With the exception of a *Spirifer* which resembles *Spirifer whitneyi* of the Upper Devonian the brachiopods are Kinderhook types and are for the most part species characteristic of the Chouteau formation.

The faunas of the Chapin, Mayne Creek, Eagle City and Iowa Falls formations contain many undescribed species but the assemblages are all distinctly Kinderhook in aspect. Occasional species of Burlington brachiopods occur in the higher formations of the series.

The appearance of characteristic Chouteau species in the upper portion of the Sheffield formation and in the Chapin beds is worthy of note. The latter formation has yielded thirty-five
species. Twenty of these have been identified specifically. Nearly all of the twenty are characteristic Chouteau forms and twelve of them occur in beds 6 and 7 of the Kinderhook at Burlington.

In this connection, Weller's conclusions regarding the age of the Chouteau fauna in Missouri are of interest.75

"From the outline of the faunal history here given, it is evident that the arrangement of the Kinderhook formations into three successive divisions, the Louisiana, Hannibal, and Chouteau, as has usually been done, does not express the proper relationships of the faunas. The Chouteau fauna, in some of its expressions, is without doubt as old as the Louisiana fauna, and it is as impracticable to make one continuous section to contain all of the Kinderhook formations, as it would be to make a standard Devonian section to include the formations of New York and Iowa."

From the above statement it is apparent that while the faunas of the upper Sheffield76 and Chapin beds have Chouteau affinities and are more closely related to the faunules of beds 6 and 7 at Burlington than to those of the underlying Kinderhook beds, this does not necessarily indicate the exact equivalency of these beds.

The evidence supports the view that the Chouteau fauna appeared earlier in Kinderhook time in the northern area, as it did in central Missouri, than in the Burlington area. The Chonopectus fauna of the lower beds in the Burlington area may have existed simultaneously with the Chouteau fauna to the north.

75 Jour. Geol., vol. 17, pp. 274, 275; 1909.

76 In connection with the term Sheffield, attention should be called to the fact that in a paper by C. L. Fenton on the Upper Devonian of Iowa in The American Journal of Science, volume xlviii, pages 355-376, 1919, the name Sheffield was applied to the plastic blue shale which underlies the nearly fossiliferous zones of the Cerro Gordo sub-stage at Rockford, Juniper Hill, Hackberry Grove, Mason City and elsewhere north and east of Sheffield. Fenton was doubtless under the impression that the shales at Sheffield were identical with those of Devonian age at Mason City and Rockford, being apparently misled by Williams' error in describing and mapping the shales at Sheffield as Upper Devonian in the Franklin county report. (Iowa Geological Survey, volume xvi, pages 477-481, 502 and map opposite page 506.) However, the beds at Sheffield are Kinderhook according to Van Tuyl's evidence and the name as employed by him seems appropriate. Since the name Sheffield for obvious reasons is unavailable for the Upper Devonian shales, the name Juniper Hill is here offered for that formation. Juniper Hill, located about one mile northwest of the Rockford Brick and Tile Plant, is in the midst of numerous good exposures of the formation and where its relation to the beds above and below may be readily observed.—A. O. Thomas.
CHAPTER III

THE OSAGE GROUP

Definition of Osage

The term Osage group was proposed by H. S. Williams in 1891 to include the Burlington and Keokuk formations. In later reports several authors have included the Warsaw beds in the Osage also, but Weller now refers the Warsaw to the overlying Meramec group.

Keyes has used the term Augusta series to include the Burlington, Keokuk and Warsaw formations but as Weller has pointed out the term Osage clearly has priority.

Distribution of the Group

Exposures of the Osage group are confined to the southeastern part of Iowa. For the most part they appear in a sinuous northwest-southeast trending belt of irregular width extending from southern Lee county on the south to Keokuk county on the north. It is probable that rocks of this age are present beneath the glacial deposits in southwestern Iowa and south-central Poweshiek counties also. The belt is bounded by the Kinderhook group on the northeast and by the Meramec group on the southwest. As a result of the study of deep well records the group is known to be present beneath Meramec and younger formations in south-central Iowa.

The Osage attains its full development in Iowa in Des Moines, Lee and Van Buren counties only. To the northwest there is a thinning of the group from above downwards probably due in part to nondeposition and in part to post-Osage erosion. In the vicinity of Keokuk both members of the group are present, though the Burlington limestone is below the surface. In south-

1 U. S. Geol. Survey Bull. 80, p. 169.
ern Des Moines county the Burlington and Keokuk formations are fully developed and both are well exposed. Still farther northwest, in Keokuk and Washington counties, the Keokuk is reduced in thickness.

**Lithologic Character**

The Osage group is composed of interstratified gray to bluish gray crinoidal limestone, gray to brownish dolomitic limestone and ash-colored to bluish shales. The bluish gray crinoidal limestones are characteristic of the Keokuk while the gray ones appear in the Burlington. Shale beds increase in number and thickness towards the top of the group, presumably as a result of a gradual recession of the sea from the area during Osage time.

**Thickness**

Where both formational members of the Osage are fully developed, it has a thickness of 134 feet. In Washington and Keokuk counties it is probably not much more than one hundred feet thick.

**Stratigraphic Relations**

The Osage group apparently is conformable with the Kinderhook beds below. It is succeeded by the Meramec beds without a break in the extreme southeastern part of the state but to the northwest, where the St. Louis limestone member of the Meramec overlaps successively older formations, a well marked disconformity exists at the top of the group.

**The Burlington Limestone**

**NOMENCLATURE**

The Burlington limestone was so named by Hall because of its typical development in the exposures in and near the city of this name in Des Moines county, Iowa.

**AREAL DISTRIBUTION**

The distribution of the Burlington limestone as an individual

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unit is not definitely indicated on the geological map of Iowa, since this member is included with the Keokuk in the Osage group, the smallest division which has been mapped. The area over which the Burlington constitutes the surface rock represents only a small part of the area indicated as Osage, owing to the fact that a large proportion of this area is underlain by the Keokuk beds. Previous studies have shown that the exposures of Burlington limestone are confined to a restricted area in the southeastern part of the state, including parts of Van Buren, Lee, Des Moines, Louisa, Washington, and possibly Keokuk counties.

In Van Buren county it forms the surface rock over a small area in the bed of Des Moines river at Bentonsport. It underlies a larger area in the eastern part of Lee county, but its outcrops are confined to a few isolated localities. Thus, there are small exposures in the bed and banks of Lost creek southeast of Denmark; in a number of small quarry openings west of Wever; and in the bed and banks of Skunk river and along its tributaries at and near South Augusta.

It doubtless constitutes the surface rock over the greater part of the eastern half of Des Moines county, but its outcrops are limited, the more important ones being along the ravines about Augusta, in the bluffs of Mississippi river, and numerous other natural exposures, quarries and street cuts in and near the city of Burlington.

The area underlain by the Burlington in Louisa county is confined to its southwestern and southern parts, the more important exposures being located in Morning Sun township.

Northwestward from Louisa county actual exposures of the Burlington have been found by the writer only in Washington county, although there is a strong probability that it underlies the drift over small areas in northeastern Keokuk and southern Iowa counties. In Washington county, it follows a broad, irregular band extending across the central part of the county from southeast to northwest. The most satisfactory exposures are located on and near Crooked creek, northwest of Washington.

**LITHOLOGIC CHARACTER**

The Burlington limestone succeeds the Kinderhook in vertical
succession with no indications of a stratigraphic break. Lithologically, the formation is a unit, but it is desirable to subdivide it into the Lower and Upper Burlington upon the basis of its crinoid fauna, as was pointed out long ago by Niles and Wachsmuth.6

The Montrose cherts, which were referred by Keyes7 to the Upper Burlington, have been demonstrated by the present study to represent the basal member of the Keokuk limestone (see page 142).

The Burlington limestone has long been noted for its profusion of crinoid remains. Probably at no other time in the earth's history have crinoids flourished so prolifically. More than four hundred species of crinoids have been described from this formation alone. At several horizons in the limestone the beds are made up almost completely of the disconnected plates of the calyces and fragments of the stems and arms of crinoids. When they are pure these crinoidal beds are light gray to whitish in color; when impure, they are discolored brownish. Normally they contain occasional discontinuous bands and nodules of chert. Stylotytic seams also are abundantly developed. Alternating with these crinoidal beds and comprising a large part of the formation are beds of fine-grained brownish magnesian, cherty limestone. In the vicinity of Burlington, Iowa, there is a seam of bluish shale averaging about one foot in thickness, in the lower part of the Upper Burlington, but this has not been observed at any other locality in Iowa.

The upper boundary of the Burlington is marked by a fish bed of widespread extent. Regarding this, Wachsmuth and Springer8 say:

"The close of the Upper Burlington limestone was marked by an extraordinary destruction of fishes whose remains, in the form of teeth and spines, are found in the greatest profusion in a stratum two to ten inches in thickness, which occurs at the very top of the regular limestone beds. It is one of the best stratigraphic landmarks that we know in this formation, as it is found over a wide area in localities over a hundred miles apart and always in the same position relative to the heavy limestone beds."

THICKNESS

The thickness of the Burlington limestone in the type section where it is fully developed is approximately seventy-one feet, of which twenty-seven feet is referred to the Upper Burlington and the remainder to the Lower. In Louisa county the lower member is only one-half as thick as at Burlington, while the upper member is seventeen feet in thickness.

AREAL DESCRIPTION BY COUNTIES

Des Moines and Lee Counties.—The type section of the Burlington limestone is at Burlington, Iowa, where numerous exposures of the formation in and near the city make it possible to work out the complete succession of beds and collect their fossils. The following generalized section will illustrate the character of the formation at this locality:

General section of Burlington limestone at Burlington.

<table>
<thead>
<tr>
<th>Bed</th>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.</td>
<td>Limestone, brownish to whitish, crinoidal; with occasional chert bands; middle part sometimes magnesian; a thin zone of fish teeth near the top</td>
<td>10-12</td>
</tr>
<tr>
<td>5.</td>
<td>Shale, bluish, argillaceous, not everywhere present</td>
<td>1½</td>
</tr>
<tr>
<td>4.</td>
<td>Limestone, light gray, crinoidal, very fossiliferous</td>
<td>5-8</td>
</tr>
<tr>
<td>3.</td>
<td>Limestone, brownish, crinoidal</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Limestone, brownish, fine-grained, magnesian, irregularly bedded; cherty, especially near the base; in places bears a layer of crinoidal limestone near the middle</td>
<td>34-39</td>
</tr>
<tr>
<td>1.</td>
<td>Limestone, brownish, crinoidal, massive, locally magnesian in part</td>
<td>8-11</td>
</tr>
</tbody>
</table>

Kinderhook

Beds 1 and 2 represent the Lower Burlington. They are well exposed in the old quarry back of the high school, in the quarries at Picnic Point and in the Mississippi river bluff at several points in and near Burlington.

Bed 3 outcrops in the bluff at the Cascade and on the slope below the Miller quarry above the Cascade.

Beds 4 and 6 are excellently exposed in the Miller quarry above the Cascade. Overlying bed 6 at this point, there appears fifteen feet of brownish magnesian limestone, crinoidal in the middle part, which yielded no identifiable fossils but which is referred to the basal Keokuk.

The fossils collected by the writer from the successive horizons of the Burlington limestone are listed below:
### List of fossils from bed 1 of the Burlington limestone at Burlington.

**Crinoidea**
- *Platycrinus ornogr anus McChesney*?
- *Platycrinus sculptus Hall*?
- *Platycrinus sp.*
- *Caenocrinus multibrachiatus (Hall)*?
- *Caenocrinus proboscidalis (Hall)*?
- *Batoocrinus subaequalis (McChesney)*
- *Batoocrinus sp.*
- *Dorycrinus unicorns (O. and Sh.)*

**Blastoidea**
- *Cryptoblastus meio O. and Sh.*

**Bryozoa**
- *Fenestella serratula Ulr.*?

**Brachiopoda**
- *Dielasma osceolensis Weller*
- *Rhipidomella burlingtonensis (Hall)*

**Gastropoda**
- *Orthonychia sp.*

**Tribrachytheria**
- *Phillipsia sp.*

**Vertebrata**
- *Fish teeth*

---

### List of fossils from bed 2 of the Burlington limestone at Burlington.

**Anthozoa**
- *Triplophyllum dalei (M.E. and H.)*
- *Zaphrentis sp.*

**Crinoidea**
- *Platycrinus sp.*

**Blastoidea**
- *Cryptoblastus meio O. and Sh.*

**Bryozoa**
- *Fenestella serratula Ulr.*?

**Brachiopoda**
- *Chonetes illinoisensis Worthen*
- *Pustula alternata (N. and P.)*
- *Spirifer grimesi Hall*
- *Brachythyr ius suborbicularis (Hall)*
- *Chiotyridina incrassata (Hall)*

**Gastropoda**
- *Orthonychia sp.*

**Tribrachytheria**
- *Phillipsia sp.*

**Vertebrata**
- *Fish teeth*

---

### List of fossils from bed 3 of the Burlington limestone at Burlington.

**Anthozoa**
- *Hadrophyllum glans White*
- *Triplophyllum dalei (M.E. and H.)*?

**Crinoidea**
- *Periechocrinus sp.*
- *Megistocrinus cf. M. evansi (O. and Sh.)*
- *Eutrochocrinus christyi (Shum.)*
- *Uperocrinus pyriformis (Shum.)*
- *Physococrinus ventricosus (Hall)*
- *Strotocrinus regalis (Hall)*
- *Platycrinus planus O. and Sh.*?
- *Platycrinus sp.*
- *Platycrinus sp.*

**Bryozoa**
- *Fenestella burlingtonensis Ulrich*
- *Rhombopora gracilis Ulrich*
- *Cystodictya sp.*

**Brachiopoda**
- *Chonetes illinoisensis Wortlien*
- *Productus burlingtonensis Hall*
- *Rhipidomella dubia (Hall)*
- *Dielasma sp.*
- *Spirifer grimesi Hall*
- *Spirifer incertus Hall*
- *Syringothyris typus Winchell*
- *Athyris lamellosa (Leveille)*

**Gastropoda**
- *Straparollus sp.*
- *Lepetopsis capulus (Hall)*
- *Platycoras sp.*
- *Orthonychia sp.*

**Tribrachytheria**
- *Phillipsia sp.*

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### List of fossils from bed 4 of the Burlington limestone at Burlington.

**Anthozoa**
- *Zaphrentis caeleola (W. and W.)*
- *Zaphrentis sp.*
- *Triplophyllum dalei (M.E. and H.)*?
- *Hadrophyllum glans (White)*

**Crinoidea**
- *Platycrinus sp.*
- *Uperocrinus pyriformis (Shum.)*

**Bryozoa**
- *Fenestella burlingtonensis Ulrich*
- *Rhombopora gracilis Ulrich*
- *Cystodictya sp.*

**Brachiopoda**
- *Chonetes illinoisensis Wortlien*
- *Productus burlingtonensis Hall*
FOSSILS FROM BURLINGTON BEDS

List of fossils from bed 6 of the Burlington limestone at Burlington.

ANTHOZOA—
Zaphrentis calceola (W. and W.)
Zaphrentis sp.
Triplophyllum dalei (M.E. and H.)
Amplexus fragilis White and St. John

CRINOIDEA—
Eutrochocrinus calyculoides (Hall)
Macrocrinus konikci (Shum.)
Dizygoocrinus rotundus (Shum.)
Dizygoocrinus andrewsi (McChesney)
Zaphrentis christyi (Shum.)
Zaphrentis sp. lovei (W. and Sp.)
Upperocrinus sp.
Aecocrinus parvus (Shum.)
Dorycrinus quinquedecimus (Hall)
Dorycrinus sp.
Aegiocrinus ornata (Hall)
Teleocrinus umbrosus (Hall)
Physocrinus ventricosus (Hall)
Physocrinus sp. (Hall)
Strotocrinus grampus (Hall) ?
Platycrinus halli Shum.
Platycrinus sp.

BLASTOIDEA—
Pentremites elongatus Shum.
Orbitremites norwoodi (O. and Sh.)

BRYOZOA—
Batostomella sp.
Fenestella burlingtonensis Ulrich
Rhopbopora sp.
Rhopbopora sp.
Rhopbopora sp.
Cystodictya sp.

GASTROPODA—
Pennites elongatus Shum.
Bryozoa sp.

VERTEBRATA—
Fish teeth

Table Showing Range of Species in Burlington Limestone at Burlington.

<table>
<thead>
<tr>
<th>Horizons</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ANTHOZOA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zaphrentis calceola (W. and W.)</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Zaphrentis sp.</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Zaphrentis sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zaphrentis sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triplophyllum dalei (M.E. and H.)</td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Amphius fragilis White and St. John</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Hadrphyllum glans (White)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monilopora sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CRINOIDEA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Periechocrinus sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>


### Table Showing Range of Species in Burlington Limestone at Burlington—Continued.

<table>
<thead>
<tr>
<th>Species</th>
<th>Horizons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Magistocrinus cf. M. evansi (O. and Sh.)</td>
<td></td>
</tr>
<tr>
<td>Batocrinus subaequalis (McChesney)</td>
<td></td>
</tr>
<tr>
<td>Batocrinus sp.</td>
<td></td>
</tr>
<tr>
<td>Eretmocrinus calyceoloides (Hall)</td>
<td></td>
</tr>
<tr>
<td>Macrocrinus konincki (Shum.)</td>
<td></td>
</tr>
<tr>
<td>Macrocrinus verneuilianus (Shum.)</td>
<td></td>
</tr>
<tr>
<td>Dizygoerinus rotundus (Shum.)</td>
<td></td>
</tr>
<tr>
<td>Dizygoerinus andrewsianus (McChesney)</td>
<td></td>
</tr>
<tr>
<td>Eutrochocerinus christyi (Shum.)</td>
<td></td>
</tr>
<tr>
<td>Fatrochocerinus lovei (W. and Sp.)</td>
<td></td>
</tr>
<tr>
<td>Aurocrinus parvus (Shum.)</td>
<td></td>
</tr>
<tr>
<td>Uperocerinus pyriformis (Shum.)</td>
<td></td>
</tr>
<tr>
<td>Uperocerinus sp.</td>
<td></td>
</tr>
<tr>
<td>Dorycrinus unicornis (O. and Sh.)</td>
<td></td>
</tr>
<tr>
<td>Dorycrinus quinquelobus (Hall)</td>
<td></td>
</tr>
<tr>
<td>Dorycrinus sp.</td>
<td></td>
</tr>
<tr>
<td>Agaricocrinus ornatremus Hall</td>
<td></td>
</tr>
<tr>
<td>Cactocrinus proboscidialis (Hall)</td>
<td></td>
</tr>
<tr>
<td>Cactocrinus multibrachiatus (Hall)</td>
<td></td>
</tr>
<tr>
<td>Teleocrinus umbrosus (Hall)</td>
<td></td>
</tr>
<tr>
<td>Physetocrinus ventricosus (Hall)</td>
<td></td>
</tr>
<tr>
<td>Physetocrinus † sp.</td>
<td></td>
</tr>
<tr>
<td>Strotocrinus regalis (Hall)</td>
<td></td>
</tr>
<tr>
<td>Strotocrinus glyptus (Hall) †</td>
<td></td>
</tr>
<tr>
<td>Platycrinus ornogrannius McChesney</td>
<td></td>
</tr>
<tr>
<td>Platycrinus sculptus Hall †</td>
<td></td>
</tr>
<tr>
<td>Platycrinus planus O. and Sh. †</td>
<td></td>
</tr>
<tr>
<td>Platycrinus halli Shum.</td>
<td></td>
</tr>
<tr>
<td>Platycrinus sp.</td>
<td></td>
</tr>
<tr>
<td>Platycrinus sp.</td>
<td></td>
</tr>
<tr>
<td>Platycrinus sp.</td>
<td></td>
</tr>
<tr>
<td>Platycrinus sp.</td>
<td></td>
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<tr>
<td>Platycrinus sp.</td>
<td></td>
</tr>
<tr>
<td>Platycrinus sp.</td>
<td></td>
</tr>
<tr>
<td>Platycrinus sp.</td>
<td></td>
</tr>
<tr>
<td>Eucladocrinus praematurus W. and Sp. †</td>
<td></td>
</tr>
<tr>
<td>Eucladocrinus sp.</td>
<td></td>
</tr>
<tr>
<td><strong>Blastoidea</strong></td>
<td></td>
</tr>
<tr>
<td>Cryptoblastus melo (O. and Sh.)</td>
<td></td>
</tr>
<tr>
<td>Orbitremites norwoodi (O. and Sh.)</td>
<td></td>
</tr>
<tr>
<td>Pentremites elongatus Shum.</td>
<td></td>
</tr>
<tr>
<td><strong>Bryozoa</strong></td>
<td></td>
</tr>
<tr>
<td>Batostomella † sp.</td>
<td></td>
</tr>
<tr>
<td>Fenestella serrata Ulrich</td>
<td></td>
</tr>
<tr>
<td>Fenestella burlingtonensis Ulrich</td>
<td></td>
</tr>
<tr>
<td>Rhombopora gracilis Ulrich</td>
<td></td>
</tr>
<tr>
<td>Rhombopora sp.</td>
<td></td>
</tr>
<tr>
<td>Rhombopora sp.</td>
<td></td>
</tr>
<tr>
<td>Rhombopora sp.</td>
<td></td>
</tr>
<tr>
<td>Cystodictya sp.</td>
<td></td>
</tr>
<tr>
<td>Coscinium latum Ulrich</td>
<td></td>
</tr>
</tbody>
</table>
## Table Showing Range of Species in Burlington Limestone at Burlington—Continued.

<table>
<thead>
<tr>
<th>Species</th>
<th>Horizons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>BRACHIOPODA</strong></td>
<td></td>
</tr>
<tr>
<td>Schellwienella † sp.</td>
<td></td>
</tr>
<tr>
<td>Chonetes illinoisensis Worthy</td>
<td></td>
</tr>
<tr>
<td>Chonetes sp.</td>
<td>x</td>
</tr>
<tr>
<td>Chonetes sp.</td>
<td>x</td>
</tr>
<tr>
<td>Productus burlingtonensis Hall</td>
<td></td>
</tr>
<tr>
<td>Productus sp.</td>
<td></td>
</tr>
<tr>
<td>Pustula alternata (N. and P.)</td>
<td></td>
</tr>
<tr>
<td>Rhipidomella burlingtonensis (Hall)</td>
<td></td>
</tr>
<tr>
<td>Rhipidomella dubia (Hall)</td>
<td></td>
</tr>
<tr>
<td>Schizophoria swallowi (Hall)</td>
<td></td>
</tr>
<tr>
<td>Rhyynchopora sp.</td>
<td></td>
</tr>
<tr>
<td>Dielasma oscoleensis Weller</td>
<td></td>
</tr>
<tr>
<td>Dielasma sp.</td>
<td></td>
</tr>
<tr>
<td>Dielasma sp.</td>
<td></td>
</tr>
<tr>
<td>Spirifer grimesi Hall</td>
<td></td>
</tr>
<tr>
<td>Spirifer incertus Hall</td>
<td></td>
</tr>
<tr>
<td>Spirifer forbesi N. and P.</td>
<td></td>
</tr>
<tr>
<td>Spirifer imbrecx Hall</td>
<td></td>
</tr>
<tr>
<td>Spirifer louisianensis Rowley</td>
<td></td>
</tr>
<tr>
<td>Spirifer sp.</td>
<td></td>
</tr>
<tr>
<td>Brachythiris suborbicularis (Hall)</td>
<td></td>
</tr>
<tr>
<td>Brachythiris sp.</td>
<td></td>
</tr>
<tr>
<td>Brachythiris sp.</td>
<td></td>
</tr>
<tr>
<td>Syringothyris typus Win.</td>
<td></td>
</tr>
<tr>
<td>Syringothyris † sp.</td>
<td></td>
</tr>
<tr>
<td>Spiriferella plena (Hall)</td>
<td></td>
</tr>
<tr>
<td>Beticularia pseudolineata (Hall)</td>
<td></td>
</tr>
<tr>
<td>Eunetria sp.</td>
<td></td>
</tr>
<tr>
<td>Athyriss lamellosa (Leveille)</td>
<td></td>
</tr>
<tr>
<td>Cloithyridina tenuilineata (Rowley) †</td>
<td></td>
</tr>
<tr>
<td>Cloithyridina obmaxima (McChesney) †</td>
<td></td>
</tr>
<tr>
<td>Cloithyridina incrassata (Hall)</td>
<td></td>
</tr>
<tr>
<td><strong>PELECYPODA</strong></td>
<td></td>
</tr>
<tr>
<td>Aviculopecten † sp.</td>
<td></td>
</tr>
<tr>
<td><strong>GASTROPODA</strong></td>
<td></td>
</tr>
<tr>
<td>Lepotopsis capulus (Hall)</td>
<td></td>
</tr>
<tr>
<td>Straparollus sp.</td>
<td></td>
</tr>
<tr>
<td>Orthonychia pabulocrius (Owen)</td>
<td></td>
</tr>
<tr>
<td>Orthonychia sp.</td>
<td></td>
</tr>
<tr>
<td>Orthonychia sp.</td>
<td></td>
</tr>
<tr>
<td>Platyceeras obliquum Keyes</td>
<td></td>
</tr>
<tr>
<td>Platyceeras latum Keyes</td>
<td></td>
</tr>
<tr>
<td>Platyceeras paralium W. and W.</td>
<td></td>
</tr>
<tr>
<td>Platyceeras sp.</td>
<td></td>
</tr>
</tbody>
</table>
Wachsmuth and Springer\(^9\) and other investigators have collected and described a large number of other invertebrates, chiefly crinoids, from the Lower and Upper Burlington limestones at this locality in addition to the forms listed above. Unfortunately, neither the time available during the present investigation nor the opportunities for collecting at Burlington rendered it possible for the writer to determine the exact horizon in the section from which each of these came.

In addition to the exposures in the Burlington area, there are other outcrops showing the various phases of the formation in their typical development in outlying districts in Des Moines county. For example, the Lower Burlington is excellently exposed in the Kemper quarries located in the Mississippi river bluff between the city of Burlington and the station of Spring Grove (T. 69 N., R. 2 W., sec. 29, NW. 1/4, SW. 1/4). The section there is as follows:

*Section at Kemper quarries.*

\[
\begin{array}{cccccc}
\text{FEET} & 5. & \text{Limestone, light gray to brown, crinoidal} & 7 \frac{1}{2} \\
4. & \text{Limestone, brownish, soft, magnesian, cherty} & 18 \\
3. & \text{Limestone, light gray or whitish where fresh, but in some places brownish} & 8 \frac{1}{2} \text{ to } 9 \frac{1}{2} \\
2. & \text{Limestone, buff to brownish, soft, magnesian; with occasional seams of brownish crinoidal limestone; grading into the limestone above} & 4 \frac{1}{2} \text{ to } 5 \\
1. & \text{Limestone, oolitic. Exposed} & 2 \\
\end{array}
\]

All the beds except numbers 1 and 2, which represent the Kinderhook, are of Lower Burlington age.

In the banks of Flint creek in the vicinity of Starr's cave two miles northwest of Burlington, the Lower Burlington is again typically exposed in contact with the Kinderhook below and the lowermost beds of the Upper Burlington above.

The Upper Burlington is very satisfactorily exposed in the quarry of the Burlington Quarry Company located one-half mile north of the Chicago, Burlington, and Quincy railroad shops at West Burlington. The succession of layers at this place is given below:

**Section near West Burlington.**

<table>
<thead>
<tr>
<th>Depth (feet)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Drift</td>
</tr>
<tr>
<td>6</td>
<td>Limestone, soft, buff, thin-bedded, cherty</td>
</tr>
<tr>
<td>5</td>
<td>Limestone, gray to brownish, crinoidal, very cherty in middle part</td>
</tr>
<tr>
<td>4</td>
<td>Limestone, cherty, thin-bedded, gray and crinoidal below, but fine-grained, soft and brownish above</td>
</tr>
<tr>
<td>3</td>
<td>Limestone, gray, crinoidal, finer-grained, with stylolytic seams, when fresh, upper one and one-half feet brownish, and grading locally into fine-grained nodular limestone. Bearing <em>Spirifer grimesi</em>, <em>Spiriferella plena</em>, <em>Dizygocrinus rotundus</em>, <em>Pentacrinus</em> sp., <em>Lepetopsis capulus</em> and other species</td>
</tr>
<tr>
<td>2</td>
<td>Limestone, gray, crinoidal, with brownish tint, locally cherty in upper portion. <em>Dizygocrinus rotundus</em>, <em>Rhipidomella bur- lingtonensis</em>, <em>Spirifer grimesi</em> and <em>Spiriferella plena</em></td>
</tr>
</tbody>
</table>

Beds 1 to 4 represent the Upper Burlington, while beds 5 and 6 are referred to the Keokuk.

In the vicinity of the town of Augusta, nine miles southwest of Burlington, both divisions of the formation are well exposed and afford an opportunity for collecting from all horizons. The most complete section is in the bluff of a creek tributary to Skunk river at South Augusta (NE. ¼, sec. 25, Denmark township).

**South Augusta section.**

<table>
<thead>
<tr>
<th>Depth (feet)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Limestone, soft, buff, not everywhere present</td>
</tr>
<tr>
<td>7</td>
<td>Limestone, light gray, crinoidal; with occasional small nodules and thin, irregular, discontinuous seams of chert; some layers very crinoidal; stylolytic</td>
</tr>
<tr>
<td>6</td>
<td>Limestone, compact, dense, brownish, nodular, cherty, magnesia; no fossils noted</td>
</tr>
<tr>
<td>5</td>
<td>Chert, in the form of a solid band, replacing a layer of crinoidal limestone; some unreplaced crinoid fragments preserved</td>
</tr>
<tr>
<td>4</td>
<td>Limestone soft, buff, magnesian</td>
</tr>
<tr>
<td>3</td>
<td>Limestone, gray to whitish, crinoidal, cherty, with occasional thin layers of soft buff limestone. The main crinoid zone</td>
</tr>
</tbody>
</table>

Beds 1 to 4 represent the Upper Burlington.
LOWER Burlington.

2. Limestone, fine-grained, soft, bluish gray when fresh but weathering buff; exhibiting numerous concretionary iron stains; with occasional layers of brownish impure cherty crinoidal limestone ranging up to two feet in thickness ............... 12½-13½

1. Limestone, gray, subcrystalline, very cherty in upper part.

Exposed ......................................................

Bed 1 is well exposed also at the mouth of the creek less than one-fourth mile below the bluff, where it causes the rapids in Skunk river.

Bed 3 is excellently exposed farther up the creek on the Frank Crabtree and Menlie properties. This bed outcrops also at the south end of the wagon bridge over Skunk river. Excellent opportunities for collecting crinoids from this bed are afforded at the above localities.

Beds 7 and 8 were formerly quarried in the face of the bluff. They are overlain at one point by twelve feet of cherty limestone of Keokuk age.

The fossils of all the beds from which identifiable specimens were collected are listed below:

**List of fossils from bed 1 in the bluff section at South Augusta.**

**BRYOZOA—**

- Schizophoria swallowi (Hall)
- Spiriferina sp.
- Spirifer sp.
- Pseudosyrinx sp.
- Reticularia sp.
- Composita trinuclea (Hall)
- Cliothyridina incrassata (Hall)

**ANTHOZOA—**

- Zaphrentis sp.
- Zaphrentis sp.
- Triplophyllum dalei (M.-E. and H.)

**BRACHIOPODA—**

- Chonetes multi costa Win.
- Productus sp.
- Orthotetes sp.
- Leptaena analoga (Phillips)
- Rhynchonella sp.
- Camarophoria bisinuata (Rowley)

**List of fossils from the bank of Skunk river at South Augusta.**

- Spirifer grimesi Hall
- Spirifer carinatus Rowley
- Spirifer insculptus Rowley
- Brachythyris suborbicularis (Hall)
- Composita sp.
- Cliothyridina parvirostris (M. and W.)

**GASTROPODA—**

- Straparollus obtusus (Hall)
- Platyceblas sp.
- Igoceblas sp.

**TRILOBITA—**

- Griffithides sp.

**CRINOIDEA—**

- Platyocrinus sp.

**List of fossils from bed 2 in the bluff section at South Augusta.**

- Spirifer sp.
- Spiriferella plena (Hall)
- Athyria lamellosa (Leveille)
- Cliothyridina incrassata (Hall)
List of fossils from bed 3 in the bluff section at South Augusta.

**ANTHOZOA**
- *Triplophyllum dalei* (M.-E. and H.)
- *Eutrochocrinus christyi* (Shum.)

**CRINOIDEA**
- *Spirifer grimesi* Hall

**BRACHIOPODA**
- *Schizophoria swallowi* (Hall)
- *Athyris lamellosa* (Leveille)
- *Brachythyris suborbicularis* (Hall)

**GASTROPODA**
- *Platyceras sp.*
- *Orthonychia sp.*

List of fossils collected from exposures of bed 3 along creek on Crabtree and Menelic properties.

**ANTHOZOA**
- *Orbitremites norwoodi* (O. and Sh.)
- *Zaphrentis sp.*
- *Cyathaxonia sp.*

**BRACHIOPODA**
- *Productus burlingtonensis* Hall
- *Tustula alternata* (N. and P.)
- *Chonetes sp.*
- *Rhipidomella dubia* (Hall)

**CRINOIDEA**
- *Nodosocrinus* missouriensis (Shum.)
- *Caelocrinus glaas* (Hall)
- *Actinocrinus multiradiatus* Shum.
- *Actinocrinus seitzii* M. and W.

**BRYOZOA**
- *Zaphrentis sp.*

**PELECYPODA**
- *Cypriacrinus* sp.
- *Lepetopsis capulus* (Hall)
- *Platyceras* (several undetermined species)

**GASTROPODA**
- *Igoceras sp.*
- *Platyceras* (several undetermined species)

**BLASTOIDEA**
- *Pentecmites elongatus* Shum.

List of fossils collected from exposures of bed 3 at south end of wagon bridge over Skunk river.

**ANTHOZOA**
- *Triplophyllum dalei* (M.-E. and H.)
- *Zaphrentis sp.*

**CRINOIDEA**
- *Undetermined* (several species)
- *Dicyocrinus rotundatus* (Shum.)
- *Physococrinus ventricosus* (Hall)
- *Uperococrinus pyriformis* (Shum.)
- *Actinocrinus sp.*
- *Barycrinus sp.*

**BRACHIOPODA**
- *Schizophoria swallowi* (Hall)
- *Spirifer grimesi* Hall

**GASTROPODA**
- *Igoceras sp.*

**BRYOZOA**
- *Undetermined* (several species)
List of fossils in bed 7 of the bluff section at South Augusta.

**Anthozoa** —
- Triplophyllum dalei (M.-E. and H.)
- Fenestella sp.
- Zaphrentis sp.
- Amphixus sp.

**Bryozoa** —
- Penestella sp.

**Brachiopoda** —
- Productus burlingtonensis Hall
- Orbitremites norwoodi (O. and S.)
- Schizophoria swallowi (Hall)
- Spirifer grimesi Hall
- Spirifer incertus Hall
- Spiriferella plena (Hall)
- Cliothyridina incrasata (Hall)

**Blastoidea** —
- Orbitremites dorodea (M. and W.)
- Dizygocrinus rotundus (Shum.)
- Dizygocrinus rotundus (Shum.)
- Dizygocrinus undrewsianus (McChesney)
- Eutrochocrinus christyi (Shum.)
- Uperocrinus hageri (McChesney)
- Aorocrinus sp.
- Cactocrinus sp.
- Platycrinus (plates of several undetermined species)
- Eucladocrinus pleurovimenus (White)
- Orbitremites norwoodi (O. and S.)
- Pentremites elongatus Shum.

It will be noted that the faunule obtained from bed 7 of the Upper Burlington limestone in the above section is meager. Much better facilities for collecting from this horizon are afforded by the exposures along the banks of Barb creek, one mile northwest of South Augusta, near the center of section 23, Denmark township. The following species were collected here:

List of fossils from bed 7 of Burlington limestone on Barb creek.

**Anthozoa** —
- Triplophyllum dalei (M.-E. and H.)
- Fenestella sp.
- Zaphrentis sp.
- Amphixus sp.

**Bryozoa** —
- Penestella sp.

**Brachiopoda** —
- Productus burlingtonensis Hall
- Orbitremites norwoodi (O. and S.)
- Schizophoria swallowi (Hall)
- Spirifer grimesi Hall
- Spirifer incertus Hall
- Spiriferella plena (Hall)
- Cliothyridina incrasata (Hall)

**Blastoidea** —
- Orbitremites norwoodi (O. and S.)
- Pentremites elongatus Shum.

**Gastropoda** —
- Lepetopsis capulus (Hall)
- Platyceras sp.

Near Augusta on the opposite side of Skunk river, there is an excellent exposure of the Upper Burlington, overlain by the Keokuk limestone, in the bed and banks of a small creek one-half mile north of the Augusta bridge in the eastern part of sec. 23, Augusta township. The following section was measured at this locality:

**Section of the Upper Burlington limestone at Augusta.**

3. Limestone, coarse-grained, crinoidal; with styloytic seams; brownish below but light gray above; upper 1 to 1 1/2 feet, fine-
grained, soft and weathering buff. Some seams in upper part filled with crinoid fragments. Zone of fish teeth 22 inches below top .......................... 16 -17

2. Limestone, soft, buff, cherty, dolomitic; resting on the irregular undulating surface of the bed beneath .......................... 1½ - 2

1. Limestone, gray, subcrystalline; with coarser-grained cherty, crinoidal layers in upper and lower parts. Exposed .......................... 3

No fossils were collected from bed 2, but beds 1 and 3 yielded numerous species.

**List of fossils from bed 1 of section of Upper Burlington limestone at Augusta.**

**ANTHOZOA**
- Triphophyllum dalei (M.E. and H.)
- Hadrophyllum glans (White)

**CRINOIDEA**
- Platycrinus (plates of several species)
- Brachiophyllum dalei (M.E. and H.)

**BLASTOIDEA**
- Orbitremites norwoodi (O. and Sh.)
- Eucladocrinus pleurovimenus (White)

**BRYOZOA**
- Rhombopora sp.
- Schizophoria swallovi (Hall)
- Brachypodites suborbicularis (Hall)

**BRACHIOPODA**
- Chonetes sp.
- Productus sp.
- Rhipidomella dubia (Hall)
- Rhipidomella burlingtonensis (Hall)

**GASTROPODA**
- Lepetopsis capulus (Hall)
- Spirifer grimesi Hall
- Spirifer incertus Hall
- Spirifer sp.
- Brachyphyrus suborbicularis (Hall)
- Syringothyris sp.
- Athys lamellosa (Leveille)
- Clotothyridina incassata (Hall)
- Clotothyridina parvostris (M. and W.)

**BRACHIOPODA**
- Chonetes sp.
- Productus sp.
- Rhipidomella dubia (Hall)
- Rhipidomella burlingtonensis (Hall)

**GASTROPODA**
- Lepetopsis capulus (Hall)
- Spirifer grimesi Hall
- Spirifer incertus Hall
- Spirifer sp.
- Brachyphyrrus suborbicularis (Hall)
- Syringothyris sp.
- Clotothyridina incassata (Hall)
- Athys lamellosa (Leveille)

**LIST OF FOSSILS FROM BED 1 OF SECTION OF UPPER BURLINGTON LIMESTONE AT AUGUSTA.**

**ANTHOZOA**
- Zaphrentis sp.
- Triphophyllum dalei (M.E. and H.)
- Hadrophyllum glans (White)

**CRINOIDEA**
- Batoecrinus laura (Hall)
- Macroecrinus verneuillianus (Shum.)
- Dizygoecrinus andrewsianus (McChesney) ⊙
- Dizygoecrinus rotundus (Shum.)
- Eutochocrinus christyi (Shum.)
- Agaricocrinus sp.
- Actinocerinus multiradiatus Shum.
- Actinocerinus sp.
- Teleioecrinus umbrosus (Hall)
- Platycerinus (plates of several species)
- Eucladocerinus pleurovimenus (White)

**BLASTOIDEA**
- Pentremites elongatus Shum.
- Orbitremites norwoodi (O. and Sh.)

**BRYOZOA**
- Cystodictya sp.

**BRACHIOPODA**
- Chonetes sp.
- Productus viminalis White
- Productus burlingtonensis Hall
- Productus sp.

**GASTROPODA**
- Lepetopsis capulus (Hall)
- Rhipidomella dubia (Hall)
- Rhipidomella burlingtonensis (Hall)
- Dielasma sp.
- Camarotoechia sp.
- Spirifer grimesi Hall
- Spirifer incertus Hall
- Spirifer sp.
- Brachyphyrus suborbicularis (Hall)
- Syringothyris sp.
- Clotothyridina incassata (Hall)
- Athys lamellosa (Leveille)

**LIST OF FOSSILS FROM BED 3 OF SECTION OF UPPER BURLINGTON LIMESTONE AT AUGUSTA.**

**ANTHOZOA**
- Zaphrentis sp.
- Triphophyllum dalei (M.E and H.)
- Hadrophyllum glans (White)

**CRINOIDEA**
- Batoecrinus laura (Hall)
- Macroecrinus verneuillianus (Shum.)
- Dizygoecrinus andrewsianus (McChesney) ⊙
- Dizygoecrinus rotundus (Shum.)
- Eutochocrinus christyi (Shum.)
- Agaricocrinus sp.
- Actinocerinus multiradiatus Shum.
- Actinocerinus sp.
- Teleioecrinus umbrosus (Hall)
- Platycerinus (plates of several species)
- Eucladocerinus pleurovimenus (White)

**BLASTOIDEA**
- Pentremites elongatus Shum.
- Orbitremites norwoodi (O. and Sh.)

**BRYOZOA**
- Cystodictya sp.

**BRACHIOPODA**
- Chonetes sp.
- Productus viminalis White
- Productus burlingtonensis Hall
- Productus sp.
From the exposures at and near South Augusta and at Augusta, the following generalized section of the Burlington has been constructed.

*Generalized section of Burlington limestone at and near Augusta.*

**UPPER BURLINGTON.**

8. Limestone, soft, fine-grained; gray when fresh but weathering buff ........................................... 0 to 1½

7. Limestone, brownish below, but light gray above, crinoidal, with stylolytic seams, bearing occasional thin, irregular, discontinuous seams of chert .......................................................... 16 to 17

6. Limestone, brownish, magnesian, subcrystalline to fine-grained, cherty, with occasional seams of crinoidal limestone .......................................................... 8

5. Chert, in the form of a solid band, replacing a layer of crinoidal limestone; some unreplaceable crinoid fragments preserved .......................................................... 1

4. Limestone, soft, buff, magnesian .......................................................... 1 to 1½

3. Limestone, gray to whitish, crinoidal, cherty, with occasional thin layers of soft buff limestone. The main crinoid zone...... 7½ to 8½

**LOWER BURLINGTON.**

2. Limestone, fine-grained, soft, bluish-gray when fresh but weathering buff and exhibiting numerous concretionary iron stains; with occasional layers of brownish impure cherty crinoidal limestone ranging up to 2 feet in thickness .......... 12% to 13½

1. Limestone, gray, subcrystalline, very cherty in upper part. Exposed .......................................................... 4

The range of the more characteristic fossils collected by the writer from the individual beds of the section is indicated on the chart which follows:

*Table Showing Range of Fossils in the Burlington Beds at and near Augusta.*

<table>
<thead>
<tr>
<th>Horizons</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ANTHOZOA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zaphrentis sp.</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyathaxonia sp.</td>
<td></td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Hadrophyllum glans (White)</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Triplophyllum dalei (M.-E. and H.)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Amplexus sp.</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **CRINOIDEA** | | | | | |
| Batoecrinus cf. B. laura (Hall) | | | x | | |
| Batoecrinus grandis W. and Sp. | | x | | | |
| Batoecrinus laura (Hall) | | | x | | |
| Macroecrinus koninecki (Shum.) | | | x | | |
| Macroecrinus verneuilianus (Shum.) | | | x | | |
| Dizygocrinus rotundus (Shum.) | | | x | | |
| Dizygocrinus dodecadactylus (M. and W.) | | | x | | |
### Table Showing Range of Fossils in the Burlington Beds at and near Augusta—Continued.

<table>
<thead>
<tr>
<th>Invertebrate Group</th>
<th>Horizons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Zincocrinus andrewsianus (McChesney)</td>
<td></td>
</tr>
<tr>
<td>Eutrochocrinus christyi (Shum.)</td>
<td></td>
</tr>
<tr>
<td>Agaricocrinus sp.</td>
<td></td>
</tr>
<tr>
<td>Rhipidomella burlingtonensis (Hall)</td>
<td></td>
</tr>
<tr>
<td>Actinoocrinus sp.</td>
<td></td>
</tr>
<tr>
<td>Uperocrinus pyriformis (Shum.)</td>
<td></td>
</tr>
<tr>
<td>Uperocrinus aequibrachiatus, var. asteriscus (M. and W.)</td>
<td></td>
</tr>
<tr>
<td>Uperocrinus burlingtonensis (McChesney)</td>
<td></td>
</tr>
<tr>
<td>Dorycrinus missouriensis (Shum.)</td>
<td></td>
</tr>
<tr>
<td>Agaricocrinus sp.</td>
<td></td>
</tr>
<tr>
<td>Actinoocrinus scitulus M. and W.</td>
<td></td>
</tr>
<tr>
<td>Actinoocrinus multiradiatus Shum</td>
<td></td>
</tr>
<tr>
<td>Actinoocrinus sp.</td>
<td></td>
</tr>
<tr>
<td>Cactocrinus longus (M. and W.)</td>
<td></td>
</tr>
<tr>
<td>Cystodictya sp.</td>
<td></td>
</tr>
<tr>
<td>Cystodictya sp.</td>
<td></td>
</tr>
<tr>
<td>Cactocrinus globiger (Hall)</td>
<td></td>
</tr>
<tr>
<td>Teleocrinus umbrosus (Hall)</td>
<td></td>
</tr>
<tr>
<td>Physocrinus ventricosus (Hall)</td>
<td></td>
</tr>
<tr>
<td>Stroctocrinus glyptus (Hall)</td>
<td></td>
</tr>
<tr>
<td>Platycrinus discoides O. and Sh.</td>
<td></td>
</tr>
<tr>
<td>Platycrinus burlingtonensis O. and Sh.</td>
<td></td>
</tr>
<tr>
<td>Eucladocrinus pleurovimosus (White)</td>
<td></td>
</tr>
<tr>
<td>Barycrinus sp.</td>
<td></td>
</tr>
</tbody>
</table>

### Blastoidaea

<table>
<thead>
<tr>
<th>Invertebrate</th>
<th>Horizons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pentactinocrinus violaceus (Shum.)</td>
<td>x</td>
</tr>
<tr>
<td>Orbitremites norwoodi (O. and S.)</td>
<td>x x x</td>
</tr>
</tbody>
</table>

### Bryozoa

<table>
<thead>
<tr>
<th>Invertebrate</th>
<th>Horizons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhombopora sp.</td>
<td>x</td>
</tr>
<tr>
<td>Evactinopora grandis M. and W.</td>
<td>x</td>
</tr>
<tr>
<td>Cystodictya sp.</td>
<td>x</td>
</tr>
<tr>
<td>Cystodictya sp.</td>
<td>x</td>
</tr>
</tbody>
</table>

### Brachiopoda

<table>
<thead>
<tr>
<th>Invertebrate</th>
<th>Horizons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leptaena analoga (Phillips)</td>
<td>x</td>
</tr>
<tr>
<td>Chonetes multifida (Winkler)</td>
<td>x x</td>
</tr>
<tr>
<td>Chonetes sp.</td>
<td>x</td>
</tr>
<tr>
<td>Productus burlingtonensis Hall</td>
<td>x x</td>
</tr>
<tr>
<td>Productus viminalis White</td>
<td>x x</td>
</tr>
<tr>
<td>Pustula alternata (N. and P.)</td>
<td>x x</td>
</tr>
<tr>
<td>Rhipidomella dubia (Hall)</td>
<td>x x x x</td>
</tr>
<tr>
<td>Rhipidomella burlingtonensis (Hall)</td>
<td>x x x x</td>
</tr>
<tr>
<td>Schizopora scrobiculata (Hall)</td>
<td>x x</td>
</tr>
<tr>
<td>Camarophoria bisinuata (Rowley)</td>
<td>x x</td>
</tr>
<tr>
<td>Canarococelia sp.</td>
<td>x</td>
</tr>
<tr>
<td>Dielesma ooeolensis Weller</td>
<td>x</td>
</tr>
<tr>
<td>Dielesma sp.</td>
<td>x</td>
</tr>
<tr>
<td>Spiriferina cf. S. subtexta White</td>
<td>x</td>
</tr>
<tr>
<td>Spirifer grimesi Hall</td>
<td>x x x x</td>
</tr>
<tr>
<td>Spirifer carinatus Rowley</td>
<td>x</td>
</tr>
<tr>
<td>Spirifer iscissus Rowley</td>
<td>x</td>
</tr>
<tr>
<td>Spirifer incertus Hall</td>
<td>x x x x</td>
</tr>
<tr>
<td>Brachythryis subhorlicularis (Hall)</td>
<td>x x x x</td>
</tr>
<tr>
<td>Reticularia pseudolinenea (Hall)</td>
<td>x x x</td>
</tr>
</tbody>
</table>

---

**RANGE OF BURLINGTON FOSSILS** 133
The mingling of Lower and Upper Burlington types of crinoids in bed 3 is worthy of attention. This is of importance in that it suggests the absence of a stratigraphic break between these divisions of the Burlington limestone.

Along Lost creek in Washington township, Lee county, three miles south of Augusta, there are several exposures of the Upper Burlington, both in the banks of the stream and in quarry openings. One such exposure appears in the south bank of the creek just back of the Lost Creek church (NE. 14, sec. 10). Eight feet of gray to brownish crinoidal limestone is shown. This corresponds in position to bed 7 of the general section at Augusta and to bed 6 of the section at Burlington. The following species were collected at this locality:

List of fossils from exposure of Upper Burlington limestone on Lost creek.

<table>
<thead>
<tr>
<th>Anthozoa</th>
<th>Crinoidae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dizygocrinus dodecadactylus (M. and W.)</td>
<td>Actinocrinus sp.</td>
</tr>
<tr>
<td>Dizygocrinus rotundus (Shum.)</td>
<td>Platycrinus (fragments of several species)</td>
</tr>
</tbody>
</table>

The mingling of Lower and Upper Burlington types of crinoids in bed 3 is worthy of attention. This is of importance in that it suggests the absence of a stratigraphic break between these divisions of the Burlington limestone.
BURLINGTON BEDS NEAR BENTONSPORT

Blastoidea—
Orbitremites norwoodi (O. and Sh.)

Bryozoa—
Fenestella sp.
Cosinium latum Ulrich

Brachiopoda—
Chonetes illinoiensis Worthen
Productus viminalis White
Productus sp.
Pustula alternata (N. and P.)
Rhipidomella dubia (Hall)
Rhipidomella burlingtonensis (Hall)
Schizophoria swallovi (Hall)
Spirifer grimesi Hall
Spirifer incertus Hall
Spirifer sp.
Brachythryris suborbicularis (Hall)
Spiriferella plena (Hall)
Cliothyridina incrassata (Hall)
Athyris lamellosa (Leveille)

On the Beebe property near Lost creek, west of Wever, there are several small quarry openings in the Upper Burlington, but the facilities for collecting at this place are not good at the present time. The forms obtained are:

List of fossils from Upper Burlington limestone west of Wever.

Anthozoa—
Zaphrentis sp.
Triplophyllum dalei (M-E. and H.)

Crinoidea—
Platycrinus (fragments of several species)
Strotocrinus sp.
Dorycerinus cornigerus (Hall)
Agaricocrinus gracilis (M. and W.)
Macrocerinus verneuilianus (Shum.)

Gastropoda—
Orthonychia sp.
Platyceras sp.
Lepetopsis capulus (Hall)

Van Buren County.—In Van Buren county, only one exposure of the Burlington limestone has been found. This is of the Upper Burlington and appears in the north bank of Des Moines river, just above the water level, one-half mile below the railway station at Bentonsport. It is due to the erosion of a small anticlinal uplift which almost parallels the river at this point. Keokuk limestone is exposed in the bluff higher up. The section is as follows:

Section of Upper Burlington limestone near Bentonsport.

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>Limestone, gray, subcrystalline ........................................</td>
</tr>
<tr>
<td>1.</td>
<td>Limestone, light gray, subcrystalline, with occasional thin crinoidal seams. Exposed ......................................</td>
</tr>
</tbody>
</table>

The fossils collected from these beds are listed below:

List of fossils from bed 1 of the Upper Burlington limestone near Bentonsport.

Anthozoa—
Zaphrentis sp.

Brachiopoda—
Productus viminalis White
Productus sp.
Productus sp.
Pustula alternata (N. and P.)
Pustula sp.
Rhipidomella burlingtonensis (Hall)
Rhyynchopora sp.
Spirifer sp.
Spirifer grimesi Hall
Spirifer sp.
Productus burlingtonensis Hall
Pustula spp.
Athyris lamiella (Leveille)
Clionothyridina incrassata (Hall)
Rhipidomella burlingtonensis (Hall)
Rhyynchopora sp.
Spirifer sp.
Platyceras sp.
Orthothyris quinceyensis (McClesney)
Orthonychia sp.

**List of fossils from bed 2 of the Upper Burlington limestone near Bentonport.**

**ANTHOZOA—**
Dielasma sp.
Amplexus sp.

**BRACHIOPODA—**
Chonetes sp.
Productus burlingtonensis Hall
Pustula alternata (N. and P.)
Pustula sp.
Rhynechonella sp.

**Louisa County.**—There are a number of important exposures of the Burlington limestone in Louisa county. These have been described previously by Udden.10

In the quarries on Honey creek near the north line of the southwest quarter of section 28, T. 73 N., R. 3 W., a nearly complete section can be worked out. Only the basal portion of the Lower Burlington fails to outcrop.

A generalized section of the Burlington at this locality, and lists of fossils collected by the writer from the successive beds are given below.

**General section of Burlington limestone in the quarries on Honey creek.**

**UPPER BURLINGTON.**

7. Limestone, gray, coarse-grained, crinoidal, cherty; lower and upper parts often dolomitized and represented by brownish soft fine-grained cavernous dolomitic limestone. A six inch layer at the top is in some places rich in fish teeth. With stylolitic seams ............................................. 10 to 10½

6. Limestone, gray, subcrystalline, locally crinoidal part. Tends to be greenish in upper part owing to included greenish specks .................................................. 6 to 7½

**LOWER BURLINGTON.**

5. Limestone, gray, subcrystalline; some layers crinoidal; filled with irregular nodules .......................................................... 1 to 2½

4. Limestone, brownish, soft, fine-grained; dolomitic for the most part, but locally crinoidal and little altered in upper part; nodular above but more massive below ........................................... 7

3. Chert band ........................................................ ½

2. Limestone, brownish, crinoidal; grading laterally into fine-grained soft dolomitic limestone except in basal part. With nodules, lenses and bands of gray chert in upper part ................. 9

1. Limestone, brownish yellow, dolomitic; with a discontinuous seam of brownish crinoidal limestone in lower part; filled with irregular nodular seams of gray chert which weathers whitish. Exposed .......................................................... 3

---

BURLINGTON FOSSILS IN LOUISA COUNTY

Beds 1 to 6 are well exposed in the creek bank just below the main quarry. Beds 5 to 7 are typically developed in the main quarry.

There is a suggestion of a disconformity at the base of bed 5 in the bluff section, the contact of this member with bed 4 being undulating. It is probable, however, that there is no stratigraphic break at this horizon, and that the relationship is due to uneven dolomitization, for the lower bed is partly altered at this place.

One-fifth mile upstream from the main quarry and in the opposite bank, there is a fresh quarry opening which shows twelve feet of basal Keokuk limestone overlying bed 7 of the above section.

A table showing the species collected and their range in the Burlington limestone on Honey creek follows:

Table Showing Range of Fossils in the Burlington Limestone, Honey Creek Section, Louisa County.

<table>
<thead>
<tr>
<th>Horizons</th>
<th>2</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anthozoa</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hadrophyllum glans (White)</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Triplophyllum dalei (M.-E. and H.)</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Zaphrentis sp.</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Zaphrentis sp.</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td><strong>Crinoidea</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actinocrinus multiradiatus Shum.</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Actinocrinus sp.</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Platyicrinus cf. P. glyptus Hall</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Platyicrinus sp.</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Platyicrinus sp.</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Platyicrinus sp.</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Uperocrinus pyriformis (Shum.)</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Batocrinus laura (Hall)</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Batocrinus clypeatus (Hall)</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macrocrinus konincki (Shum.)</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macrocrinus verneuiianus (Shum.)</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Dichocrinus sp.</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Euryocrinus sp.</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Strotocrinus regalis (Hall)</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Strotocrinus glyptus (Hall)</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Physostocrinus ventricosus (Hall)</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Teleocrinus umbrosus (Hall)</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Dizygocrinus rotundus (Shum.)</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Eutrochocrinus christyi (Shum.)</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Horizons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------</td>
<td>----------</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td><strong>Blastoidea</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pentremites elongatus</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Pentremites sp.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metablastus lineatus</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Orbitremites norwoodi</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td><strong>Bryozoa</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fenestella burlingtonensis</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fenestella serratula</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Fenestella sp.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhombopora gracilis</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Rhombopora sp.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Brachiopoda</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chonetes sp.</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Chonetes sp.</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Orthotetes sp.</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Pustula sp.</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Pustula sp.</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Productus burlingtonensis</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhipidomella burlingtonensis</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhipidomella sp.</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Schizopora swallowi</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Spirifer inerti</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Spirifer grimesi</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Spirifer sp.</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Brachythyris suborbicularis</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Spiriferella plena</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Reticularia pseudolineata</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Athyris lamellosa</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td><strong>Pelecypoda</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ariculopecten sp.</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Myalina sp.</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td><strong>Gastropoda</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orthonychia sp.</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Lepetopsis capulus</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td><strong>Vertebrata</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fish teeth</td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

The Anderson quarry exposure is of interest in that it shows the contact between the Kinderhook and the Lower Burlington.
The Kinderhook section at this locality has been described on page 63. The Burlington succession is as follows:

Section in Anderson’s quarry on the east bank of Smith creek west of the center of the SW. ¼, sec. 23, Tp. 73 N., R. 2 W.

7. Drift ................................................................. 5

**UPPER Burlington.**

6. Limestone, gray, coarse-grained, crinoidal (bed 7 of the Honey creek section) .................................................. 1½

5. Limestone, gray, subcrystalline, with crinoidal seams, stylolytic (bed 6 of the Honey creek section) ........................................ 5½

**LOWER Burlington.**

4. Limestone, gray, subcrystalline, cherty (bed 5 of the Honey creek section) .............................................................. 1½

3. Mostly concealed. Probably consisting of crinoidal limestone and brownish dolomitic rock. (Beds 3 and 4 and upper part of bed 2 of the Honey creek section) ........................................ 12

2. Limestone, soft, dolomitic, brownish; cherty in middle and less dolomitic above ..................................................... 7

1. Limestone, buff, dolomitic, soft ......................................... 1

The following species were collected by the writer from bed 5 at this place:

List of fossils from bed 5 of Burlington limestone in Anderson quarry.

**Anthozoa—**

<table>
<thead>
<tr>
<th>Species</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hadrophyllum glans</td>
<td>White</td>
</tr>
<tr>
<td>Bryozoa—</td>
<td></td>
</tr>
<tr>
<td>Cystodictya sp.</td>
<td></td>
</tr>
</tbody>
</table>

**Brachiopoda—**

<table>
<thead>
<tr>
<th>Species</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chonetes illinoensis</td>
<td>Worthen</td>
</tr>
<tr>
<td>Chonetes sp.</td>
<td></td>
</tr>
<tr>
<td>Productus burlingtonensis</td>
<td>Hall</td>
</tr>
<tr>
<td>Rhipidomella dubia</td>
<td>(Hall)</td>
</tr>
<tr>
<td>Rhipidomella burlingtonensis</td>
<td>(Hall)</td>
</tr>
<tr>
<td>Spirifer grimesi</td>
<td>Hall</td>
</tr>
<tr>
<td>Spiriferella plena</td>
<td>(Hall)</td>
</tr>
<tr>
<td>Brachythryris</td>
<td>suborbicularis (Hall)</td>
</tr>
</tbody>
</table>

The marked thinning of both divisions of the Burlington in tracing them from Des Moines county northwestward is emphasized by the two preceding sections. Thus the Lower Burlington has decreased in thickness from forty-three feet at Burlington to one-half that amount in Louisa county, while the Upper Burlington has decreased in the same way from twenty-seven to seventeen feet.

The following sections have been copied from Udden’s report on the Geology of Louisa County. 11

**Section in a quarry belonging to James Elrick near the south county line on the left bank of Smith creek (After Udden).**

<table>
<thead>
<tr>
<th>Bed Number</th>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Weathered limestone</td>
<td>22</td>
</tr>
<tr>
<td>11</td>
<td>Chert</td>
<td>⅓</td>
</tr>
<tr>
<td>10</td>
<td>Crinoidal limestone, with fish teeth near top</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>Soft limestone</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bed</th>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Blue shale, with some chert below</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Fine-grained, yellowish limestone, with <em>Productus semiverticulatus</em>, <em>Spirifer plenus</em>, a <em>Pentremites</em>; in straight even ledges, with fish teeth above</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Blue shale</td>
<td>1/2</td>
</tr>
<tr>
<td>5</td>
<td>Bluish, rather fine-grained limestone</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Chert layers, interrupted</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Coarse-grained, yellowish or white, crinoidal limestone</td>
<td>4 1/2</td>
</tr>
<tr>
<td>2</td>
<td>Bluish white crinoidal limestone, upper ledges very evenly bedded, lower ledges somewhat fine-grained, with <em>Dietasma</em> rules</td>
<td>8</td>
</tr>
<tr>
<td>1</td>
<td>Softer limestone, with some quartz geodes</td>
<td>1</td>
</tr>
</tbody>
</table>

Bed 1 and possibly a part of bed 2 doubtless belong to the Lower Burlington, while those above are referred to the Upper Burlington, except beds 11 and 12 which represent the basal Keokuk.

"Section seen in some quarries on Gospel run, near the north line of sec. 27, Tp. 73 N., R. 3 W. (After Udden)."

<table>
<thead>
<tr>
<th>Bed</th>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Chert and disintegrated limestone, with <em>Entrochoerinus lovei</em></td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Crinoidal limestone, somewhat thin-bedded, with a <em>Pentremites</em></td>
<td>9</td>
</tr>
<tr>
<td>6</td>
<td>Thin-bedded, crinoidal limestone</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Chert</td>
<td>3/4</td>
</tr>
<tr>
<td>4</td>
<td>Yellow irregularly bedded limestone</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Yellow disintegrated crinoidal limestone</td>
<td>3 1/2</td>
</tr>
<tr>
<td>2</td>
<td>Coarsely aggregated crinoidal limestone, with <em>Lobocrinus pyriformis</em></td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>Shaly, disintegrated material</td>
<td>1&quot;</td>
</tr>
</tbody>
</table>

Beds 1 to 5 of this section represent the Lower Burlington, and the higher beds, the Upper Burlington.

"Sections in a ravine following the west bank of the railroad one and a half miles north of Morning Sun, in the northeast corner of sec. 13, Tp. 73 N., R. 5 W. (After Udden)."

<table>
<thead>
<tr>
<th>Bed</th>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Chert layers</td>
<td>5/6</td>
</tr>
<tr>
<td>3</td>
<td>White or yellowish, crinoidal limestone, with teeth of <em>Orodus, Deltodus and Cladodus</em></td>
<td>2 1/2</td>
</tr>
<tr>
<td>2</td>
<td>Greenish white crinoidal limestone, with <em>Lobocrinus pyriformis</em>, <em>Dicyocrinus rotundus</em>, <em>Dorycrinus quinquedactylus</em>, <em>Entrochoerinus lovei</em>, <em>Pentremites elongatus</em>, <em>Actinocrinus scitulus</em></td>
<td>1 1/2</td>
</tr>
<tr>
<td>1</td>
<td>White crinoidal limestone, with <em>Echinodomella burlingtonensis</em>, and <em>Spirifer plenus</em></td>
<td>4&quot;</td>
</tr>
</tbody>
</table>

All of these beds are referable to the Upper Burlington.

"Section in J. H. Wasson's quarry in the south bank of the south branch of Long creek in the northwest corner of sec. 23, Tp. 74 N., R. 5 W. (After Udden)."

<table>
<thead>
<tr>
<th>Bed</th>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Disintegrated limestone, with bands of chert</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Yellow, disintegrated limestone</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Blue shale</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Yellow slightly disintegrated crinoidal limestone, with small holes filled with calcite crystals (also zinc blende)</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Yellowish, partly disintegrated limestone, with fish teeth, such as</td>
<td></td>
</tr>
</tbody>
</table>
Deltoodus spatulatus, Psammodus glyptus, Cladodus sp., Helodus sp., and Orodus sp. ................................................................. 1½
1. Crinoidal white limestone in ledges from six to ten inches in thickness with Eutrocorinus loeci, Batoerinus laura var. sinuosus, Batoerinus laura, Dizygoerinus rotundus .................. 4½"'

 Beds 1 and 2 are of Upper Burlington age; beds 3 to 6 are basal Keokuk.

"Section in Gray's quarry near the north bank of the north branch of Long creek in the NE.1/4 of the NW.1/4 of sec. 3, Tp. 74 N., R. 5 W. (After Udden).

5. Yellow disintegrated crinoidal limestone, with fish teeth near the base, and with Schizophoria walloti, Eutrocorinus christyi, Batoerinus laura, Dizygoerinus rotundus, and teeth of Deltoodus 5
4. Enerinitial white limestone in heavy ledges, with Productus semireticulatus, Productus burlingtonensis, Spirifer grimesi 3
3. Chert ................................................................. 5/6
2. Brownish yellow porous, disintegrated limestone ........................................ 3
1. Bluish white crinoidal limestone, with occasional crinoids near top .................. 5"

This succession is entirely of Upper Burlington age.


6. Bands of chert .......................................................... 1
5. Yellowish shaly material or disintegrated limestone ................................. 2
4. Yellow partly disintegrated limestone, with chert bands and fish teeth in the upper part, containing Deltoopsis bivalvatus, Deltoopsis conexus, Deltoodus spatulatus, Cladodus, fragments of spines ................................................................. 2
3. Bluish white crinoidal limestone in ledges from six to ten inches in thickness, with Productus burlingtonensis ........................................ 2
2. Shelly limestone, with many brachiopods and Igoceis capulus 1
1. Crinoidal white limestone .................................................. 2"

These beds again represent the Upper Burlington.

Washington County.—In Washington county, the Burlington and Keokuk limestones have not been differentiated in previous reports. Thus, Bain12 in his Geology of Washington County describes them under the title of "Augusta formation." He says:

"The greater number of fossils found belong to the Burlington fauna, though a few Keokuk forms occur. The formation is, however, as a whole, a distinct, well marked, stratigraphic unit for the region studied. It is neither advisable nor possible to divide it into formations which could be separately mapped".

In the course of the present study, it has been found that the Burlington and Keokuk limestones are recognizable as strati-

graphic units, although their formational characteristics are not nearly so pronounced as in the counties to the southeast.

The best exposures are on and near Crooked creek, northwest of the town of Washington. The Eckles quarry section is typical (SW. 1/4, sec. 2, Tp. 75 N., R. 8 W.).

**Eckles quarry section.**

<table>
<thead>
<tr>
<th><strong>FEET</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Drift</td>
<td>................................................. 12</td>
</tr>
<tr>
<td>4. Limestone, gray, medium-grained, with slight bluish tint, thin-bedded</td>
<td>.................................................</td>
</tr>
<tr>
<td>3. Shaly parting</td>
<td>................................................. 2½</td>
</tr>
<tr>
<td>2. Limestone, gray, crinoidal, with occasional small lenses of chert and thin layers of brown dolomitic limestone, with stylolytic seams</td>
<td>................................................. 6</td>
</tr>
<tr>
<td>1. Limestone, gray, crinoidal, with greenish tint above; stylolytic seams. Bears <em>Costatum latum</em> and other Burlington fossils</td>
<td>................................................. 10</td>
</tr>
</tbody>
</table>

The fauna of the above beds indicates their Upper Burlington age.

**The Keokuk Limestone**

**NOMENCLATURE AND CHARACTER**

The Keokuk formation as defined by Hall consists of cherty limestone at the base, the encrinal limestone or "Lower Archimedes Limestone" of Owen directly above, which is well exposed at Keokuk, and the overlying geode bearing shales. Worthen's classification is essentially the same as that of Hall.

In the reports on the geology of Lee and Des Moines counties Keyes designated the basal cherty limestone as the Montrose cherts and referred them to the Upper Burlington. He described the Geode bed as a distinct formation. Gordon likewise referred the Montrose cherts exposed in Van Buren county to the Burlington. He includes the Keokuk limestone, the Geode shales and the Warsaw shales and limestones in the Keokuk stage. In his Geology of Henry County, Savage includes the limestone phase and the Geode shales in the Keokuk.

The present study has demonstrated the Keokuk age of the Montrose cherts. The Geode shales on the other hand are more

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13 Geol. of Iowa, vol. I, part I, p. 94; 1858.
14 Idem, p. 193.
closely related faunally to the Warsaw formation than to the Keokuk. As at present defined, therefore, the Keokuk formation consists of the transition beds known as the Montrose cherts, which are about thirty feet in thickness, and the Keokuk limestone, which is about forty feet in thickness. The lower division consists of alternating layers of gray and bluish cherty limestone. In this division, several Keokuk types of brachiopods appear for the first time. Some of these evidently represent forms intermediate between typical Burlington types and true Keokuk forms. The crinoid fauna of the beds shows similar characteristics, as was pointed out by Wachsmuth and Springer. They say:

"The transition beds are more or less fossiliferous throughout, though the occurrence of the fossils is irregular, and their preservation very variable. They exhibit in an irregular manner the lithologic characters of both formations, while the crinoidal remains which have been obtained from them show such an intermingling and blending of the Burlington and Keokuk species, that it is impossible to say where the one begins and the other ends. The majority of the crinoids found in them can neither be called Burlington nor Keokuk series, and may often be identified as either. They constitute a kind of intermediate type between them, and throw much light upon the growth of the individual and the development of species in the course of time."

This part of the Keokuk formation is well exposed near Augusta, Iowa, and in Cedar Glen, between Hamilton and Warsaw, Illinois. The beds above, constituting the Keokuk limestone of earlier writers, consist of layers of gray to bluish limestone, alternating with beds of shale, which are increasingly prevalent and thicker towards the top. It appears that there was a slow contraction of the sea during Keokuk time, as is indicated by this change in the sediments.

**STRATIGRAPHIC RELATIONS**

No convincing evidence of a stratigraphic break has been found either at the base or at the top of the Keokuk. Indeed the faunal transition from the Burlington into the Keokuk be-

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low and from the Keokuk into the Lower Warsaw (Geode bed) above is such as to preclude the possibility of an important disconformity at either level. However, the presence of rolled shells of *Spirifer grimesi* in the basal bed of the Keokuk suggests a shallowing of the sea in the region at the close of Burlington time.

**AREAL DISTRIBUTION**

The Keokuk limestone forms the surface rock over a comparatively small area in southeastern Iowa. It has been recognized in Lee, Van Buren, Des Moines, Henry, Louisa, Washington and Keokuk counties. It outcrops also in Hancock county, Illinois, situated directly east of Lee in Iowa, and in Clark county, Missouri, to the south of Lee. In all of the Iowa counties, however, its areal extent is limited. In Van Buren county it comes to the surface only along the valley of Des Moines river in the vicinity of Bonaparte and Bentonsporn where it has been exposed by the erosion of a small anticlinal uplift.

Its distribution in Lee county is shown on the geological map of this area prepared by Keyes. The more important areas underlain by the Keokuk are (1) along the valley of Mississippi river and its tributaries at and near the city of Keokuk; (2) in northern Washington township and (3) over the greater part of Denmark township.

It also forms a northwest-southeast belt several miles wide in the southwestern part of Des Moines county, to the north of Lee.

The Keokuk of Henry county comes to the surface only over a small area along the valley of Skunk river in Jackson township and appears to have been exposed by the erosion of a gentle anticline.

The Keokuk and Burlington limestones have not been differentiated on the geological map of Louisa county but all known exposures of the Keokuk are confined to Morning Sun, southern Wapello and southwestern Elliot townships, in the southern part of the county.

The Keokuk of Washington county likewise has not been dif-

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ferentiated by previous workers in the field nor has there been found an exposure of typical Keokuk in the area during the present investigation. It seems probable, however, that this limestone underlies the drift over a narrow belt extending through the middle of the county in a northwest-southeast direction, bounded on the northeast by the Burlington beds and on the southwest by the St. Louis limestone, which succeeds the Keokuk directly in this part of the state.

In Keokuk county, exposures of the Keokuk limestone occur along Rock creek north of Ollie. But doubtless it forms the surface rock at several other localities, notably along a belt between the St. Louis and Burlington areas in the northeastern part of the county.

AREAL DESCRIPTION BY COUNTIES

Lee County and adjacent parts of Illinois.—The type section of Keokuk limestone is at Keokuk, Iowa. Excellent facilities for studying the formation at that place are afforded in the exposures along Soap creek and in a quarry in the Mississippi river bluff, near the mouth of the creek, where an almost complete succession of the beds is shown (fig. 3).
Generalized section of Keokuk limestone along Soap creek and near its mouth, Keokuk.

16. Limestone, gray, subcrystalline .................................................1 1/3-3 1/2
15. Shale, bluish, argillaceous; locally grading wholly or in part into gray subcrystalline limestone .........................................2 1/2-3 1/2
14. Limestone, ash-colored, fine-grained, magnesian; locally grading in part into gray more crystalline fossiliferous limestone. The "cottonwood ledge" of quarrymen .......... 1 1/2-2 1/2
13. Limestone, bluish gray, subcrystalline; Composita globosa abundant .................................................1 1/2-2 1/2
12. Limestone, bluish gray, thin-bedded, cherty; with shaly seams .................................................1 5/6-2 1/2
11. Limestone, massive, bluish, subcrystalline; with layers and seams of gray fine-grained magnesian limestone and calcareous shale. Fish teeth locally abundant at base ............... 4 1/2-6
10. Limestone, bluish, subcrystalline, Spirifer keokuk abundant .................................................0 -1 1/2
9. Shale, bluish, argillaceous, very fossiliferous; locally with seams of gray subcrystalline limestone .........................................1 -1 1/2
8. Limestone, gray, compact, most of the layers thin and lentillic; with thin intercalated shaly seams. Fish teeth in topmost layer ..................................................2 3/4-3
7. Limestone, gray, subcrystalline, the "gray ledge" or "eighteen inch ledge" of quarrymen. Bearing a few fish teeth ................................................................. 1 -2 1/2
6. Limestone, light gray, massive, cherty; locally grading into shale in part. A shaly parting at the base is rich in crinoids. The "white ledge" of quarrymen ..................................................3 -4
5. Limestone, gray, impure, massive, fine-grained, magnesian, cherty; locally with occasional seams of gray, subcrystalline limestone; bearing a few large calcite geodes many of which contain millerite: the "millerite ledge" of quarrymen ..................................................5 -6
4. Limestone, light gray, impure, soft; bearing occasional crinoids .................................................. 5/6-1
3. Limestone, bluish, medium grained; bearing a few fish teeth .................................................. 3/4-1 1/3
2. Limestone, grayish, medium-grained ................................................. 2 -3
1. Limestone, grayish, medium-grained, cherty; fish teeth locally abundant. Exposed .................................................. 6

The fossils of the successive beds are listed below:

List of fossils from bed 1 of the Keokuk limestone at Keokuk.

ANTHozoA—
Triplophyllum dalei (M.-E. and H.)
Palaeaeis obtusus (M. and W.)

BRYozoA—
Fenestella triserialis Ulrich f
Fenestella species II f
Fenestella limitaris Ulrich f
Fenestella serratula Ulrich
Fenestella tenax Ulrich
Polypora burlingtonensis Ulrich f
Cystodictya lineata Ulrich
Worthenopora spinosa Ulrich
Glyptopora sp.

BrachiopoDA—
Orthotetes keokuk (Hall)
Productus cf. P. gallatinensis Girty
Productus setigerus Hall
Avonia sp.
Pustula alternata (N. and P.)

Pustula biseriata (Hall)
Tetraecamera subtrigona (M. and W.)
Spirifer cf. S. keokuk Hall
Spirifer tenuicostatus Hall
Brachythyrus suborbicularis (Hall)
Syngothyris subesuidatus (Hall) f
Spiriferella neglecta (Hall)
Reticularia pseudolineata (Hall)
Athyris lamellosa (Leveille) f
Composita trinuclea (Hall)

Pelecypoda—
Aviculopecten sp.
Cypricardium f sp.

Gastropoda—
Platycerium equilateralis Hall
Orthothyrea pabulocrinus (Owen)

Vertebrata—
Fish teeth (Sandalodus, etc.)
The following additional species are listed from this bed by C. H. Gordon:

Eutrochocrinus planodiscus (Hall)
Platyceras fissurella Hall

List of fossils from bed 2 of Keokuk limestone at Keokuk.

**ANTHOZOA**
- Triplophyllum dalei (M.-E. and H.)

**VERMES**
- Enchostoma sp.

**CRINOIDEA**
- Actinocrinus sp.

**BRYOZOA**
- Fenestella multispinosa Ulrich

**BRACHIOPODA**
- Productus viminalis White
- Productus setigerus Hall
- Productus sp.
- Pustula biseriata (Hall)
- Rhipidomella dubia (Hall)
- Tetracamera subuneata (Hall)
- Rhynchohorea beecheri (Greger)

**PELICYPODA**
- Myalina keokuk Wothen

**GASTROPODA**
- Platyceras equilateralis Hall

**VERTEBRATA**
- Fish teeth

List of fossils from bed 3 of Keokuk limestone at Keokuk.

**ANTHOZOA**
- Triplophyllum dalei (M.-E. and H.)

**BRACHIOPODA**
- Orthotetes keokuk (Hall)
- Productus setigerus Hall
- Pustula biseriata (Hall)
- Rhipidomella dubia (Hall)

**CRINOIDEA**
- Spiriferella neglecta (Hall)
- Brachythyris suborbicularis (Hall)
- Syringothyris sp.
- Reticularia pseudolineata (Hall)
- Cliothyridina parvirostris (M. and W.)

List of fossils from bed 4 of Keokuk limestone at Keokuk.

**ANTHOZOA**
- Triplophyllum dalei (M.-E. and H.)
- Amplexus sp.

**CRINOIDEA**
- Actinocrinus pernodosus Hall
- Actinocrinus lowei Hall
- Agaricocrinus americanus var. tuberosus Hall

**BRYOZOA**
- Fenestella multispinosa Ulrich

**BRACHIOPODA**
- Productus sp.
- Pustula alternata (N. and P.)
- Spiriferella neglecta (Hall)
- Brachythyris suborbicularis (Hall)
- Reticularia pseudolineata (Hall)
- Cliothyridina sp.

**GASTROPODA**
- Platyceras equilateralis Hall

Gordon reports three species of crinoids from this bed which were not found by the writer, namely:

Agaricocrinus americanus (Roemer)
Macrocrinus lagunculus (Hall)
Platycrinus saffordi Hall

List of fossils from bed 5 of Keokuk limestone at Keokuk.

**ANTHOZOA**
- Triplophyllum dalei (M.-E. and H.)
- Barycrinus sp.

**CRINOIDEA**
- Eucladocrinrus sp.
- Barycrinus sp.

**BRYOZOA**
- Fenestella compressa Ulrich
- Fenestella serrata Ulrich
- Fenestella tenax Ulrich
- Archimedes owenanus Hall
- Polypora halliana Prout
- Rhombopora dichotoma Ulrich
- Cystodictya lineata Ulrich

List of fossils from bed 6 of Keokuk limestone at Keokuk.

**ANTHOZOA**
- Zaphrentis sp.
- Amplixus sp.
- Triplophyllum dalei (M.-E. and H.)
- Hadrophyllum (species undescribed)
- Palaeacis obtusus (M. and W.)

**CRINOIDEA**
- Agaricocrinus americanus var. tuberosus Hall
- Actinocrinus sp.
- Actinocrinus lowei Hall
- Actinocrinus pernodosus Hall
- Uperocrinus nashvillae (Hall)
- Platycrinus affordi Hall
- Platycrinus sp.
- Platycrinus sp.
- Barycrinus spurius (Hall)
- Barycrinus stellatus (Hall)

**BRYOZOA**
- Fenestella serrata Ulrich
- Fenestella tenax Ulrich
- Fenestella compressa Ulrich
- Fenestella species III
- Fenestella species II
- Polypora halliana Prout
- Polypora varsoviensis Prout
- Polypora species II
- Composita trinuclea (Hall)

**PELECYPODA**
- Conocardium sp.
- Myalina keokuk Worthen

**GASTROPODA**
- Platyceras equilateralis Hall

Gordon found the following crinoids in this bed:

**ANTHOZOA**
- Zaphrentis sp.
- Agaricocrinus americanus (Roemer)
- Barycrinus magister (Hall)

**CRINOIDEA**
- Dorycrinus sp.
- Agaricocrinus americanus var. tuberosus Hall

**BRYOZOA**
- Fistulipora spergenensis Rominger

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Stenopora sp.
Fenestella serrulata Ulrich
Fenestella multispinosa Ulrich
Fenestella triserialis Ulrich
Fenestella compressa Ulrich
Fenestella species I
Fenestella species II
Hemitypna perstriata Ulrich
Polypora simulatrix Ulrich
Polypora species I
Polypora sp.
Archimedes cf. A. negligens Ulrich
Pinnatopora sp.
Rhombopora attenuata Ulrich

BRACHIOPODA—
Orthotetes keokuk (Hall)
Productus cf. P. gallatinensis Girty
Productus setigerus Hall
Productus ovatus Hall
Productus sp.
Productus sp.
Pustula biseriata (Hall)
Pustula alternata (N. and P.)

List of fossils from bed 10 of the Keokuk limestone at Keokuk.

ANTHOZOA—
Zaphrelius varsoviensis Worthen
Triplophyllum dalei (M.-E. and H.)
Amplexus sp.
Monilopora beecheri Grabau

CRINOIDEA—
Batoicrinus sp.
Dorycrinus mississippiensis Roemer
Dorycrinus sp.
Agaricocrinus americananus var. tuberosus Hall
Barycrinus tumidus (Hall)
Barycrinus stellatus (Hall)

BRYOZOA—
Fistulipora sp.
Leioclema punctatum (Hall)
Fenestella serrulata Ulrich
Fenestella tenax Ulrich
Fenestella multispinosa Ulrich
Fenestella triserialis Ulrich
Fenestella compressa Ulrich
Fenestella rudia Ulrich
Fenestella sp.
Fenestella sp.
Hemitypna proutana Ulrich
Hemitypna perstriata Ulrich
Polypora varsoviensis Prout
Polypora rectorosa Ulrich
Polypora maccoyanas Ulrich
Polypora simulatrix Ulrich
Polypora sp.

List of fossils from bed 9 of the Keokuk limestone at Keokuk.

ANTHOZOA—
Zaphrelius varsoviensis Worthen
Triplophyllum dalei (M.-E. and H.)
Amplexus sp.
Monilopora beecheri Grabau

CRINOIDEA—
Batoicrinus sp.
Dorycrinus mississippiensis Roemer
Dorycrinus sp.
Agaricocrinus americananus var. tuberosus Hall
Barycrinus tumidus (Hall)
Barycrinus stellatus (Hall)

BRYOZOA—
Fistulipora sp.
Leioclema punctatum (Hall)
Fenestella serrulata Ulrich
Fenestella tenax Ulrich
Fenestella multispinosa Ulrich
Fenestella triserialis Ulrich
Fenestella compressa Ulrich
Fenestella rudia Ulrich
Fenestella sp.
Fenestella sp.
Hemitypna proutana Ulrich
Hemitypna perstriata Ulrich
Polypora varsoviensis Prout
Polypora rectorosa Ulrich
Polypora maccoyanas Ulrich
Polypora simulatrix Ulrich
Polypora sp.

Pustula biseriata (Hall)
Pustula alternata (N. and P.)

List of fossils from bed 10 of the Keokuk limestone at Keokuk.

ANTHOZOA—
Zaphrelius varsoviensis Worthen
Triplophyllum dalei (M.-E. and H.)
Amplexus sp.
Monilopora beecheri Grabau

CRINOIDEA—
Batoicrinus sp.
Dorycrinus mississippiensis Roemer
Dorycrinus sp.
Agaricocrinus americananus var. tuberosus Hall
Barycrinus tumidus (Hall)
Barycrinus stellatus (Hall)

BRYOZOA—
Fistulipora sp.
Leioclema punctatum (Hall)
Fenestella serrulata Ulrich
Fenestella tenax Ulrich
Fenestella multispinosa Ulrich
Fenestella triserialis Ulrich
Fenestella compressa Ulrich
Fenestella rudia Ulrich
Fenestella sp.
Fenestella sp.
Hemitypna proutana Ulrich
Hemitypna perstriata Ulrich
Polypora varsoviensis Prout
Polypora rectorosa Ulrich
Polypora maccoyanas Ulrich
Polypora simulatrix Ulrich
Polypora sp.

Pustula biseriata (Hall)
Pustula alternata (N. and P.)

List of fossils from bed 9 of the Keokuk limestone at Keokuk.

ANTHOZOA—
Zaphrelius varsoviensis Worthen
Triplophyllum dalei (M.-E. and H.)
Amplexus sp.
Monilopora beecheri Grabau

CRINOIDEA—
Batoicrinus sp.
Dorycrinus mississippiensis Roemer
Dorycrinus sp.
Agaricocrinus americananus var. tuberosus Hall
Barycrinus tumidus (Hall)
Barycrinus stellatus (Hall)

BRYOZOA—
Fistulipora sp.
Leioclema punctatum (Hall)
Fenestella serrulata Ulrich
Fenestella tenax Ulrich
Fenestella multispinosa Ulrich
Fenestella triserialis Ulrich
Fenestella compressa Ulrich
Fenestella rudia Ulrich
Fenestella sp.
Fenestella sp.
Hemitypna proutana Ulrich
Hemitypna perstriata Ulrich
Polypora varsoviensis Prout
Polypora rectorosa Ulrich
Polypora maccoyanas Ulrich
Polypora simulatrix Ulrich
Polypora sp.

Pustula biseriata (Hall)
Pustula alternata (N. and P.)
MISSISSIPPIAN STRATA OF IOWA

BRACHIOPODA—
Orthotetes keokuk (Hall)
Productus setigerus Hall
Pustula alternata (N. and P.)
Pustula biseriata (Hall)
Rhipidomella dubia (Hall)
Dielasma sinuata Weller
Spirifer keokuk Hall

Spirifer tenuicostatus Hall
Syringothyris textus (Hall)
Spiriferella neglecta (Hall)
Reticularia pseudolineata (Hall)
Eumetria veerneiuliana (Hall)
Composita globosa Weller

PELECYPODA—
Myalina keokuk Worthen

List of fossils from bed 11 of Keokuk limestone at Keokuk.

ANTHOZOA—
Triplophyllum dalei (M.-E. and H.)

BRYOZOA—
Stenopora sp.

BRACHIOPODA—
Orthotetes keokuk (Hall)
Productella sp.
Productus setigerus Hall
Productus sp.
Productus sp.
Pustula alternata (N. and P.)
Pustula biseriata (Hall)
Rhipidomella dubia (Hall)
Dielasma sp.

Spirifer keokuk Hall

GASTROPODA—
Platyceras sp.
Orthonychia sp.
Conularia cf. C. missouriensis Swallow

TRILOBITA—
Griffithides sp.

List of fossils from bed 12 of Keokuk limestone at Keokuk.

ANTHOZOA—
Triplophyllum dalei (M.-E. and H.)

BRYOZOA—
Stenopora sp.
Stenopora sp.
Archimedes sp.
Fenestella tenax Ulrich

Ptilopora sp.
Rhombozoa sp.

BRACHIOPODA—
Stenopora sp.
Pustula alternata (N. and P.)
Spirifer cf. S. keokuk Hall
Composita obmaxima (McChesney)

List of fossils from bed 13 of Keokuk limestone at Keokuk.

ANTHOZOA—
Triplophyllum dalei (M.-E. and H.)
Zaphrentis cf. Z. spinulosus (M.-E. and H.)
Zaphrentis sp.
Monilopora beecheri Grabau

Agaricocrinus americanus var. tuberosus Hall
Actinoeinus pernodosus Hall
Dorycrinus sp.

Fenestella species III
Ptyloceras sp.

BRYOZOA—
Fistulipora spergosensis Rom.
Fenestella serrata Ulrich
Fenestella species II
Fenestella sp.

Fenestella striata Cumin.
Fenestella varsoviensis Prout
Rhombozoa varians Ulrich

BRACHIOPODA—
Productus sp.
Pustula alternata (N. and P.)
Spirifer keokuk Hall
Brachythyrus subcardiformis (Hall)
Composita globosa Weller

TRILOBITA—
Griffithides sp.

List of fossils from bed 14 of Keokuk limestone at Keokuk.

ANTHOZOA—
Triplophyllum dalei (M.-E. and H.)
Monilopora beecheri Grabau

Barycrinus sp.

BRYOZOA—
Fenestella sp.
Cystodictya lineata Ulrich

BRACHIOPODA—
Fustula biseriata (Hall)
Several additional species are reported from this bed by Gordon, viz:

- Uperocrinus nashvilleae (Hall)
- Dizygoocrinus biturbinatus (Hall)
- Dorycrinus mississippiensis Roemer
- Agaricocrinus wortheni Hall
- Agaricocrinus americanus (Roemer)
- Barycrinus tumidus (Hall)
- Archimedes owenanus Hall

List of fossils from bed 15 of Keokuk limestone at Keokuk.

| ANTHOZOAA | Triplophyllum dalei (M.-E. and H.) | Rhipidomella dubia (Hall) |
| NYOZOA | Stenopora sp. | Spirifer cf. S. keokuk Hall |
| BRACHIOPODA | Pustula alternata (N. and P.) | Brachythyris subbicornaris (Hall) |
| | | Brachythyris subcardiformis (Hall) |
| | | Composita globosa Weller |

List of fossils from bed 16 of Keokuk limestone at Keokuk.

| ANTHOZOAA | Triplophyllum dalei (M.-E. and H.) | Productus ovatus Hall |
| NYOZOA | Monilopora beacheri Grabau | Productus cf. P. gallatinensis Girty |
| | Stenopora sp. | Productus sp. |
| | Stenopora sp. | Pustula biseriata (Hall) |
| | Archimedes owenanus Hall | Rhipidomella dubia (Hall) |
| | Polypora varsoviensis Prout | Tetracamera subtrigona (M. and W.) |
| | Hemitrypa sp. | Dielasma sp. |
| | Fenesella serrata Ulrich | Spirifer cf. S. keokuk Hall |
| | Fenesella compressa Ulrich | Spirifer tenuicostatus Hall |
| | Fenesella triserialis Ulrich | Brachythyris subcardiformis (Hall) |
| | Fenesella compressa var. nododorsalis Ulrich | Symmetrothyris textus (Hall) |
| | | Reticularia sp. |
| | | Clithyridina (?) sp. |
| | | Composita trinuclea (Hall) |
| PELECYPODA | Fenesella multispinosa Ulrich | Myalina keokuk Worthen |
| | Fenesella species II | Aviculopecten sp. |
| | Pinnatopora sp. | Aviculopecten sp. |
| | Rhombopora sp. | GASTROPODA |
| | Cystodictya lineata Ulrich | Platycoelas equilateralis Hall (?) |
| | Worthyopora spinosa Ulrich | Ptychophalalus (?) sp. |
| | Orthotetes keokuk (Hall) | TRILOBITA |
| | Chonetes sp. | Griffithides (?) sp. |
| | Productus setigerus Hall | VERTEBRATA |

The vertical range of all the more characteristic species listed above is shown in the following table:

Table Showing Range of Species in the Keokuk Limestone at Keokuk.

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**BRACHIOPODA**

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</table>
The lower portion of the Keokuk, comprising the beds called in earlier reports the Montrose cherts, is not exposed at Keokuk at the present time, but was formerly opened to observation in the excavation beneath the bed of Mississippi river for the Keokuk dam.
### KEOKUK BEDS AT CEDAR GLEN

**Section of Montrose cherts in excavation below bed of Mississippi river at Keokuk.**

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<th>Bed</th>
<th>Description</th>
<th>Thickness</th>
<th>Approximate Percentage</th>
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<td>1.</td>
<td>Limestone, dark gray; impregnated with small irregular patches of chert and chaledony, and containing small, imperfect calcareous geodes</td>
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<td>50</td>
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<td>2.</td>
<td>Limestone, red; very fine-grained; cherty</td>
<td>3</td>
<td>80-50</td>
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<td>3.</td>
<td>Limestone, red; containing small irregular patches of chert and chaledony</td>
<td>3</td>
<td>80</td>
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<tr>
<td>4.</td>
<td>Limestone, gray; bearing small crinoid stems; with whitish chert band in middle</td>
<td>3</td>
<td>80</td>
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<tr>
<td>5.</td>
<td>Limestone, red; containing small irregular patches of chert and chaledony</td>
<td>3</td>
<td>80</td>
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<td>6.</td>
<td>Limestone, red; containing small irregular patches of chert and chaledony</td>
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<td>80</td>
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<tr>
<td>7.</td>
<td>Limestone, gray; bearing small crinoid stems; with whitish chert band in middle</td>
<td>3</td>
<td>80</td>
</tr>
<tr>
<td>8.</td>
<td>Limestone, red; containing small irregular patches of chert and chaledony</td>
<td>3</td>
<td>80</td>
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<tr>
<td>9.</td>
<td>Limestone, red; containing small irregular patches of chert and chaledony</td>
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<td>80</td>
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<td>11.</td>
<td>Limestone, red; containing small irregular patches of chert and chaledony</td>
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<td>80</td>
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<td>Limestone, red; containing small irregular patches of chert and chaledony</td>
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<td>15.</td>
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<td>16.</td>
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<td>18.</td>
<td>Limestone, red; containing small irregular patches of chert and chaledony</td>
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The basal cherty beds of the Keokuk may be studied to good advantage at the present time along Cedar Glen, a small creek on the Illinois side of Mississippi river, about midway between the towns of Hamilton and Warsaw. The section of the Keokuk, which is nearly complete at this place, is as follows:

**Section of Keokuk limestone at Cedar Glen, Illinois**

<table>
<thead>
<tr>
<th>Bed</th>
<th>Description</th>
<th>Feet</th>
<th>Inches</th>
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<tbody>
<tr>
<td>17.</td>
<td>Drift, yellowish, sandy, of variable thickness.</td>
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<tr>
<td>16.</td>
<td>Limestone, grayish, coarse-grained, cherty. <em>Spirifer keokuk</em> common. Bed 10 of Keokuk section</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>15.</td>
<td>Limestone, grayish, cherty; in thin irregular layers separated by shaly partings</td>
<td>2</td>
<td>4</td>
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</table>
14. Limestone, grayish, subcrystalline; cherty in lower part. *Orthotetes keokuk* abundant. Bed 7 of the Keokuk section ................. 1

13. Limestone, light gray, in places cherty; weathering to an irregular chippiness; the "White ledge" of the Keokuk section. Lower part somewhat shaly .......... 2

12. Limestone, grayish; upper and lower parts subcrystalline, and weathering to thin irregular chips; middle part consisting of ash-colored magnesian limestone in heavy layers. The "Millerite ledge" of the Keokuk section .... 5

11. Limestone, bluish gray, coarse-grained, *Palaecois obtusus* and fish teeth common ........................................ 1

10. Limestone, grayish with slight bluish tint, coarse-grained, highly fossiliferous. Bed 2 of Keokuk section 2

9. Limestone, consisting of cherty gray subcrystalline limestone, with thin cherty seams of bluish gray coarse-grained limestone. Bed 1 of Keokuk section .................. 5

8. Limestone, fine-grained, ash-colored, magnesian; with very irregular chert patches, and with interbedded seams of bluish gray coarse-grained cherty limestone. Upper part somewhat shaly ........................................ 4

7. Limestone, bluish gray, coarse-grained, cherty ................. 4

6. Limestone, fine-grained, cherty, ash-colored, magnesian. Chert in form of very irregular patches. No fossils noted .......................................................... 6

5. Limestone, grayish, medium to coarse-grained; locally in massive layers but for the most part split into thin layers of cherty bands .................. 8

4. Limestone, gray, fine-grained, cherty, magnesian; with discontinuous layers of cherty gray coarse-grained non-magnesian limestone. Locally the coarse-grained limestone predominates. Grading into the bed below through a layer of fossiliferous limestone about 8 inches to 1 foot thick. This is bluish and coarse-grained above, but is gradually a finer and lighter gray chert crinoidal limestone below ........................................ 9

3. Limestone, grayish to whitish, crinoidal, with occasional bands or lenses of whitish chert; massive where fresh; weathered surfaces flaking off obliquely ........... 4

2. Limestone, light gray, subcrystalline; some layers crinoidal; tending irregular chert nodules many of which exhibit concretionary structure in the form of alternating bands of lighter and darker colored material. Chert much shattered where weathered, as in other layers. Bed receding slightly; tending to scale off obliquely to weathered surface ........................................ 4

1. Limestone, light gray, crinoidal, with occasional large whitish chert nodules; massive where fresh, but scaling off obliquely to weathered surface. Exposed ........... 2

Collections were made from the lower members of the section. The forms identified from each bed are as follows:

List of fossils from bed 1 of Keokuk limestone at Cedar Glen, Illinois.

**ANTHozoA**—

*Triplophyllum dalei* (M.-E. and H.)

**ERYzoA**—

*Cystodictya* sp.

**BRACHIOPODA**—

*Pustula alternata* (N. and P.)

*Spirifer tenuicostatus* Hall

*Spirifer logani* Hall

*Spirifer* sp.

*Brachythiris suborbicularis* (Hall)

*Istecularia pseudolineata* (Hall)

*Athyris lamellosa* (Leveille)

*Clothocephala oblonga* (McChesney)

**GASTROPODA**—

*Spirifer* sp.
List of fossils from bed 2 of Keokuk limestone at Cedar Glen, Illinois.

**ANTHOZOA**
- Cyathaxonia ? sp.
- Triplophyllum dalei (M.-E. and H.)
- Zaphrentis sp.

**BRYOZOA**
- Cystodictya sp.

**BRACHIOPODA**
- Productus sp.
- Productus sp.

**GASTROPODA**
- Tetraamira subtrigosa (M. and W.)
- Delasma sp.
- Spirifer cf. S. grimesi Hall

List of fossils from bed 3 of Keokuk limestone at Cedar Glen, Illinois.

**BRYOZOA**
- Cystodictya sp.

**BRACHIOPODA**
- Chonetes sp.
- Productus sp.
- Pustula alternata (N. and P.)

**GASTROPODA**
- Delthyris similis Weller ?
- Spirifer cf. S. grimesi Hall
- Spirifer cf. S. g. Hall

List of fossils from bed 4 of Keokuk limestone at Cedar Glen, Illinois.

**ANTHOZOA**
- Triplophyllum dalei (M.-E. and H.)
- Amplexus sp.

**BRYOZOA**
- Stenopora ? sp.
- Fenestella multispinosa Ulrich
- Fenestella serrata Ulrich
- Fenestella sp.
- Fenestella sp.
- Taeniocystida ramulosa Ulrich ?

**BRACHIOPODA**
- Orthotetes keokuk (Hall)
- Chonetes sp.
- Productus sp.
- Productus sp.
- Avonia sp.

**GASTROPODA**
- Pustula alternata (N. and P.)
- Pustula sp.
- Tetraamira subtrigosa (M. and W.)
- Delasma sp.
- Spirifer cf. S. grimesi Hall
- Spirifer cf. S. g. Hall

List of fossils from bed 5 of Keokuk limestone at Cedar Glen, Illinois.

**ANTHOZOA**
- Cyathaxonia ? sp.
- Triplophyllum dalei (M.-E. and H.)
- Amplexus sp.
- Palaeaeis obtusus (M. and W.)

**CRINOIDEA**
- Platycterus ? sp.

**BRYOZOA**
- Fenestella serrata Ulrich
- Rhombobora varians Ulrich
- Cystodictya sp.

**BRACHIOPODA**
- Orthotetes keokuk (Hall)
- Productus sp.
- Pustula alternata (N. and P.)
- Rhipidomella dubia (Hall)
- Tetraamira subtrigosa (Hall)
- Delasma sp.

**PELECEPODA**
- Conocardium sp.
- Myalina keokuk Worthen

**GASTROPODA**
- Orthonychia ? sp.

**TRILOBITA**
- Griffithides ? sp.

**VERTEBRATA**
- Fish teeth
List of fossils from bed 7 of Keokuk limestone at Cedar Glen, Illinois.

**ANTHOZOA—**
- Triplophyllum dalei (M.-E. and H.)
- Amplexus sp.
- Paleaeacis obtusus (M. and W.)

**BRYOZOA—**
- Meekopora sp.
- Fenestella multispinosa Ulrich
- Fenestella sp.
- Hemitrypa sp.
- Cystodictya sp.
- Cyclopora † sp.

**BRACHIOPODA—**
- Orthotetes keokuk (Hall)
- Chonetes sp.
- Productus sp.
- Productus sp.
- Pustula alternata (N. and P.)
- Rhipidomella dubia (Hall)
- Schizoporia sp.

**List of fossils from bed 8 of Keokuk limestone at Cedar Glen, Illinois.**

**ANTHOZOA—**
- Triplophyllum dalei (M.-E. and H.)

**BRYOZOA—**
- Meekopora † sp.
- Leiolema punctatum (Hall)
- Polypora retrorsa Ulrich †
- Cystodictya sp.
- Cystodictya sp.
- Cyclopora † sp.

**BRACHIOPODA—**
- Avonia sp.
- Productus sp.
- Productus sp.
- Rhipidomella dubia (Hall)
- Schizorhysis sp.
- Orthotetes keokuk (Hall)
- Cystodictya sp.
- Cystodictya sp.
- Cyclopora † sp.
- Reticularia pseudolineata (Hall)
- Athyris lamellosa (Leveille)
- Composita trinuclea (Hall)

**List of fossils from bed 9 of Keokuk limestone at Cedar Glen, Illinois.**

**ANTHOZOA—**
- Triplophyllum dalei (M.-E. and H.)
- Paleaeacis obtusus (M. and W.)

**BRACHIOPODA—**
- Orthotetes keokuk (Hall)
- Productus sp.
- Productus sp.
- Avonia sp.
- Rhipidomella dubia (Hall)
- Tetrasacamera subtrigona (M. and W.)
-Diclasma † sp.
- Spiriferella neglecta (Hall)

**GASTROPODA—**
- Cypricardinia † sp.

**PELECYPODA—**
- Orthonychia † sp.

**VERTEBRATA—**
- Fish teeth

A fairly complete section of the Keokuk limestone appears near Nauvoo, Illinois, opposite Montrose, Iowa. The following section is exposed in the banks of a small creek and in a quarry near its mouth a short distance south of the city limits of Nauvoo.

**Section of Keokuk limestone near Nauvoo, Illinois.**

14. Thin layers of gray cherty limestone and bluish shale interbedded, weathering buff. Exposed only in quarry 2
13. Limestone, gray, thin-bedded, fine-grained and cherty in bank of creek, but more massive, bluish and coarser-grained in quarry ......................................................... 4
12. Limestone, bluish, medium-grained, tough; locally pass-
KEOKUK FOSSILS AT NAUVOO

1. Limestone, gray, fine-grained, irregularly stratified; with thin layers of medium-grained bluish gray cherty limestone. *Fenestella* sp.; *Pustula* sp.; *Orthotetes* keokuk; *Rhipidomella dubia*; *Dielasma* sp.; *Spirifer* sp.; *Reticularia pseudolineata*; *Phillipsia* ? sp. 10

2. Shaly parting with thin seams of cherty limestone. *Fenestella* sp.; *Hemitrypa* sp.; *Cystodictya* sp.; *Produetus* sp.; *Productus setigerus*; *Pustula alternata*; *Orthotetes* keokuk; *Brachythiris suborbicularis*; *Phillippsia* ? sp. 3

3. Limestone, gray, fine-grained, weathering to thin flakes. *Pustula alternata*; *Orthotetes keokuk*; *Pustula* sp.; *Palaeacis obtusus*; *Platyceras* sp. 7

4. Limestone, like No. 1. A bluish layer 3 to 4 inches thick in middle part is rich in fish teeth. *Palaeacis obtusus*; *Orthotetes keokuk*; *Pustula alternata*; *Dielasma* sp.; *Platyceras* sp. 1

5. Limestone, gray, dense, brittle, thinly and irregularly bedded, cherty. Some layers passing laterally into gray calcareous shale locally. *Cystodictya* sp.; *Orthotetes keokuk*; *Dielasma* sp.; *Spirifer* sp.; *Reticularia pseudolineata*; *Hemitrypa* sp.; *Spirifer* cf. *S. keokuk* 2

6. Limestone, gray, dense, brittle, thinly and irregularly bedded, cherty. *Cystodictya* sp.; *Orthotetes keokuk*; *Dielasma* sp.; *Spirifer* sp.; *Reticularia pseudolineata*; *Hemitrypa* sp.; *Spirifer* cf. *S. keokuk* 2

7. Limestone, gray, fine-grained, weathering to thin flakes. *Pustula alternata*; *Orthotetes keokuk*; *Spirifer* sp.; *Rhipidomella dubia*; *Spirifer tenuicostatus*; *Spirifer* sp.; *Reticularia pseudolineata*; *Hemitrypa* sp.; *Spirifer* cf. *S. keokuk* 1

8. Shaly parting with thin seams of limestone. *Fenestella* sp.; *Pustula* sp.; *Orthotetes keokuk*; *Girtyella indianaensis*; *Reticularia pseudolineata* 1

9. Limestone, grey, fine-grained to medium-grained, brittle; weathering to thin irregular layers. *Triplophyllum dalei*; *Fenestella* sp.; *Hemitrypa* sp.; *Cystodictya* sp.; *Productus* sp.; *Productus setigerus*; *Pustula alternata*; *Orthotetes* keokuk; *Brachythiris suborbicularis*; *Phillippsia* ? sp. 12-15

10. Limestone, bluish gray, medium-grained; massive when fresh but weathering to thin irregular layers. Contact with bed above very uneven and undulating. 4-4 1/2

11. Shale, with thin layers of bluish fossiliferous limestone. 1 1/2-2

The uppermost part of the exposure is very fossiliferous.

Collections were made from beds 9, 10, 11, 13 and 14. The following lists were prepared from these:

**List of fossils from bed 9 of the Keokuk limestone at Nauvoo, Illinois.**

**ANTHOZOAA—**
- Zaphrentis varsoviensis Worthen
- Triplophyllum dalei (M.-E. and H.)
- Amplexus sp.
- Monilopora beecheri Grabau

**CRINOIDEA—**
- Actinoecrinus lowei Hall
- Doryecrinus sp.

**BRYOZOA—**
- Leioclema punctatum (Hall)

**List of fossils from bed 10 of Keokuk limestone at Nauvoo, Illinois.**

**ANTHOZOAA—**
- Triplophyllum dalei (M.-E. and H.)
- Amplexus sp.
- Monilopora beecheri Grabau
- Palaeacis obtusus (M. and W.)

**BRACHIOPODA—**
- Spirifer sp.
- Rhipidomella dubia
- *Dielasma* sp.
- *Spirifer* sp.
- *Reticularia pseudolineata* (Hall)
- *Girtyella indianaensis*

**GASTROPODA—**
- Ptychospira sp.
- *Platyceras* sp.
- *Platyceras* sp.
BRYOZOA—
Cyclopora sp.
 Fistulipora sp.
 Bactropora simplex Ulrich
 Fenestella sp.
 Polypora sp.
 Archimedes negligens Ulrich
 Hemitrypa sp.
 Leioclera punctata (Hall)
 Cystodictya sp.
 Phractopora trifolia (Rominger)

List of fossils from bed 11 of Keokuk limestone at Nauvoo, Illinois.

ANTHOZOA—
Triplophyllum dalei (M.-E. and H.)
 Monsilopora beecheri Grabau
 Amphipexus sp.
 Zaphrentis varioviensis Worthen
 Palaeaicos obtusus (M. and W.)

CRINOIDEA—
Parichthyocrinus meeki (Hall)

BRYOZOA—
Leioclera punctata (Hall)
 Fenestella serrata Ulrich
 Fenestella multispinosa Ulrich
 Hemitrypa pateriformis Ulrich
 Archimedes neglectens Ulrich
 Polypora simulata Ulrich
 Polypora halliana Hall
 Bactropora simplex Ulrich
 Rhombopora attenuata Ulrich
 Rhombopora varia Ulrich

List of fossils from bed 13 of Keokuk limestone at Nauvoo, Illinois.

BRYOZOA—
Stenopora sp.
 Chaetetes sp.
 Taeniodictya ramulosa Ulrich
 Worthenopora spinosa Ulrich
 Archimedes sp.
 Rhombopora attenuata Ulrich

BRACHIOPODA—
Chonetes illinoisensis Worthen

List of fossils from bed 14 of the Keokuk limestone at Nauvoo, Illinois.

ANTHOZOA—
Monsilopora beecheri Grabau

CRINOIDEA—
Dorferinthus sp.
 Barycrinus sp.

BRYOZOA—
Stenopora sp.
 Leioclera multispinosa Ulrich
 Worthenopora spinosa Ulrich
 Cystodictya sp.
 Phractopora trifolia (Rominger)
 Rhombopora attenuata Ulrich
 Grenaticola arespulata Ulrich
 Streblotrypa major Ulrich

BRACHIOPODA—
Orthotetes keokuk (Hall)
 Productus sp.
 Fusula alternata (N. and P.)
 Rhipidomella dubia (Hall)
 Spirifer tenuicostatus Hall
 Brachythiris suborbicularis (Hall)
 Reticularia pseudolineata (Hall)
 Chlothyridina parvirstris (M. and W.)
 Chlothyridina obmaxima (McChesney)

Streblotrypa major Ulrich
 Cystodictya sp.
 Phractopora trifolia Ulrich
 Worthenopora spinosa Ulrich

Productus sp.
 Orthotetes keokuk (Hall)
 Fusula alternata (N. and P.)
 Camarocoebia mutata (Hall)
 Rhipidomella dubia (Hall)
 Spiriferina sp.
 Spirifer keokuk Hall
 Rhipidomella attenuata Ulrich
 Reticularia pseudolineata (Hall)
 Composita truncula (Hall)
 Chlothyridina parvirstris (M. and W.)

Griffithides sp.

Pustula alternata (N. and P.)
 Productus mesialis Hall
 Productus sp.
 Spiriferina sp.
 Spirifer keokuk Hall
 Syringothellia sp.
 Spiriferella negletata (Hall)
 Eumetria verneuiliana (Hall)

Glyptopora keyserlingi (Prout)
 Fenestella cingulata Ulrich
 Fenestella serrata Ulrich
 Polyopora biseriata Ulrich
 Polyopora retorsa Ulrich
 Hemitrypa sp.
 Phractopora trifolia (Rominger)
 Archimedes neglectens Ulrich

Productus sp.
 Rhipidomella dubia (Hall)
 Camarocoebia mutata Hall
 Spiriferina sp.
 Spirifer keokuk Hall

P. 160 MISSISSIPPIAN STRATA OF IOWA
Near Niota, Illinois, opposite Fort Madison, Iowa, there are other good exposures of the Keokuk limestone. The following section was measured two miles southwest of Niota in the banks of a small creek tributary to Mississippi river.

<table>
<thead>
<tr>
<th>Section of Keokuk limestone near Niota, Illinois.</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEET</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>29.</td>
</tr>
<tr>
<td>27.</td>
</tr>
<tr>
<td>26.</td>
</tr>
<tr>
<td>25.</td>
</tr>
<tr>
<td>24.</td>
</tr>
</tbody>
</table>

Beds 1 to 25 inclusive constitute the Keokuk limestone; beds
26 to 28, on the other hand, represent the Geode bed or Lower Warsaw.

In Denmark township, Lee county, Iowa, the Keokuk limestone is well exposed in a bluff two and one-half miles northwest of the town of Denmark.

Section of Keokuk limestone northwest of Denmark.

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.</td>
<td>Massive, gray limestone bearing numerous broad shells of <em>Orthotetes keokuk</em></td>
</tr>
<tr>
<td>18.</td>
<td>Limestone layers with thin intercalated shale bands</td>
</tr>
<tr>
<td>17.</td>
<td>Shale, calcareous below but more argillaceous above</td>
</tr>
<tr>
<td>16.</td>
<td>Limestone, gray and buff</td>
</tr>
<tr>
<td>15.</td>
<td>Limestone, cherty, stratification very irregular or lacking; checking into irregular blocks and weathering buff; <em>Spirifer keokuk</em> common</td>
</tr>
<tr>
<td>14.</td>
<td>Shaly parting</td>
</tr>
<tr>
<td>13.</td>
<td>Limestone, gray and blue, very fossiliferous. The following forms were noted: <em>Conularia</em> sp., <em>Spirifer keokuk</em>, <em>Orthotetes keokuk</em>, <em>Clothyrina</em> sp., <em>Reticularia pseudodolometa</em> and <em>Tetragonoceras subtrigona</em></td>
</tr>
<tr>
<td>12.</td>
<td>Limestone, argillaceous, buff, non-fossiliferous, stratification obscure, disintegrating into angular blocks</td>
</tr>
<tr>
<td>11.</td>
<td>Shaly parting</td>
</tr>
<tr>
<td>10.</td>
<td>Limestone, dense, gray, cherty above</td>
</tr>
<tr>
<td>9.</td>
<td>Shale, highly calcareous, massive, unfossiliferous; checking irregularly and containing irregular bands of chert and a few imperfect geodes</td>
</tr>
<tr>
<td>8.</td>
<td>Limestone, in the form of a dense gray layer</td>
</tr>
<tr>
<td>7.</td>
<td>Shaly parting</td>
</tr>
<tr>
<td>6.</td>
<td>Limestone, massive, weathering to thin spalls</td>
</tr>
<tr>
<td>5.</td>
<td>Shale, argillaceous, thinly laminated</td>
</tr>
<tr>
<td>4.</td>
<td>Limestone, massive, crinoidal, cherty below</td>
</tr>
<tr>
<td>3.</td>
<td>Shale, calcareous; showing no bedding; bands of cherty limestone intercalated</td>
</tr>
<tr>
<td>2.</td>
<td>Limestone, coarse-grained, crinoidal, bearing nodular chert below. <em>Fusulina alternata</em>, <em>Productus setigerus</em> and <em>Reticularia pseudodolometa</em></td>
</tr>
<tr>
<td>1.</td>
<td>Shale, passing laterally into limestone</td>
</tr>
</tbody>
</table>

In a bluff at South Augusta (NE. 1/4 sec. 25, Denmark township) the basal beds of the Keokuk are exposed in contact with the Upper Burlington limestone.

Section of Keokuk limestone at South Augusta.

<table>
<thead>
<tr>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.</td>
</tr>
<tr>
<td>3.</td>
</tr>
<tr>
<td>2.</td>
</tr>
<tr>
<td>1.</td>
</tr>
</tbody>
</table>
List of fossils from bed 1 of Keokuk limestone at South Augusta.

ANTHOZOA—
Zaphrentis sp.

BRACHIOPODA—
Spirea grimesi Hall
Spirea tenuicostatus Hall

TRILOBITA—
Griffithides ? sp.

List of fossils from bed 2 of Keokuk limestone at South Augusta.

BRACHIOPODA—
Spirea grimesi Hall
Spirea sp.

VERTEBRATA—
Fish teeth

List of fossils from bed 3 of Keokuk limestone at South Augusta.

CRINOIDEA—
Composita trinuclea (Hall)
Batoecrinoidea (Hall)

BRYOZOA—
Fenestella sp.
Teeniadictya ramulosa Ulrich
Prouetia ? sp.

BRACHIOPODA—
Productus ovatus Hall
Avonia sp.
Dielasma sp.
Tricamerate subtrigona (M. and W.)
Spireaella sp.

PELECYPODA—
Conocardium sp.

Des Moines County.—The Des Moines county exposures of the Keokuk limestone are confined chiefly to the area about Augusta in the southern part of the county. However, the basal beds of this formation have been recognized at localities farther north.

One of the most complete sections in the county occurs along the banks of a small creek one-half mile north of the Augusta wagon bridge in the eastern part of section 23, Augusta township. The succession of beds there is as follows:

Section of Keokuk limestone near Augusta.  

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>13. Drift</td>
<td>2</td>
</tr>
<tr>
<td>12. Limestone, bluish gray, impure. Exposed</td>
<td>1</td>
</tr>
<tr>
<td>11. Concealed, probably soft shaly limestone; loose blocks on surface highly fossiliferous</td>
<td>3</td>
</tr>
<tr>
<td>10. Limestone, bluish gray, medium-grained, dense</td>
<td>2</td>
</tr>
<tr>
<td>9. Limestone, consisting of thin layers of bluish gray coarse-grained limestone alternating with layers of thin-bedded gray fine-grained cherty limestone which weathers buff</td>
<td>7</td>
</tr>
<tr>
<td>8. Limestone, bluish gray, medium-grained, bearing Orthotetes keokuk and Pustula alternata</td>
<td>7</td>
</tr>
<tr>
<td>7. Limestone, gray, subcrystalline, thinly and irregularly bedded, cherty</td>
<td>11</td>
</tr>
<tr>
<td>6. Limestone, bluish gray, medium-grained, Orthotetes keokuk and Peltaster obtusus abundant</td>
<td>6</td>
</tr>
<tr>
<td>5. Limestone, dark gray to bluish gray, thinly and irregularly bedded, cherty</td>
<td>2</td>
</tr>
<tr>
<td>4. Limestone, bluish gray, medium-grained to crinoidal; for the</td>
<td></td>
</tr>
</tbody>
</table>
most part massive but in places divided into thin layers by chert bands .......................................................... 1 6
3. Limestone, gray, subcrystalline, thin-bedded, cherty: with a
massive layer of crinoidal limestone in upper part ................. 10
2. Limestone, light gray, coarse-grained, crinoidal, with occasional
chert nodules or bands ............................................. 6 3
1. Limestone, coarse-grained, crinoidal, gray below but bluish
above; the topmost layer, which is 8 inches thick, bears
water-worn specimens of *Spirifer grimesi* .................................. 1 6

The Keokuk limestone is underlain at this point by twenty-
one feet of crinoidal limestone of Upper Burlington age. This
has been described in a previous chapter. The fossils of the
successive beds of the Keokuk limestone near Augusta are listed
below.

*List of fossils from bed 1 of Keokuk limestone near Augusta.*

**ANTHOZOA**—

- *Triplophyllum dalei* (M.-E. and H.)
- *Cyathaxonia* sp.
- *Amplexus* sp.

**BRYOZOA**—

- *Fenestella* sp.
- *Cystodictya* sp.

**BRACHIOPODA**—

- *Orthotetes* sp.
- *Pustula alternata* (N. and P.)
- *Tetraclomma subtrigona* (Hall)
- *Spirifer grimesi* Hall
- *Spirifer tenuicostatus* Hall

**PELICYPoda**—

**GASTROPODA**—

**VERTEBRATA**—

- Fish teeth

*List of fossils from bed 2 of Keokuk limestone near Augusta.*

**CRINOIDEA**—

- *Actinocrinus* sp.

**BRYOZOA**—

- *Fenestella* sp.

**BRACHIOPODA**—

- *Productus* sp.
- *Pustula alternata* (N. and P.)
- *Spirifer incertus* Hall
- *Spirifer grimesi* Hall

**PELICYPoda**—

**GASTROPODA**—

**TRILOBITA**—

- *Griffithides* sp.

*List of fossils from bed 3 of Keokuk limestone near Augusta.*

**BRYOZOA**—

- *Fenestella* sp.
- *Proutella* sp.

**BRACHIOPODA**—

- *Tetraclomma subtrigona* (M. and W.)
- *Productus ovatus* Hall
- *Productus* sp.
- *Pustula* sp.
- *Dielasma* sp.

**PELICYPoda**—

**GASTROPODA**—

**VERTEBRATA**—

- Fish teeth

*List of fossils from bed 5 of Keokuk limestone near Augusta.*

**ANTHOZOA**—

- *Triplophyllum dalei* (M.-E. and H.)

**BRACHIOPODA**—

- *Productus ovatus* Hall
FOSSILS OF KEOKUK NEAR AUGUSTA

Productus sp.
Avonia sp.
Chonetes sp.
Delthyris ? sp.
Spirifer logani Hall
Spirifer sp.

Brachthyris suborbicularis (Hall)
Reticularia pseudolineata (Hall)
Composita trinuclea (Hall)

PELECYPOSIDA—
Cypricardinia sp.

List of fossils from bed 6 of Keokuk limestone near Augusta.

ANTHOZOA—
Palaeacis obtusus (M. and W.)
Tripholyllum dalei (M.-E. and H.)

BRACHIOPODA—
Pustula alternata (N. and P.)
Tetraclenera subtrigona (M. and W.)
Spiliferina sp.
Spirifer sp.

Brachthyris suborbicularis (Hall)
Reticularia pseudolineata (Hall)
Syringothyris sp.
Clithyridina obmaxima (McChesney)

GASTROPODA—
Platyceras sp.

VETEBRATA—
Fish teeth

List of fossils from bed 7 of Keokuk limestone near Augusta.

ANTHOZOA—
Zaphrentis sp.
CRINOIDEA—
Dorycrinus (spine)
Platycrinus sp.
BRACHIOPODA—
Cystodictya sp.
Worthenopora sp. Ulrich ?
BRACHIOPODA—
Pustula alternata (N. and P.)
Dielasma sp.

Tetraclenera subtrigona (M. and W.)
Spiliferina sp.
Reticularia pseudolineata (Hall)
Athyris lamellosa (Leveille)
Clithyridina incrassata (Hall) ?
Clithyridina obmaxima (McChesney)

GASTROPODA—
Platyceras sp.
Orthonychia sp.

TRILOBITA—
Griffithides ? sp.

List of fossils from bed 9 of Keokuk limestone near Augusta.

CRINOIDEA—
Actinocrinus lowei Hall
BRACHIOPODA—
Tetraclenera subtrigona (M. and W.)
Spirifer logani Hall

Spiriferella neglecta (Hall) ?
Clithyridina incrassata (Hall)

GASTROPODA—
Platyceras sp.

List of fossils from bed 10 of Keokuk limestone near Augusta.

BRACHIOPODA—
Phraetopora trifolia (Rominger)

Spirifer keokuk Hall
Spirifer logani Hall
Reticularia pseudolineata (Hall)

List of fossils from bed 11 of Keokuk limestone near Augusta.

ANTHOZOA—
Zaphrentis varsoviensis Worthen ?
Tripholyllum dalei (M.-E. and H.)
Amplexus sp.
Moulopora beecheri Grabau
CRINOIDEA—
Actinocrinus sp.
Platyaminus sp.
Synaptocerinus sp.
BRACHIOPODA—
Cyclopora ? sp.
Leiocelasma gracilimum Ulrich
Leiocelasma punctatum (Hall)
Phraetopora trifolia (Rominger)

Taeniocerita ramulosa Ulrich
Glyptopora kuyserlingi (Prout)
Rhomboptera variant Ulrich
Rhomboptera attenuata Ulrich
Rhomboptera transversalis Ulrich
Cystodictya pustulosa Ulrich
Fenestella serrata Ulrich
Fenestella multispinosa Ulrich ?
Streblotrypa radialis Ulrich

BRACHIOPODA—
Orthotetes ? sp.
Productus wortheni Hall ?
Pustula sp.
Tetraclenera subtrigona (M. and W.)
Tetraclamera subcuneata (Hall)  
Rhipidomenella dubia (Hall)  
Spiriferina † sp.  
Spirifer tenuecostatus Hall †  
Spirifer logani Hall  
Spirifer cf. S. keokuk Hall  
Spirifer postellatus Hall  
Spiriferella neglecta (Hall)  
Spiriferina, gp. Syringothyris sp.  
Spirifer tenuicostatus Hall  
Spiriferina † sp.  
Clithyridina incrassata (Hall)  
PELECYPODA—  
Spiriferina † sp.  
Platyceras sp.  

The following faunal table includes the more characteristic species of the collections made at both South Augusta and Augusta.

Table Showing Range of Fossils in the Keokuk Beds at Augusta and South Augusta.

<table>
<thead>
<tr>
<th>Horizons</th>
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### Range of Fossils of Keokuk Beds

Table Showing Range of Fossils in the Keokuk Beds at Augusta and South Augusta. Continued.

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<td><em>Composita trinuclea</em> (Hall)</td>
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**Pelecyphoda**

| Conocardium sp. | x | x |   |   |   |   |   |   |   |    |    |
| Cypriocardium sp. | x |   |   |   |   |   |   |   |   |    |    |

**Gastropoda**

| Platyceras sp. |   |   |   |   |   |   | x | x |   |    |    |
| Platyceras sp. | x |   |   |   |   |   |   |   |   |    |    |
| Orthonychia sp. |   |   |   |   |   |   | x |   |   |    |    |
| Orthonychia sp. | x |   |   |   |   |   |   |   |   |    |    |
| Orthonychia sp. | x |   |   |   |   |   |   |   |   |    |    |
| Orthonychia sp. |   |   |   |   |   |   |   |   |   |    |    |

**Triobita**

| Griffithides sp. | x | x | x |   |   |   | x |   |   |    |    |

Approximately two miles northeast of Augusta the Keokuk limestone is again well exposed in the south bank of Long creek on the Harry Hillgardner property. The following beds are exposed at this place:
Section in the south bank of Long creek.

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<tr>
<td>12.</td>
<td>Drift, to brow of hill</td>
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<td>11.</td>
<td>Limestone, as in bed 7. Interbedded with layers of soft shale</td>
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</tr>
<tr>
<td>10.</td>
<td>Limestone, bluish gray, slightly crinoidal. Orthotetes keokuk, Spirifer keokuk, Reticuluria pseudolineata, R. dubia, Pustula sp.</td>
<td>2</td>
</tr>
<tr>
<td>9.</td>
<td>Limestone as in bed 7. Spirifer tenuicoastatus</td>
<td>4 6</td>
</tr>
<tr>
<td>8.</td>
<td>Limestone, gray, medium-grained; in thin layers separated by shaly seams</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Limestone, gray to drab, soft, magnesian; flaking off obliquely to surface. No fossils noted</td>
<td>2 8</td>
</tr>
<tr>
<td>6.</td>
<td>Limestone, gray, medium-grained; with seams of fine-grained soft limestone</td>
<td>3 6</td>
</tr>
<tr>
<td>5.</td>
<td>Shaly seam</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Limestone, gray, fine-grained, soft, cherty; with layers and seams of gray to bluish coarser-grained slightly crinoidal fossiliferous limestone. A thin bluish crinoidal layer at the top bears many fish teeth. Palaeacis obtusa, Zaphrentis varroviensis, Fenestella sp.</td>
<td>5 6</td>
</tr>
<tr>
<td>3.</td>
<td>Limestone, bluish gray, cherty, slightly crinoidal. Triplophyllum dalei, Brachythyris suborbicularis, Pustula alternata, Rhipidomella dubia, Conocardium sp. Reticuluria pseudolineata, Spirifer tenuicoastatus and fragments of fish teeth</td>
<td>10</td>
</tr>
<tr>
<td>2.</td>
<td>Shaly seam</td>
<td>3</td>
</tr>
<tr>
<td>1.</td>
<td>Limestone, drab, fine-grained, magnesian, with segregations of calcite. To water in creek</td>
<td>4 6</td>
</tr>
</tbody>
</table>

Thirty rods north of this exposure there is a bluff section on the opposite bank of the creek. Bed 10 is overlain at this point by eighteen feet of bluish shale, calcareous in the lower part, which is referred to the Lower Warsaw. This member is in turn followed above by five feet of Spergen dolomitic limestone.

In the region about Burlington only the basal beds of the Keokuk are preserved. Thus, in the Miller quarry above the Cascade the following beds are seen in contact with the upper Burlington limestone.

Section of Keokuk limestone in Miller quarry.

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td>Limestone, brownish, magnesian, very cherty</td>
<td>7 1/2</td>
</tr>
<tr>
<td>2.</td>
<td>Limestone, brownish, crinoidal</td>
<td>1 5</td>
</tr>
<tr>
<td>1.</td>
<td>Limestone, yellowish, magnesian, cherty, especially near the base</td>
<td>5 3</td>
</tr>
</tbody>
</table>

No identifiable fossils were found in any of the layers but their position above the Upper Burlington suggests their Keokuk age.

Van Buren County.—The exposures of the Keokuk limestone in Van Buren county are confined to a narrow belt along Des Moines river where the overlying formations have been eroded
as a result of the uplift of an anticline which nearly parallels the river. A general section of the Keokuk limestone as exposed at and near the town of Bentonsport is as follows:

*Generalized section of the Keokuk limestone at Bentonsport and vicinity.*

<table>
<thead>
<tr>
<th>BED</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.</td>
<td>Limestone, bluish gray, coarse-grained; in one massive ledge...</td>
</tr>
<tr>
<td>19.</td>
<td>Shale, bluish, argillaceous, highly fossiliferous; with discontinuous seams and flakes of gray impure, cherty limestone</td>
</tr>
<tr>
<td>18.</td>
<td>Limestone, gray, medium-grained</td>
</tr>
<tr>
<td>17.</td>
<td>Shale, bluish, argillaceous, slightly fossiliferous</td>
</tr>
<tr>
<td>16.</td>
<td>Limestone, bluish, rather coarse-grained; separated from the bed below by a shaly parting 5 to 10 inches thick</td>
</tr>
<tr>
<td>15.</td>
<td>Limestone, gray, subcrystalline, with irregular nodules of chert; massive when fresh but weathering into thin layers; locally shaly in lower part</td>
</tr>
<tr>
<td>14.</td>
<td>Limestone, bluish, coarse-grained, cherty; for the most part in one massive ledge</td>
</tr>
<tr>
<td>13.</td>
<td>Limestone, light gray to whitish, medium-grained, slightly crinoidal; grading locally into gray subcrystalline limestone which weathering into yellowish shaly layers</td>
</tr>
<tr>
<td>12.</td>
<td>Limestone, consisting of alternating layers of rather coarse-grained bluish limestone and gray subcrystalline limestone</td>
</tr>
<tr>
<td>11.</td>
<td>Limestone, bluish gray, rather coarse-grained; with shaly partings between the layers in lower part</td>
</tr>
<tr>
<td>10.</td>
<td>Limestone, grayish, subcrystalline; with seams of coarse-grained bluish cherty limestone in lower part</td>
</tr>
<tr>
<td>9.</td>
<td>Shale, bluish, calcareous, weathering drab and yellowish, unfossiliferous</td>
</tr>
<tr>
<td>8.</td>
<td>Limestone, bluish gray, subcrystalline, with a shaly parting four inches thick near the middle</td>
</tr>
<tr>
<td>7.</td>
<td>Limestone, fine-grained, impure, ash-colored, dolomitic; shaly towards the top; weathering buff; with a few cherty seams...</td>
</tr>
<tr>
<td>6.</td>
<td>Limestone, gray, subcrystalline, cherty</td>
</tr>
<tr>
<td>5.</td>
<td>Limestone, bluish gray and medium-grained in lower part, but fine-grained and ash-colored above</td>
</tr>
<tr>
<td>4.</td>
<td>Limestone, gray, fine-grained, structureless, cherty; locally passing into gray subcrystalline fossiliferous limestone</td>
</tr>
<tr>
<td>3.</td>
<td>Limestone, bluish gray, medium-grained to coarse-grained, slightly crinoidal; upper one-half locally bearing fish teeth and pygidia of trilobites; middle part rich in crinoids</td>
</tr>
<tr>
<td>2.</td>
<td>Limestone, grayish, subcrystalline, very cherty; locally grading into coarse-grained bluish crinoidal limestone</td>
</tr>
<tr>
<td>1.</td>
<td>Limestone, bluish gray, cherty</td>
</tr>
</tbody>
</table>

Beds 1 to 4 represent the basal portion of the formation and are well exposed on Lexington creek, nearly one mile above its mouth, in section 7, Bonaparte township. Beds 5 to 20, on the other hand, are exposed in the north bluff of Des Moines river about one-fourth mile below the station at Bentonsport. Bed 20 is overlain here by highly fossiliferous shales and shaly limestones of the Lower Warsaw (Geode bed). These are described in a later chapter devoted to this formation.
The fossils of the individual beds of the Keokuk limestone in this area are listed below.

List of fossils from bed 1 of Keokuk limestone in Bentonsport area.

**CRINOIDEA**
- Dorycinus sp.

**BRYOZOA**
- Leiolema punctatum (Hall)

**BRACHIOPODA**
- Productus setigerus Hall
- Productus sp.
- Pustula biseriata (Hall)
- Tetracamera subtrigona (M. and W.)
- Dielasma sp.
- Dielasma sp.
- Spiriferina sp.

List of fossils from bed 2 of Keokuk limestone in Bentonsport area.

**BRACHIOPODA**
- Avonia sp.
- Dielasma ? sp.

**GASTROPODA**
- Orthonychia sp.

List of fossils from bed 3 of Keokuk limestone in Bentonsport area.

**ANTHOZOA**
- Cyathaxonia sp.
- Amplexus sp.
- Zaphrentis varsoviensis Worthen (?)
- Triplophyllum dalei (M.-E. and H.)
- Palaeocera obtusus (M. and W.)

**CRINOIDEA**
- Actinocrinus sp.
- Dorycinus sp.

**EHOIDEA**
- Archaeocidaris sp.

**BRYOZOA**
- Stenopora sp.
- Cyclopora ? sp.

**BRACHIOPODA**
- Orthotetes keokuk (Hall)
- Productus setigerus Hall
- Productus sp.
- Pustula alternata (N. and P.)
- Pustula ? sp.
- Rhipidomella dubia (Hall)

List of fossils from bed 4 of Keokuk limestone in Bentonsport area.

**BRYOZOA**
- Stenopora sp.
- Fenestella serratula Ulrich
- Fenestella sp.

**BRACHIOPODA**
- Orthotetes keokuk (Hall)
- Chonetes shumardanus De Konink
List of fossils from bed 6 of Keokuk limestone in Bentonsport area.

**ANTHOZOA**
- Cyathaxonia sp.
- Triplophyllum dalei (M.-E. and H.)

**CRINOIDEA**
- Platycrinus sp.
- Actinocrinus f sp.

**BRYOZOA**
- Cystodictya sp.

**BRACHIOPODA**
- Schuchertella f sp.
- Productus sp.
- Pustula alternata (N. and P.)
- Rhipidomella dubia (Hall)
- Tetrapachora subtrimagana (M. and W.)

**GASTROPODA**
- Pseudosyrinx keokuk Weller
- Psuedosyrinx albiolens (M.-E. and H.)
- Platyceras sp.
- Pterotrachium subcompositum (Hall)
- Orthotetes sp.
- Pustula alternata (N. and P.)
- Rhipidomella dubia (Hall)
- Spiriferina sp.
- Delthyris f sp.
- Spirifer rostellatus Hall
- Spirifer cf. S. keokuk Hall
- Pseudoosyrinx keokuk Weller
- Reticularia pseudolineata (Hall)

**PELECYPODA**
- Ariculopecten cf. A. oblongus (M. and W.)
- Allorisma sp.
- Gastroxata sp.
- Platyteris sp.
- Reticularia pseudolineata (McChesney)
- Orthoceras sp.

List of fossils from bed 7 of Keokuk limestone in Bentonsport area.

**ANTHOZOA**
- Triplophyllum dalei (M.-E. and H.)

**CRINOIDEA**
- Dorycrinus mississippiensis Roemer
- Eutrochocrinus planodiscus Hall

**BRACHIOPODA**
- Pustula alternata (N. and P.)
- Pustula sp.
- Craspathis subcomposita (Hall)
- Tetrapachora subtrimagana (M. and W.)

**GASTROPODA**
- Dielasma sp.
- Orthoceras sp.
- Pustula sp.
- Rhipidomella dubia (Hall)

List of fossils from bed 8 of Keokuk limestone in Bentonsport area.

**ANTHOZOA**
- Triplophyllum dalei (M.-E. and H.)
- Zaphrentis varsoviensis Worthen
- Zaphrentis sp.
- Actinocrinus f sp.

**CRINOIDEA**
- Actinocrinus sp.

**BRYOZOA**
- Meekopora sp.
- Cystodictya sp.

**BRACHIOPODA**
- Orthotetes f sp.
- Schuchertella f sp.
- Productus wortheni Hall f
- Productus mesialis Hall
- Productus sp.
- Pustula alternata (N. and P.)
- Pustula sp.
- Rhipidomella dubia (Hall)
- Spirifer tenuicostatus Hall
- Spirifer rostellatus Hall
- Spirifer keokuk Hall
- Spirifer logani Hall
- Brachythyris suborbiicularis (Hall)
- Spiriferella neglecta (Hall)
- Reticularia pseudolineata (Hall)

**GASTROPODA**
- Platyceeras sp.
- Platyceeras sp.
- Orthonychia sp.
- Orthonychia sp.

**TRILOBITA**
- Griffithides f sp.

**VERTEBRATA**
- Fish teeth
### List of fossils from bed 10 of Keokuk limestone in Bentonsport area.

**ANTHOZOA**
- Amplexus sp.

**BRYOZOA**
- Rhombopora varians Ulrich
- Cyclopora sp.
- Worthenopora spinosa Ulrich

**BRACHIOPODA**
- Schuchertella sp.
- Orthotetes keokuk (Hall)
- Productus setigerus Hall
- Productus ovatus Hall
- Productus sp.
- Pustula alternata (N. and P.)
- Pustula sp.
- Rhipidomella dubia (Hall)
- Tetracamera subtrigona (M. and W.)
- Dielasma sinuata WELLER

**PELECYPODA**
- Aviculopecten sp.
- Axiopecten sp.

**GASTROPODA**
- Orthonychia sp.

**VERTEBRATA**
- Fish teeth

### List of fossils from bed 11 of Keokuk limestone in Bentonsport area.

**ANTHOZOA**
- Palaeanes obtusus (M. and W.)
- Dorycerinus sp.

**BRYOZOA**
- Stenopora sp.
- Hemitrypa sp.
- Cystodictya sp.

**BRACHIOPODA**
- Schuchertella sp.
- Productus setigerus Hall
- Productus wortheni Hall
- Productus ovatus Hall
- Productus sp.
- Avonia sp.
- Avonia sp.
- Pustula biseriata (Hall)
- Pustula alternata (N. and P.)

**GASTROPODA**
- Orthonychia sp.

**VERTEBRATA**
- Fish teeth

### List of fossils from bed 12 of Keokuk limestone in Bentonsport area.

**ANTHOZOA**
- Zaphrentis illinoisensis Worthen
- Triplophyllum daele (M.-E. and H.)
- Amplexus sp.

**BRYOZOA**
- Stenopora sp.
- Fenestella serrata Ulrich
- Fenestella cingulata Ulrich
- Fenestella sp.
- Hemitrypa sp.
- Cystodictya sp.
- Worthenopora spinosa Ulrich
- Cyclopora sp.

**BRACHIOPODA**
- Schuchertella sp.
- Productus setigerus Hall

**GASTROPODA**
- Orthonychia sp.

**VERTEBRATA**
- Fish teeth


**List of fossils from bed 13 of Keokuk limestone in Bentonport area.**

**ANTHOZOA—**
Amplexus † sp.

**CRINOIDEA—**
Agaricocrinus sp.
Platycrinus † sp.

**BRYOZOA—**
Meekopora † sp.
Leioclema punctatum (Hall)
Fenestella serratula Ulrich
Fenestella (several species)
Cystodictya (several species)
Wortheinopora spinosa Ulrich

**BRACHIOPODA—**
Schuchertella † sp.
Productus setigerus Hall †
Avonia sp.
Pustula biseriala (Hall)
Pustula sp.

**List of fossils from bed 14 of Keokuk limestone in Bentonport area.**

**BRYOZOA—**
Stenopora sp.
Fenestella serratula Ulrich
Cystodictya sp.

**BRACHIOPODA—**
Productus setigerus Hall
Productus sp.
Pustula sp.
Rhipidomella dubia (Hall) †
Dielasma † sp.
Spirifer tenuecostatus Hall

**List of fossils from bed 15 of Keokuk limestone in Bentonport area.**

**ANTHOZOA—**
Molliilopora beecheri Grabau
Palaeacis obtusus (M. and W.)

**BRACHIOPODA—**
Schuchertella † sp.
Productus setigerus Hall
Productus ovatus Hall
Productus sp.
Productus sp.
Productus sp.

**List of fossils from bed 16 of Keokuk limestone in Bentonport area.**

**ANTHOZOA—**
Palaeacis obtusus (M. and W.)

**BRYOZOA—**
Stenopora † sp.
Fenestella serratula Ulrich

**BRACHIOPODA—**
Orthotetes keokuk (Hall)

**GASTROPODA—**
Orthonychia sp.

**PELICYPODA—**
Orthonychia sp.

**TRILOBITA—**
Griffithides † sp.

**VERTEBRATA—**
Fish teeth
List of fossils from bed 18 of Keokuk limestone in Bentonsport area.

**ANTHOZOA**

- Palaeacis obtusus (M. and W.)
- Zaphrentis varsoviensis Worthen
- Triplophyllum dalei (M.-E. and H.)
- Monilopora beecheri Grabau

**BRYOZOA**

- Meekopora sp.
- Stenopora sp.
- Leioelema punctatum (Hall)
- Penestella serratula Ulrich
- Hemitrypa sp.
- Cystodictya sp.
- Cyclopora † sp.
- Cyclopora † sp.
- Worthenopora spinosa Ulrich

**BRACHIOPODA**

- Chonetes illinoisensis Schuchertella sp.
- Orthotetes keokuk (Hall)
- Productus setigerus Hall
- Productus ovatus Hall
- Productus cf. P. altonensis Weller
- Productus sp.
- Pustula alternata (N. and P.)
- Pustula biseriata (Hall)
- Rhipidomella dubia (Hall)
- Spirifer tenuecostatus Hall
- Spirifer cf. S. keokuk Hall
- Spirifer sp.
- Reticularia pseudolinceta (Hall)
- Eumetria verneuliiana (Hall)
- Eumetria † sp.
- Composita trinuclea (Hall)

**PELECYPODA**

- Conocardium sp.
- Myalina keokuk Worthen

**TRILOBITA**

- Griffithides † sp.

List of fossils from bed 20 of Keokuk limestone in Bentonsport area.

**ANTHOZOA**

- Zaphrentis varsoviensis Worthen
- Triplophyllum dalei (M.-E. and H.)

**BRYOZOA**

- Stenopora sp.
- Taeniodictya ramosa Ulrich

**BRACHIOPODA**

- Orthotetes keokuk (Hall)
- Productus setigerus Hall
- Pustula alternata (N. and P.)
- Pustula biseriata (Hall)

**GASTROPODA**

- Orthonychia Ep.

Henry County.—The only exposures of the Keokuk limestone of importance in Henry county appear along a creek emptying into Skunk river from the south, a short distance west of Webster’s mill in the western part of section 4 of Jackson township. This section has been described previously by Savage 26 in his Geology of Henry County. Fifty-two feet of Keokuk limestone overlain by impure limestones and shales of the Lower Warsaw (Geode bed) is exposed along this creek. The section is given below.

Section of Keokuk limestone near Webster’s mill.

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.</td>
<td>Limestone, bluish gray, medium-grained, upper part gray, very cherty; filled with bryozoans</td>
</tr>
<tr>
<td>18.</td>
<td>Limestone, as above, with fish teeth</td>
</tr>
<tr>
<td>17.</td>
<td>Shale, soft, bluish, argillaceous</td>
</tr>
<tr>
<td>16.</td>
<td>Limestone, bluish gray</td>
</tr>
</tbody>
</table>

---

KEOKUK FOSSILS AT WEBSTER'S MILL

<table>
<thead>
<tr>
<th>Bed</th>
<th>Description</th>
<th>Fossils</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>Shale, soft, bluish, argillaceous</td>
<td>1&lt;br&gt;4</td>
</tr>
<tr>
<td>14</td>
<td>Limestone, bluish gray, medium-grained, weathering into thin layers</td>
<td>1&lt;br&gt;4</td>
</tr>
<tr>
<td>13</td>
<td>Shale, bluish, argillaceous</td>
<td>1&lt;br&gt;4</td>
</tr>
<tr>
<td>12</td>
<td>Limestone, dark gray, medium-grained</td>
<td>1&lt;br&gt;6</td>
</tr>
<tr>
<td>11</td>
<td>Shale, and gray subcrystalline limestone in alternating layers.</td>
<td>1&lt;br&gt;6</td>
</tr>
<tr>
<td>10</td>
<td>Limestone, gray, subcrystalline, with wavy boundaries</td>
<td>7&lt;br&gt;2</td>
</tr>
<tr>
<td>9</td>
<td>Shale, bluish, argillaceous above but calcareous below. No fossils noted</td>
<td>4&lt;br&gt;2</td>
</tr>
<tr>
<td>8</td>
<td>Limestone, bluish, argillaceous above; bluish gray and medium-grained below</td>
<td>3&lt;br&gt;3</td>
</tr>
<tr>
<td>7</td>
<td>Shale, bluish, argillaceous</td>
<td>1&lt;br&gt;1</td>
</tr>
<tr>
<td>6</td>
<td>Limestone, gray and subcrystalline above but bluish and coarse-grained below; shaly in middle part; with a band of fine-grained, cherty limestone 3 to 10 inches thick in lower part</td>
<td>4&lt;br&gt;6</td>
</tr>
<tr>
<td>5</td>
<td>Shale, bluish, argillaceous</td>
<td>1&lt;br&gt;1</td>
</tr>
<tr>
<td>4</td>
<td>Limestone, ash-colored, soft, impure, dolomitic, nonfossiliferous</td>
<td>7&lt;br&gt;1</td>
</tr>
<tr>
<td>3</td>
<td>Limestone, bluish gray, medium-grained, contact with bed above not seen</td>
<td>2 to 3</td>
</tr>
<tr>
<td>2</td>
<td>Shale, bluish, argillaceous</td>
<td>8&lt;br&gt;8</td>
</tr>
<tr>
<td>1</td>
<td>Limestone, gray, medium-grained, with a band of chert at the top</td>
<td>1&lt;br&gt;1</td>
</tr>
</tbody>
</table>

Collections made from the various beds were identified as follows:

**List of fossils from bed 1 of Keokuk limestone near Webster's mill.**

**BRACHIOPODA—**
- Pustula alternata (N. and P.)
- Spirifer logani Hall

**ANTHOZOA**
- Amplexus sp.
- Productus myosialis Hall

**List of fossils from bed 3 of Keokuk limestone near Webster's mill.**

**ANTHOZOA—**
- Zaphrentis varsoviensis Worthen
- Palaeocis obtusus (M. and W.)

**CRINOIDEA—**
- Batocrinus sp.
- Dorycrinus sp.

**BRACHIOPODA—**
- Productus sp.

**List of fossils from bed 6 of Keokuk limestone near Webster's mill.**

**ANTHOZOA—**
- Pustula alternata (N. and P.)
- Orthotetes keokuk (Hall)
- Tetracamera sp.
- Spirifer keokuk Hall

**CRINOIDEA—**
- Batocrinus sp.
- Dorycrinus sp.

**BRACHIOPODA—**
- Productus sp.
- Spiriferina sp.
- Spirifer rostellaris Hall
- Spirifer cf. S. keokuk Hall
- Clithyridina parvirostris (M. & W.)

**List of fossils from bed 8 of Keokuk limestone near Webster's mill.**

**BRACHIOPODA—**
- Productus sp.
- Orthotetes keokuk (Hall)
- Rhipidomella dubia (Hall)
- Dielasma sp.

**List of fossils from bed 10 of Keokuk limestone near Webster's mill.**

**BRACHIOPODA—**
- Pustula biseriata (Hall)
- Spirifer keokuk Hall

**List of fossils from bed 12 of Keokuk limestone near Webster's mill.**

**BRACHIOPODA—**
- Pustula biseriata (Hall)
- Spirifer keokuk Hall
List of fossils from bed 11 of Keokuk limestone near Webster's mill.

**ANTHOZOA—**
- Zaphrentis varsoviensis Worthen
- Triplophyllum dalei (M.-E. and H.)
- Ampexus sp.
- Monilopora beecheri Grabau

**BRYOZOA—**
- Stenopora sp.
- Leioclema punctatum (Hall)
- Cystodictya pustulosa Ulrich
- Cystodictya lineata Ulrich
- Phractopora trifolia (Bominger)
- Bactropora simplex Ulrich
- Rhombopora attenuata Ulrich
- Rhombopora transversalis Ulrich
- Streblotrypa major Ulrich
- Streblotrypa radialis Ulrich
- Fenestella tenax Ulrich

**BRACHIOPODA—**
- Productus setigerus Hall
- Productus sp.
- Camarotoechia mutata (Hall)
- Dryidomella dubia (Hall)
- Rhipidomella dubia (Hall)
- Dielasma sp.
- Dielasma sp.
- Spirifer tenuicostatus Hall
- Composita trinuclea (Hall)
- Reticularia pseudolineata (Hall)

List of fossils from bed 12 of Keokuk limestone near Webster's mill.

**ANTHOZOA—**
- Palaeacis obtusus (M. and W.)
- Zaphrentis varsoviensis Worthen
- Zaphrentis sp.

**BRACHIOPODA—**
- Productus sp.

List of fossils from bed 14 of Keokuk limestone near Webster's mill.

**ANTHOZOA—**
- Zaphrentis sp.

**BRYOZOA—**
- Leioclema punctatum (Hall)
- Fenestella tenax Ulrich
- Cystodictya lineata Ulrich

**BRACHIOPODA—**
- Orthotetes keokuk (Hall)

List of fossils from bed 19 of Keokuk limestone near Webster's mill.

**ANTHOZOA—**
- Monilopora beecheri Grabau

**BRYOZOA—**
- Leioclema punctatum (Hall)
- Fenestella radiis Ulrich
- Fenestella serrataula Ulrich
- Hemitrypa sp.
- Cystodictya lineata Ulrich
- Rhombopora varians Ulrich

**BRACHIOPODA—**
- Productus setigerus Hall
- Productus sp.
- Productus setigerus Hall
- Productus setigerus Hall
- Productus sp.

Louisa County.—Only the lowermost beds of the Keokuk limestone, corresponding to the Montrose chert horizon, are known to occur in Louisa county. These have been recognized by Udden27 in a number of exposures.

A section in a Honey creek quarry opening one-fifth mile up—

---
stream from the main quarry, which is located near the north line of the southwest quarter of section 28, Morning Sun township, has been measured and redescribed by the writer.

Section of Keokuk limestone on Honey creek.

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.</td>
<td>Drift</td>
</tr>
<tr>
<td>7.</td>
<td>Limestone, brownish yellow, soft, dolomitic, cherty; with occasional layers and lenses of gray subcrystalline, non-dolomitic fossiliferous limestone</td>
</tr>
<tr>
<td>6.</td>
<td>Limestone, gray, tough, crinoidal; with small irregular chert nodules</td>
</tr>
<tr>
<td>5.</td>
<td>Limestone, brownish yellow, soft, dolomitic, fine-grained, with a chert band in the lower part</td>
</tr>
<tr>
<td>4.</td>
<td>Limestone, gray, compact, tough, crinoidal</td>
</tr>
<tr>
<td>3.</td>
<td>Limestone, soft, brownish, dolomitic, crinoidal in upper part</td>
</tr>
<tr>
<td>2.</td>
<td>Shale, bluish, argillaceous</td>
</tr>
<tr>
<td>1.</td>
<td>Limestone, crinoidal, bluish with greenish specks below but brownish and with soft fine-grained dolomitic seams above; a chert band 2 to 8 inches thick in upper part</td>
</tr>
</tbody>
</table>

A few identifiable fossils collected from beds 1 and 7 are listed below:

List of fossils from bed 1 of Keokuk limestone on Honey creek.

- **Anthozoa**
  - Zaplicrinitis sp.
- **Brachiopoda**
  - Chonetes sp.
  - Riftidomella sp.
  - Schizophoria sp.
  - Spirifer tenuicostatus Hall
  - Spirifer grimesi Hall
  - Brachythyris suborbicularis (Hall)
  - Cloothyrina sp.

List of fossils from bed 7 of Keokuk limestone on Honey creek.

- **Brachiopoda**
  - Productus sp.
  - Dielesma sp.
  - Spirifer rostellatus Hall
  - Spirifer sp.
  - Reticularia pseudolincata (Hall)
  - Composita globosa Weller
  - Composita triploma (Hall)

In the Elrick quarry located near the south county line on the left bank of Smith creek, Udden\(^2^8\) found twenty-two feet of weathered limestone overlying the Upper Burlington. However, no fossils are listed by him from this exposure. Again Udden\(^2^9\) reports fifteen feet of "weathered shaly limestone and shale with cherty layers" of this horizon in an exposure along Long creek in the southeast corner of section 33 of Columbus township.

The following section from Udden\(^2^9\), located in the south bank of Long creek near the west line in the northwest quarter

---

\(^2^8\) Iowa Geol. Survey, vol. XI, p. 75; 1901.
\(^2^9\) Idem, p. 81.
of section 32, Columbus township, also represents the basal Keokuk.

Section of Keokuk limestone in section 32, Columbus township (After Udden).

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Shaly limestone</td>
<td>5</td>
</tr>
<tr>
<td>2. Blue shale</td>
<td>1</td>
</tr>
<tr>
<td>1. Yellow limestone, somewhat fine-grained</td>
<td>8</td>
</tr>
</tbody>
</table>

Keokuk County.—Several exposures of the Keokuk limestone have been reported from Keokuk county. The more important ones appear along Rock creek northwest of Ollie. One of the more typical of these is shown in the “Granite” quarry in the southwest quarter of the southeast quarter of section 10, Jackson township.

Section of Keokuk limestone in “Granite” quarry

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>8. Concealed. With chips of soft brownish dolomitic limestone on slope. Indications of bluish argillaceous shale in upper part. Probably consists of shale with interbedded layers of brownish dolomitic limestone</td>
<td>8</td>
</tr>
<tr>
<td>7. Limestone, brownish, soft, dolomitic, cherty</td>
<td>1 10</td>
</tr>
<tr>
<td>6. Conceded, chips of soft brownish dolomitic limestone on slope</td>
<td>7 10</td>
</tr>
<tr>
<td>5. Limestone, soft, brownish, dolomitic, with irregular bands of compact gray chert</td>
<td>3 6</td>
</tr>
<tr>
<td>4. Shale, bluish, argillaceous</td>
<td>3 6</td>
</tr>
<tr>
<td>3. Limestone, bluish gray, coarse-grained</td>
<td>2 7</td>
</tr>
<tr>
<td>2. Shale, bluish, argillaceous</td>
<td>2</td>
</tr>
<tr>
<td>1. Limestone, bluish gray, coarse-grained, crinoidal; in rather heavy layers. Top layer weathering into thin shaly seams</td>
<td>5</td>
</tr>
</tbody>
</table>

Collections were made from beds 1 and 8. These have been identified as follows:

List of fossils from bed 1 of Keokuk limestone in “Granite” quarry.

ANTHOZOA—

| Triphyma dalei (M.E. and H.) |
| Zaphrentis varioiensis Worthen |
| Palaeos obtusus (M. and W.) |

CRINOIDEA—

| Platyctenus sp. |

BRACHIOPODA—

| Orthotetes keokuk (Hall) |
| Productus sp. |
| Pustula alternata (N. and P.) |
| Rhipidomella dubia (Hall) |
| Girtyella indiannensis (Girty) |
| Spirifer keokuk Hall |

List of fossils from bed 8 of Keokuk limestone in “Granite” quarry.

BRYOZOA—

| Leiolea punctatum (Hall) |
| Rhombonora varians Ulrich |
| Fenestella sp. |

List of fossils from bed 8 of Keokuk limestone in “Granite” quarry.

PELECYPODA—

| Spiroceras sp. |

GASTROPODA—

| Stretobrya sp. |

TRILOBITA—

| Griffithides sp. |

List of fossils from bed 8 of Keokuk limestone in “Granite” quarry.

BRACHIOPODA—

| Spirifer f sp. |

List of fossils from bed 8 of Keokuk limestone in “Granite” quarry.
Three hundred yards south of the above section a small abandoned quarry opening shows several beds of the Upper St. Louis. The basal bed of the section lies about twenty-two feet above the level of the top of bed 8 of the "Granite" quarry. It is believed that the Lower St. Louis limestone occupies the concealed interval between the two beds and that the latter formation succeeds the Keokuk formation directly, the Warsaw beds and the Sperrgen limestone being absent in this area.

Less than half a mile north of the "Granite" quarry a good exposure of the Keokuk beds appears in the north bank of Rock creek, just west of the wagon bridge, in the northeast quarter of the southwest quarter of section 10, Jackson township.

Section of Keokuk beds in section 10, Jackson township.

<table>
<thead>
<tr>
<th>Section of Keokuk beds in section 10, Jackson township.</th>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. Drift ..................................................................</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>10. Limestone, buff, dolomitic, soft, rotten, with chert bands. Bed 5 of &quot;granite&quot; quarry section</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>9. Shale, bluish, argillaceous. Bed 4 of &quot;granite&quot; quarry section</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>8. Limestone, bluish gray, coarse-grained except in middle part, which is dolomitic, buff and fine-grained. Bed 3 of &quot;granite&quot; quarry section</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>6. Limestone, bluish gray, coarse-grained, with intercalated layers of gray subcrystalline limestone. A layer at top filled with Spirifer keokuk. Bed 1 of &quot;granite&quot; quarry section</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>5. Limestone, ash-colored, fine-grained, dolomitic, impure, soft, weathering yellowish</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>4. Limestone, gray, subcrystalline, cherty; interbedded with layers of soft buff cherty dolomitic limestone</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>3. Shale, calcareous, ash-gray in color, weathering slightly yellowish</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>2. Limestone, gray, dense, brittle, subcrystalline, cherty</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>1. Limestone, gray, crinoidal, with occasional chert bands. Lower part poorly exposed</td>
<td>5</td>
<td>9</td>
</tr>
</tbody>
</table>

The following species were identified from the various beds:

**List of fossils from bed 1 of Keokuk limestone in section 10, Jackson township.**

**Anthozoa—**
- Zaphrentis varsoviensis Worthen
- Triplophyllum dalei (M.-E. and H.)

**CRINOIDA—**
- Macrocrinus verneuillianus (Shumard)
- Actinocrinus sp.

**BRACHIOPODA—**
- Orthotetes keokuk (Hall)
- Orthotetes sp.
- Productus sp.
- Pustula alternata (N. and P.)
- Rhipidomella dubia (Hall)
- Tetracamera subtrigona (M. and W.)
- Delasma sp.
- Spirifer grimesi Hall
- Spirifer sp.
- Brachythiris suborbicularis (Hall)
- Syringothyris sp.
- Reticularia pseudolineata (Hall)
- Cliothyridina incrassata (Hall)

**GASTROPODA—**
- Platyceles sp.
- Platyceras sp.
- Platyceras sp.
- Orthoceras sp.
- Orthoceras sp.
- Orthoelychia sp.

**TRILOBITA—**
- Phillipsia sp.
List of fossils from bed 2 of Keokuk limestone in section 10, Jackson township.

**BRYOZOA—**
- Fenestella serratula Ulrich
- Fenestella multispinosa Ulrich
- Fenestella sp.
- Cystodictya sp.
- Pustula sp.
- Spirifer tenuicostatus Hall
- Brachythryris subbicolor Hall
- Reticularia pseudolineata (Hall)

**GASTROPODA—**
- Platymeris sp.

List of fossils from bed 4 of Keokuk limestone in section 10, Jackson township.

**BRYOZOA—**
- Stenopora sp.

**Brachiopoda—**
- Chonetes sp.
- Productus sp.
- Pustula sp.
- Avonia sp.
- Spirifer tenuicostatus Hall
- Spirifer keokuk Hall
- Spirifer rosetellatus Hall
- Syringothyris sp.
- Syringothyris textus (Hall)
- Reticularia pseudolineata (Hall)
- Athyris lamellosa (Leveille)
- Cliothyridina obmaxima (McChesney)
- Composita trinuclea (Hall)

**GASTROPODA—**
- Orthonychia sp.
- Orthotetes keokuk (Hall)

List of fossils from bed 6 of Keokuk limestone in section 10, Jackson township.

**ANTHOZOA—**
- Amplexus sp.
- Zaphrentis varsoviensis Worthen
- Monilopora sp.
- Palaeacis obtusus (M. and W.)

**CRINOIDEA—**
- Euadadocinus sp.

**BRACHIOPODA—**
- Stenopora sp.
- Leioclena gracillim Ulrich
- Fenestella multispinosa Ulrich
- Hemitrype sp.
- Polyopora sp.
- Rhombopora varians Ulrich
- Rhombopora attenuata Ulrich
- Cystodictya sp.
- Glyptopora keysorama (Prout)
- Orthotetes keokuk (Hall)
- Spirifer tenuicostatus Hall
- Spirifer rosetellatus Hall
- Syringothyris sp.
- Syringothyris textus (Hall)
- Reticularia pseudolineata (Hall)
- Eumetria verneuiliana (Hall)

**PELECYODA—**
- Schizodus sp.

**GASTROPODA—**
- Orthonychia sp.
- Bulimorpha f keokuk (Worthen)

List of fossils from bed 8 of Keokuk limestone in section 10, Jackson township.

**Brachiopoda—**
- Spirifer keokuk Hall
- Bulimorpha f keokuk (Worthen)

One-half mile north of the preceding section is located the Weber quarry now owned by Elbert Davis (NW. 1/4 NE. 1/4 sec. 10, Jackson township). Sixteen feet of gray coarse-grained cherty crinoidal limestone, interbedded with gray subcrystalline cherty limestone and soft buff cherty dolomitic limestone is exposed. The outcrop is believed to represent beds 1 to 5 of the preceding bluff section.

Bain^30 describes the Keokuk ("Augusta") limestone in Con-

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nor's quarry, in the southwest quarter of the southeast quarter of section 15, Sigourney township, as being in contact with the St. Louis limestone. His section is as follows:

Section in Connor's quarry (after Bain).

<table>
<thead>
<tr>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Limestone, coarse, subcrystalline. Exposed at water's edge... 4</td>
</tr>
<tr>
<td>2. Limestone, yellow, soft, magnesian; apparently arenaceous in part, massive. Exposed ........................................... 10</td>
</tr>
</tbody>
</table>

He refers bed 1 to the "Augusta" and bed 2 to the St. Louis. Bed 1 is concealed at the present time. Bain further makes the following statement:

"About two and one-half miles west of Conner's quarry (Tp. 75 N., R. 12 W., sec. 18, SE. qr., SE.1/4) the Augusta limestone having the usual characteristics rises above the water four feet. Both above and below this point the St. Louis is well developed."

At the Springvale mill five miles south of the town of Delta in Warren township an exposure of bluish calcareous shales appears in a low bluff of Skunk river. In the Keokuk county report Bain designates these shales the Springvale beds and correlates them provisionally with the lower division of the St. Louis limestone. These shales possess all the characteristics of those present in the upper part of the Keokuk limestone elsewhere in Keokuk county and although they have not been found to contain fossils sufficiently well preserved to make this correlation positive they are referred to this formation on lithologic grounds. The term Springvale as applied to the lower division of the St. Louis limestone in this part of Iowa is therefore believed to be a misnomer.

31 Idem, p. 273.  
32 Idem, pp. 277-279; 1894.
CHAPTER IV

THE MERAMEC GROUP

Definition of Meramec

Ulrich\(^1\) proposed the name Meramec in 1904 to include the Warsaw, Spergen Hill and St. Louis formations which outcrop along Meramec river in Missouri. Several later authors have restricted the group to include only the St. Louis and Spergen, the underlying Warsaw being referred to the Osage.

Weller\(^2\) in his report on the geology of Hardin county, Illinois, includes the Warsaw in this group as well as the Ste. Genevieve formation. The following quotation from his report will make his position in the matter clear:

"As originally defined, the Meramec group included in ascending order, the Warsaw limestone, the Spergen (Salem) limestone, and the St. Louis limestone. In the present report the Ste. Genevieve limestone is also included as a fourth formation in the group, above the St. Louis limestone. For many years after the original definition of the Ste. Genevieve limestone by Shumard in 1859, the formation was scarcely or not at all recognized, the beds representing it being commonly included with the St. Louis limestone. Ulrich revived the name of the formation in 1905, but excluded it from the Meramec group, making it the lowest formation of the Chester group, an interpretation that he still holds to at this time. All the evidence, however, that has been gathered during a period of a dozen years, shows the much closer relationship of the Ste. Genevieve to the St. Louis limestone than to any of the Chester formations. In a number of publications during recent years, as a compromise measure, the Ste. Genevieve has been treated as a separate unit in the Mississippian system, being united with neither the Meramec group below, nor the Chester group above, but the time has now come when it is desirable to place the Ste. Genevieve limestone where it properly belongs, with the St. Louis limestone. In order to accomplish this result it is necessary either to modify the original definition of the Meramec group so that it shall include the Ste. Genevieve limestone, or to

\(^1\) U. S. Geol. Survey Prof. Paper 24, table opp. p. 90.
\(^2\) Illinois Geol. Survey, Bull. 41, pp. 96, 97; 1920.
propose a new group name for the four formations. As it seems more desirable to retain the name already in use with a slightly modified definition, than to add confusion to the nomenclature by introducing a totally new name, such a procedure is consequently followed here."

The revised usage of the term Meramec as recommended by Weller is adopted in this report.

Distribution of the Group

The Warsaw and Spergen members of the Meramec group are restricted to the southeastern part of the state, but the St. Louis and Ste. Genevieve formations extend far beyond to the north-central part. On the geologic map of Iowa, the Warsaw deposits are included in the Osage areas while the Spergen, St. Louis and Ste. Genevieve, all of which were formerly identified as St. Louis limestone, are mapped under that heading. The group forms the highest consolidated rock over a much larger area in southeastern Iowa than farther northwest. It appears in the southern and northwestern parts of Lee county, over almost the entire area of Henry county, the southwestern parts of Louisa and Washington counties, and the greater part of Keokuk county. It has been mapped also along the valleys of Skunk and Des Moines rivers and some of their larger tributaries in Van Buren, Jefferson, Wapello, Mahaska, Marion and southern Poweshiek counties.

In west-central Story county, the St. Louis member of the group has been exposed as a result of the erosion of the overlying Pennsylvanian rocks over a low dome. Small inliers of the Ste. Genevieve and St. Louis also appear in Webster county, while farther north in central and western Humboldt county there are restricted outliers of the St. Louis in the Kinderhook area. The extent of the group to the southwest beneath the Pennsylvanian is not definitely known, but evidently is considerable.

Lithologic Character

The Meramec group is made up of a larger proportion of clastic material and is much more diversified in character than is true of the preceding Osage deposits. It is represented in
Iowa by marginal facies of formations which are thicker, more typically developed and more uniform in character farther south in the Mississippi valley.

The Warsaw formation consists of bluish argillaceous shales with thin intercalated layers of gray fine-grained fossiliferous limestone. The Spergen is represented typically by brownish arenaceous magnesian limestone but locally some layers pass into shales or cross-bedded crinoidal limestone. The St. Louis consists for the most part of limestone which in the unaltered condition is thin-bedded, gray, fine-grained and dense. Locally it grades laterally in part into brownish massive dolomite or into sandstone. In some of its exposures it is brecciated. The Ste. Genevieve is normally made up of a fine-grained bluish gray basal sandstone, followed above by shale and then limestone, but in north-central Iowa it is nearly all shale.

**Thickness**

The Meramec group attains its maximum thickness in Iowa only in the southeastern part of the state where all its members are present. The aggregate thickness there is approximately two hundred feet. However, this value is subject to considerable variation from place to place owing to the thickening and thinning of the individual formations.

**Stratigraphic Relations**

In Lee, Henry, Van Buren and Des Moines counties, where the Warsaw beds are present, there appears to be a transition from the Osage into the Meramec group but farther northwest the Spergen and St. Louis formations overlap the Warsaw and there a disconformity is present. Disconformities appear within the group between the Spergen and St. Louis and between the St. Louis and Ste. Genevieve. However, these represent erosion intervals of limited duration. Between the Meramec and basal Pennsylvanian deposits there exists a profound stratigraphic break.

**The Warsaw Formation**

**NOMENCLATURE AND DISTRIBUTION**

The Warsaw formation as defined by Hall\(^3\) and described by

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\(^3\) Geol. of Iowa, vol. I, pt. 1, p. 97; 1858.
later writers, consists of approximately forty feet of interbedded shale and limestone, typically developed near the town of Warsaw, in Hancock county, western Illinois. The present investigation, however, has demonstrated the advisability of including the underlying Geode bed with this formation. This division, as has been pointed out, was included with the Keokuk limestone by Hall and his successors. But a study of its fauna indicates a stronger relationship to the Warsaw. In the present report it is designated the Lower Warsaw, while the Warsaw of Hall is referred to the Upper Warsaw. Altogether one hundred and twelve fossils have been specifically identified from this member by the writer. According to all the evidence at hand, about forty-five of these (chiefly crinoids and bryozoans) appear for the first time. Eighteen of this number occur either in the Warsaw of Hall or in the overlying Spergen formation.

The fauna of the Warsaw of Hall, or the Upper Warsaw as revised, is noted for its profusion of bryozoans and other fossils. Many of these fossils are of a distinctly Spergen aspect, in spite of the fact that in Iowa a disconformity separates the two members.

Both divisions of the Warsaw pinch out to the north and northwest, probably due in part to the proximity of the old shore line in that direction, and in part to pre-Spergen erosion. The upper division pinches out much more abruptly than the lower. At Keokuk, Iowa, about four miles northwest of Warsaw, this member is less than two-thirds as thick as at the type locality, and a few miles beyond, it evidently wedges out completely. It has been found nowhere north of the limits of Lee county. The northernmost exposures of beds known certainly to represent the Lower Warsaw occur along Mud creek near Lowell in southern Henry county and in the banks of Long creek about two miles northwest of the town of Augusta in southern Des Moines county. To the northwest it has been observed as far as Van Buren county. In the marginal areas this member is usually succeeded above by the Spergen due to the overlap of that formation beyond the Upper Warsaw but at some localities the Lower St. Louis limestone appears above as a result of the disconformity between this formation and the Spergen.
THE LOWER WARSAW BEDS
LITHOLOGIC CHARACTER

This division is approximately thirty-six feet in thickness in the vicinity of Warsaw, Illinois, which is the type locality. Near Warsaw and at Keokuk, Iowa, it is divisible into three portions. The lower one-third is usually represented by a fine-grained soft ash-colored massive, impure, geode-bearing magnesian limestone which upon exposed surfaces scales off obliquely to the surface of the bluff. At some localities this is interbedded with thin layers of grayish blue fossiliferous limestone similar to that of the underlying Keokuk formation. A layer of gray thin-bedded cherty limestone overlies this bed. It is locally brownish and dolomitized and is two to four feet thick.

The upper portion of the Lower Warsaw is a tough argillaceous or slightly calcareous shale which breaks down readily to a gritty clay on exposure. It is laminated in many exposures, a character which is in contrast to the massive beds below. At some localities geodes are more numerous in this than in the lower portion, but they are generally much smaller and more poorly developed.

The Lower Warsaw is represented by geodiferous and non-geodiferous phases. In places these pass into each other laterally within short distances. The only apparent physical difference between the two phases is the usual presence of fossils in that phase which bears no geodes, and their paucity in the geodiferous portions. The Lower Warsaw at some localities contains calcareous nodules, whose relationship to the containing rock is the same as that of the geodes.

The composition of the lower portion of the Lower Warsaw at a point along Soap creek at Keokuk, where it contains large well developed geodes, is shown by the following analysis:

<table>
<thead>
<tr>
<th>Component</th>
<th>Per Cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insoluble matter (largely free silica)</td>
<td>33.80</td>
</tr>
<tr>
<td>Fe₂O₃ + Al₂O₃</td>
<td>2.80</td>
</tr>
<tr>
<td>CaCO₃</td>
<td>39.99</td>
</tr>
<tr>
<td>MgCO₃</td>
<td>12.50</td>
</tr>
<tr>
<td>Moisture and carbonaceous matter</td>
<td>7.70</td>
</tr>
<tr>
<td>Undetermined</td>
<td>3.21</td>
</tr>
</tbody>
</table>

Satisfactory outcrops of the Lower Warsaw are not often found where the formation is not capped by more resistant lay-
ers, because of the tendency of the shaly parts to weather back in the form of gentle slopes which become covered by vegetation. Slumping of the shale, which likewise is common, also has obscured many exposures. Well defined outcrops of this division of the Warsaw occur locally along the banks of the larger streams and their tributaries in southern and eastern Lee county, southeastern Van Buren county, and southern Henry and Des Moines counties. Good exposures appear also in Hancock county, Illinois, and Clark county, Missouri.

AREAL DESCRIPTION BY COUNTIES

Hancock County, Illinois.—The most typical exposure of the fossiliferous facies of the Lower Warsaw known to the writer is that along the creek known as Soap Factory Hollow, which joins the Mississippi from the east about one-half mile south of Lower Warsaw, Illinois. The section begins with the city quarry. From this point the exposures continue along the creek bed and in its banks for nearly one-half mile up stream.

In the upper part of the quarry there is exposed a few feet of shales, with thin layers of limestone interbedded, followed below by three and one-half feet of gray thin-bedded cherty limestone, representing the middle member of the Lower Warsaw. Under this comes eleven and one-half feet of fine-grained bluish magnesian, cherty limestone with interbedded seams and layers of grayish to bluish coarse-grained fossiliferous limestone which is correlated with the lower member. Geodes are wanting except for an occasional imperfectly developed one. About three feet of bluish fossiliferous Keokuk limestone is shown in the quarry face below this member. Still lower layers of the Keokuk limestone are shown in the creek bed nearby.

The lower member of the Lower Warsaw is excellently exposed along the bed of the creek above the quarry. Some of the limestone layers of this member bear sinuous pipelike fucoid markings on their surfaces. A few of these are selectively replaced by chert. They range from a fraction of an inch to an inch or more in greatest diameter. They are somewhat compressed vertically. Excellent opportunities are afforded for collecting from this member at this locality. At no other known place is the Lower Warsaw so highly fossiliferous.
The middle limestone member of the Lower Warsaw is well exposed in the creek bed a short distance farther up stream around the first bend. It grades gradually upward into the upper member of the Lower Warsaw.

The upper member of the Lower Warsaw is represented farther up the creek by the following beds listed in descending order:

*Section of upper member of Lower Warsaw beds in Soap Factory Hollow.*

6. Shale, bluish, argillaceous, overlain by thin-bedded, nonmagnesian fossiliferous limestone of the basal Upper Warsaw .... 2
5. Geode bed, with many siliceous geodes .................................. 1½-1
4. Shale, argillaceous, bluish .................................................. 3
3. Limestone, in thin shaly, cherty layers filled with bryozoa .... 2
2. Shale, ash-colored, calcareous; weathering to very irregular flakes with a few poorly preserved fossils ........................................... 9½
1. Limestone, shaly; with thin interbedded cherty layers of gray subcrystalline limestone, which is increasingly prevalent towards the base. The shaly limestone layers bear a rich bryozoan fauna, while the subcrystalline limestone bears a fauna nearly identical with the middle member of the Lower Warsaw, which it resembles very closely physically. This division outcrops along the bed of the creek only and its thickness could not be determined accurately. It is believed to be about ten feet .......................................................... 10±

The geodes of bed 5 range in diameter from a few inches to over two feet. Locally they are so closely crowded as to form a continuous layer for several yards. In such cases of crowding the geodes are very irregular in shape, and in some instances several specimens are grown closely together. Many of them are imperfectly developed. Quartz and dolomite appear to be the common minerals lining their interiors. Pockets of kaolin appear in the chalcedonic shells and in the interiors of imperfect specimens.

The faunules of the three members of the Lower Warsaw at Soap Factory Hollow are listed below:

*List of fossils from the basal member of the Lower Warsaw beds.*

**Anthoza**—
- *Triplathyllum* cælei (M.-E. and H.)
- *Amplexus* sp.
- *Monilopora* beecheri Grabau

**Crinoida**—
- *Barycerinus* sp.
- *Uperocrinus* nashvillae (Hall)
- *Agaricerinus* wortheni Hall

**Blastoida**—
- *Schizoblastus* granulosus (M. and W.)

**Echinoidea**—
- *Archaeocidaris* keenkuk Hall

**Bryozoa**—
- *Stenopora* sp.
- *Fenestella* serratula Ulrich
- *Fenestella* limitaria Ulrich
- *Fenestella* triseriata Ulrich
- *Fenestella* tenax Ulrich
- *Fenestella* multipinosa Ulrich
- *Fenestella* funicula Ulrich
<table>
<thead>
<tr>
<th>FOSSILS OF LOWER WARSAW BEDS</th>
<th>189</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fenestella compressa Ulrich</td>
<td>Productus ovatus Hall</td>
</tr>
<tr>
<td>Fenestella sp.</td>
<td>Productus setigerus Hall</td>
</tr>
<tr>
<td>Fenestella sp.</td>
<td>Pustula alternata (N. and P.)</td>
</tr>
<tr>
<td>Hemitrype pateriformis Ulrich</td>
<td>Camarotoechia mutata (Hall)</td>
</tr>
<tr>
<td>Archimedes owenanus Hall</td>
<td>Dielasma sp.</td>
</tr>
<tr>
<td>Polypora gracilis Prout</td>
<td>Spirifer rostellatus Hall</td>
</tr>
<tr>
<td>Polypora varsoviensis Prout</td>
<td>Spirifer cf. S. keokuk Hall</td>
</tr>
<tr>
<td>Ptilopora sp.</td>
<td>Spirifer tenuicostatus Hall</td>
</tr>
<tr>
<td>Ptilopora sp.</td>
<td>Brachythrysis suborbicularis (Hall)</td>
</tr>
<tr>
<td>Pinnaeopteris conferta Ulrich</td>
<td>Brachythrysis subcardiformis (Hall)</td>
</tr>
<tr>
<td>Rhombopora varians Ulrich</td>
<td>Spirella neglcta (Hall)</td>
</tr>
<tr>
<td>Rhombopora attenuata Ulrich</td>
<td>Reticularia setigera (Hall)</td>
</tr>
<tr>
<td>Cystodictya pustulosa Ulrich</td>
<td>Clothyrinida parvirostris (M. and W.)</td>
</tr>
<tr>
<td>Cystodictya lineata Ulrich</td>
<td>Composita trinuclea (Hall)</td>
</tr>
<tr>
<td>Worthenopora spinosa Ulrich</td>
<td><strong>GASTROPODA</strong></td>
</tr>
<tr>
<td><strong>BRACHIOPODA</strong></td>
<td>Platyceeras equilateralis Hall</td>
</tr>
<tr>
<td>Orthotetes keokuk (Hall)</td>
<td></td>
</tr>
<tr>
<td><strong>List of fossils from the middle member of the Lower Warsaw beds.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>ANTHOOZA</strong></td>
<td>Dielasma sp.</td>
</tr>
<tr>
<td><strong>Triplophyllum dalei (M.-E. and H.)</strong></td>
<td>Crassaena sulcata Weller</td>
</tr>
<tr>
<td>Zaphrentis (?) sp.</td>
<td>Crassaena sp.</td>
</tr>
<tr>
<td>Amphilectus sp.</td>
<td>Spirifer bifurcatus Weller</td>
</tr>
<tr>
<td><strong>VERMES</strong></td>
<td>Spirifer tenuicostatus Hall</td>
</tr>
<tr>
<td><strong>Spirorbis (?) sp.</strong></td>
<td>Spirifer cf. S. keokuk Hall</td>
</tr>
<tr>
<td><strong>BRYOZOA</strong></td>
<td>Brachythrysis subcardiformis (Hall)</td>
</tr>
<tr>
<td>Fenestella tenax Ulrich</td>
<td>Brachythrysis suborbicularis (Hall)</td>
</tr>
<tr>
<td>Fenestella serratula Ulrich</td>
<td>Reticularia setigera (Hall)</td>
</tr>
<tr>
<td>Fenestella multispinosa Ulrich</td>
<td>Eumetria verneuiliana (Hall)</td>
</tr>
<tr>
<td>Fenestella triserialis Ulrich</td>
<td>Clothyrinida parvirostris (M. and W.)</td>
</tr>
<tr>
<td>Hemitrype pateriformis Ulrich</td>
<td>Composita trinuclea (Hall)</td>
</tr>
<tr>
<td>Hemitrype sp.</td>
<td>Composita globosa Weller</td>
</tr>
<tr>
<td>Polythora retrovosa Ulrich</td>
<td><strong>PELECYPODA</strong></td>
</tr>
<tr>
<td>Rhombopora attenuata Ulrich</td>
<td>Allocistea sp.</td>
</tr>
<tr>
<td>Cystodictya pustulosa Ulrich</td>
<td>Aviculopecten sp.</td>
</tr>
<tr>
<td>Worthenopora spinosa Ulrich</td>
<td>Aviculopecten sp.</td>
</tr>
<tr>
<td>Cyclopora sp.</td>
<td><strong>SCAPHOPODA</strong></td>
</tr>
<tr>
<td><strong>BRACHIPODA</strong></td>
<td>Laedidentalium sp.</td>
</tr>
<tr>
<td>Productus setigerus Hall</td>
<td><strong>GASTROPODA</strong></td>
</tr>
<tr>
<td>Pustula alternata (N. and P.)</td>
<td>Holopea proutana Hall</td>
</tr>
<tr>
<td>Pustula biseriata (Hall)</td>
<td>Strophostylus carleyana (Hall)</td>
</tr>
<tr>
<td>Camarotoechia mutata (Hall)</td>
<td></td>
</tr>
<tr>
<td><strong>List of fossils from the upper member of the Lower Warsaw beds.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>ANTHOOZA</strong></td>
<td>Fenestella tenax Ulrich</td>
</tr>
<tr>
<td>Zaphrentis sp.</td>
<td>Fenestella radiis Ulrich</td>
</tr>
<tr>
<td>Triplouphyllum dalei (M.-E. and H.)</td>
<td>Fenestella triserialis Ulrich</td>
</tr>
<tr>
<td>Amphilectus sp.</td>
<td>Fenestella exigua Ulrich</td>
</tr>
<tr>
<td>Monilopora beecheri Grabau</td>
<td>Fenestella multispinosa Ulrich</td>
</tr>
<tr>
<td>Monilopora (?) sp.</td>
<td>Fenestella compressa Ulrich</td>
</tr>
<tr>
<td><strong>VERMES</strong></td>
<td>Fenestella sp.</td>
</tr>
<tr>
<td><strong>Spirorbis sp.</strong></td>
<td>Archimedes owenanus Hall</td>
</tr>
<tr>
<td><strong>CRINOIDEA</strong></td>
<td>Archimedes wortheni Hall</td>
</tr>
<tr>
<td><strong>Berycinus sp.</strong></td>
<td>Hemitrype pateriformis Ulrich</td>
</tr>
<tr>
<td><strong>BRYOZOA</strong></td>
<td>Hemitrype sp.</td>
</tr>
<tr>
<td>Fistulipora (?) sp.</td>
<td>Polythora biseriata Ulrich</td>
</tr>
<tr>
<td>Meekopora sp.</td>
<td>Polypora varsoviensis Prout</td>
</tr>
<tr>
<td>Batostomella (?) sp.</td>
<td>Polypora gracilis Prout</td>
</tr>
<tr>
<td>Stenopora sp.</td>
<td>Polypora retrovosa Ulrich</td>
</tr>
<tr>
<td>Leiocoma punctatum (Hall)</td>
<td>Ptilopora valida Ulrich</td>
</tr>
<tr>
<td>Fenestella serratula Ulrich</td>
<td>Ptilopora sp.</td>
</tr>
</tbody>
</table>
Good exposures of the Lower Warsaw in contact with the Upper Warsaw are present in the bluffs of a small creek tributary to the Mississippi, a short distance northeast of the town of Warsaw. The Lower Warsaw is geode-bearing at this locality and is almost barren of recognizable fossils. The section is as follows:

Section of Lower Warsaw beds northeast of Warsaw.

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Upper Warsaw shales and limestone</td>
<td>18 6</td>
</tr>
<tr>
<td>3. Shale, argillaceous, weathering into thin laminé; more resistant layers slightly projecting; bearing numerous small geodes arranged in bands</td>
<td>23</td>
</tr>
<tr>
<td>2. Limestone, impure, buff, magnesian, containing discontinuous bands and nodules of chert</td>
<td>3 3</td>
</tr>
<tr>
<td>1. Limestone, drab, fine-grained, impure, magnesian, massive, scaling off obliquely to the face of the bluff; geodes few and scattered in upper part but more abundant below; many of them broken because of the fragile condition of their shells. Exposed</td>
<td>6</td>
</tr>
</tbody>
</table>

The Lower Warsaw in its typical development comprises numbers 1 to 3 of this section. Attention is called to the fact that the middle member is here dolomitic.

The Lower Warsaw is exposed also near Hamilton, Illinois, four miles north of Warsaw, in the clay pits of the Hamilton Clay Company. The blue calcareous shale of the upper member is here used in the manufacture of brick and tile and large numbers of geodes which have been picked from the clay are available for study.

In the vicinity of Niota, in Hancock county, the Lower Wa-
LOWER WARSAW BEDS NEAR NIOTA

saw is exposed at several localities. The following beds outcrop on the west bluff of a small creek one-half mile east of the town.

Section of Lower Warsaw beds east of Niota.

2. Shale, argillo-calcareous, with flakes of impure nonfossiliferous limestone; bearing a few geodes ranging up to four inches in diameter ................................................................. 19
1. Limestone, impure, fine-grained, magnesian; interstratified near the middle with bands of bluish fossiliferous limestone 6 to 8 inches thick; a few geodes in the more impure parts ........... 15

At the Fort Madison-Appanoose quarries, which are located in the Mississippi river bluff two miles above Niota, twenty-two and one-half feet of dolomitie Spergen limestone rests disconformably upon the bluish calcareous geodiferous shale of Lower Warsaw age. The Upper Warsaw, if ever present at this place, was completely eroded before the deposition of the Spergen.

Many of the geodes which are found to the south of Niota bear asphaltic material and the rocks in which they occur are locally also bituminous. About one-half mile south of the town the Lower Warsaw may be studied along a small creek. A section of the strata at this place follows:

Section of Lower Warsaw beds south of Niota.

5. Drift ........................................................................................................................................................................ 1
4. Shale, argillaceous, bluish, with thin layers of limestone intercalated near the top ...................................................... 5
3. Shale, calcareous, ash-colored; upper part bearing small geodes whose shells are fragile and usually stained with bitumen; lower part with a bituminous band which bears broken geodes 3 6
2. Shale, argillaceous .................................................................................................................................................. 1 8
1. Limestone, in bed of creek ........................................................................................................................................... 18

Another section of interest is located two miles south of Niota on the north branch of the first main creek below that town.

Section of Lower Warsaw beds south of Niota.

11. Till, yellow, bearing boulders of St. Louis limestone .......... 9
10. Shale, argillaceous, bluish gray when fresh but weathering yellow; some layers more calcareous and bearing geodes ...... 4 6
9. Shale, calcareous, geodiferous ................................................. 1 6
8. Shale, bluish when fresh; few or no geodes .............................. 1 3
7. Shale, highly calcareous, gray, bearing many geodes studded with dolomite ................................................................................. 2
6. Limestone, impure, buff, magnesian; bearing fronds of a fenestelloid bryozoan; small masses of sphalerite common........... 6
5. Shale, argillaceous; breaking down to ash-colored clay; no geodes noted ........................................................................ 3 10
4. Shale, argillaceous, grayish blue; bituminous geodes scattered throughout, although shale is not appreciably stained with this material .................................................................................. 2
3. Shale, highly calcareous, ash-colored, bearing a few geodes, none of which was found to contain bitumen ...................... 1 7
2. Shale, argillaceous, grayish blue in color, no geodes noted ...... 2 10
1. Limestone, gray, crinoidal ................................................................................................................................. 1 10

All of the members of this section except 1 and 11, which represent the Keokuk and Pleistocene respectively, belong to the Lower Warsaw.

Lee County, Iowa.—Numerous exposures showing the Lower Warsaw in contact with both the Keokuk limestone and the Upper Warsaw may be seen in and near the city of Keokuk, Iowa, in the extreme southern part of Lee county. These occur in the bluffs of Soap creek, and in the north bluff of Mississippi river, at intervals from the Union Station to the Taber lumber mills, two miles down stream (fig. 4).

The section on Soap creek near the end of Fourteenth Street is typical (fig. 5).
Fig. 5.—View of Lower Warsaw bed along Soap creek at Keokuk.

Section of Lower Warsaw beds on Soap creek.

3. Shale, bluish, argillaceous, geodiferous, with occasional thin layers of magnesian limestone near the top .............................. 20
2. Limestone, light gray, fine-grained, cherty .................................. 1-2½
1. Limestone, ash-colored, impure, siliceous, magnesian, geodiferous; with occasional seams and layers of grayish or bluish fossiliferous limestone ..................................................... 7½

The following faunal lists were prepared from collections made by the writer along Soap creek and in the Mississippi river bluff sections.

List of fossils from bed 1 of the Lower Warsaw beds at Keokuk.

**Anthozoa**—
- Zaphrentis sp.
- Triplophyllum dalei (M.-E. and H.)
- Monilopora beecheri Grabau

**Crinoidea**—
- Dizygocrinus ? sp.
- Uperocrinus nashvillae (Hall)
- Dorycrinus mississippiensis Roemer
- Dorycrinus sp.
- Agrayeocrinus americanus var. tuberosus Hall
- Barycrinus spurius (Hall)
- Barycrinus sp.

**Echinodermata**—
- Archaeocardaris sp.

**Bryozoa**—
- Fistulipora sp.
- Fenestella compressa Ulrich
- Fenestella multipinosa Ulrich
- Fenestella exigua Ulrich
- Fenestella tenuis Ulrich
- Fenestella serrata Ulrich
- Fenestella sp.
- Hemitripya sp.
- Archimedes owenanus Hall
- Polypora gracilis Prout
- Polypora varsovienisis Prout
- Pinnatopora conferta Ulrich
- Rhombopora dichotoma Ulrich
- Rhombopora sp.
In the Mississippian crinoid collection at the Walker Museum, University of Chicago, the following species of crinoids listed from Keokuk, Iowa, are believed to have been collected from this bed as suggested by the character of their matrix.

**List of fossils from bed 2 of the Lower Warsaw beds at Keokuk.**

<table>
<thead>
<tr>
<th>ANTHOZOA</th>
<th>BRACHIOPODA</th>
<th>CEPHALOPODA</th>
<th>GASTROPODA</th>
<th>PELECYPODA</th>
<th>VERTEBRATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplexus sp.</td>
<td>Productus ovatus Hall</td>
<td>Spirifer tenuicostatus Hall</td>
<td>Dielasma sp.</td>
<td>Pinna subpatulata Worthen</td>
<td>Fish teeth</td>
</tr>
<tr>
<td>Zaphrentis sp.</td>
<td>Productus setigerus Hall</td>
<td>Spirifer keokuk Hall</td>
<td>Dielasma sp.</td>
<td>Aviculopecten sp.</td>
<td></td>
</tr>
<tr>
<td>Stenopora sp.</td>
<td>Orthotetes keokuk (Hall)</td>
<td>Brachythyris subcardiformis (Hall)</td>
<td>Dielasma sp.</td>
<td>Composita sp.</td>
<td></td>
</tr>
<tr>
<td>Fenestella aequalula Ulrich</td>
<td>Rhipidomella dubia (Hall)</td>
<td>Spiriferella neglecta (Hall)</td>
<td>Dielasma sp.</td>
<td>Clithysidina parvirostris (M. and W.)</td>
<td></td>
</tr>
<tr>
<td>Fenestella tenax Ulrich</td>
<td>Orthotetes keokuk (Hall)</td>
<td>Reticularia pseudolineata (Hall)</td>
<td>Dielasma sp.</td>
<td>Pinna subpatulata Worthen</td>
<td></td>
</tr>
<tr>
<td>Hemitrypa proutana Ulrich</td>
<td>Orthotetes keokuk (Hall)</td>
<td>Eumetria verneuiliana (Hall)</td>
<td>Dielasma sp.</td>
<td>Aviculopecten sp.</td>
<td></td>
</tr>
<tr>
<td>Polypora sp.</td>
<td>Pustula alternata (N. and P.)</td>
<td>Composita sp.</td>
<td>Dielasma sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cystodictya lineata Ulrich</td>
<td>Pustula biseriata (Hall)</td>
<td>Orthotetes keokuk (Hall)</td>
<td>Dielasma sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worthenopora spinosa Ulrich</td>
<td>Worthenopora spinosa Ulrich</td>
<td>Orthotetes keokuk (Hall)</td>
<td>Dielasma sp.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**List of fossils from bed 3 of the Lower Warsaw beds at Keokuk.**

<table>
<thead>
<tr>
<th>ANTHOZOA</th>
<th>CRINOIDEA</th>
<th>BRYOZOA</th>
<th>VERTEBRATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triplophyllum dalei (M. E. and H.)</td>
<td>Dorycerinus sp.</td>
<td>Fistulipora sp.</td>
<td>Fish teeth</td>
</tr>
<tr>
<td>Zaphrentis sp.</td>
<td></td>
<td>Stenopora sp.</td>
<td></td>
</tr>
<tr>
<td>Zaphrentis sp.</td>
<td></td>
<td>Leioclena punctata (Hall)</td>
<td></td>
</tr>
<tr>
<td>Monilopora beecheri Grabau</td>
<td></td>
<td>Archimedes cf. A. owenanus Hall</td>
<td></td>
</tr>
</tbody>
</table>
LOWER WARSAW NEAR FOX CITY

Fenestella serratula Ulrich
Fenestella multi spinosa Ulrich
Fenestella tenax Ulrich
Fenestella compressa Ulrich
Fenestella triseriata Ulrich
Polypora varsoviensis Prout
Polypora cf. P. biseriata Ulrich
Polypora retrorsa Ulrich
Polypora spininodata Ulrich
Polypora sp.
Hemitrypa aspera Ulrich
Hemitrypa proutiana Ulrich
Hemitrypa perstriata Ulrich
Hemitrypa plumosa Prout
Hemitrypa sp.
Ptilopora prouti Hall
Rhombopora sp.
Rhombopora attenuata Ulrich

Cystodictya lineata Ulrich
Cystodictya pustulosa Ulrich
Glyptopora elegans (Prout)
Glyptopora keyserlingi (Prout)
Glyptopora sp.
Worthenopora spinosa Ulrich
Cyclopora fungia Ulrich

Polypora cf. biseriata Prout
Polypora spininodata Ulrich
Polypora sp.
Hemitrypa aspera Ulrich
Hemitrypa proutiana Ulrich
Hemitrypa perstriata Ulrich
Hemitrypa plumosa Prout
Hemitrypa sp.
Ptilopora prouti Hall
Rhombopora sp.
Rhombopora attenuata Ulrich

Worthen has described several species of crinoids from the upper shales of the Geode bed one mile below Keokuk in Volume VII of the Geological Survey of Illinois. Inasmuch as these undoubtedly came from bed 3 of the writer’s section they are listed here, the revised nomenclature being used.

Rhodocrinus coxanus Worthen
Scaphiodrinus briaricus (Worthen)
Scaphiodrinus extensus W. and S.
Scaphiodrinus iowensis (Worthen)
Scaphiodrinus obscurus W. and S.

Zoocrinus keokuk Worthen
Zoocrinus keokuk Worthen
Woodocrinus asperatus (Worthen)
Woodocrinus testiculatus (Worthen)

The Lower Warsaw outcrops seven and one-half miles north of Keokuk in the banks of a small creek just south of the town of Montrose. This member is thirty feet in thickness at this locality and is succeeded directly by the Spergen formation, the Upper Warsaw being absent.

Clark County, Missouri.—The Lower Warsaw is well exposed in Clark county, Missouri, along the north bluff of Fox river four miles northwest of Wayland and one-fourth mile northwest of Fox City. The geodes and their relation to the containing rock may be very satisfactorily studied at this place. The section is given below:

Section of Lower Warsaw beds in north bluff of Fox river near Fox City.

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>8. Drift</td>
<td>..........................................................</td>
</tr>
<tr>
<td>7. Shale, argillo-calcareous, pyritiferous, bluish when fresh but breaking down readily to a gray friable clay and releasing a few small geodes</td>
<td>..........................................................</td>
</tr>
<tr>
<td>6. Limestone, gray, crinoidal; shaly in places; cherty near the base</td>
<td>..........................................................</td>
</tr>
</tbody>
</table>
5. Limestone, impure, magnesian, fine-grained, drab; scaling off obliquely in large slabs ........................................ 3 8
4. Shale, highly calcareous, bluish; locally more argillaceous and exhibiting laminated structures. Geodes present, some exceeding 15 inches in diameter; arranged roughly in bands; many closely arranged ........................................................................................................... 6
3. Limestone, gray, crinoidal; cherty near the base ........................................ 7
2. Limestone, impure, shaly, fine-grained; bearing a few scattered but large geodes .......................................................... 1 6
1. Limestone, gray, crinoidal; exposed ................................................................. 6

Bed 1 of this section evidently represents the uppermost member of the Keokuk limestone. All of the succeeding layers are referable to the Lower Warsaw except bed 8.

Des Moines County, Iowa.—The Lower Warsaw is considerably thinner in Des Moines county than in Lee and adjacent counties to the south. The only important exposures in this county which are known to the writer occur along Long creek in the eastern part of Augusta township.

At a small quarry opening on the Wm. Madlener property, in the southwest one-fourth of the southeast quarter of section 12, twelve feet of bluish argillaceous shale with occasional siliceous nodules is exposed. This shale is overlain by thirty feet of buff, dolomitic Spergen limestone. Lower Warsaw shale of similar character outcrops a short distance down the creek. The bed is eighteen feet thick and is underlain by nine feet of Keokuk limestone and overlain by five feet of brownish massive dolomitic Spergen limestone.

Henry County.—The Lower Warsaw is exposed along Mud creek, a stream emptying into Skunk river about one mile east of Lowell in Henry county. Outcrops of this subdivision occur at intervals along the banks of the creek for a distance of one mile north of the iron bridge which crosses the stream in the southern part of section 27, Baltimore township. Farther up the creek outcrops of the Keokuk limestone appear, a fact which suggests an upward flexure of the strata at this place.

Complete sections of the Lower Warsaw are wanting at this locality as a result of erosion and slumping. But for the abundance and perfection of its geodes this place is unexcelled. The section here given was measured a few rods north of the iron bridge mentioned above, at a low bluff on the east side of the creek.
Section of Lower Warsaw beds on Mud creek.

6. Drift .......................................................... 1

5. Shale, argillaceous, bluish, breaking down to a gritty drab-colored clay; containing a few scattered irregular siliceous nodules which contain geodic cavities ........................................ 10

4. Limestone, impure, buff, magnesian; checking into irregular blocks and bearing the impressions of fronds of fenestelloid bryozoans; lenticular siliceous masses near the base include material identical with that of the surrounding rock .......... 2

3. Shale, bluish when fresh; thickly set with geodes less than 6 inches in diameter, which are not confined to bands .................. 2

2. Shale, highly calcareous, gray and buff in color; geodes scarce 1

1. Shale, calcareous, bluish. Some of the fossils collected from this layer are: Orthotetes kookuk, Spirifer kookuk?, Reticularia sp., imperfectly preserved bryozoans, and numerous small fish teeth. Exposed .......................................................... 8

An outcrop a short distance up the creek at a point just west of the second bridge over Mud creek exposes number 1 of the previous section to a height of about three feet. The upper part of this member at this place bears many rounded concretionary nodules of material which appears to be more calcareous than the containing rock. These nodules range from less than an inch to more than six inches in diameter.

Bluffs of the Lower Warsaw beds about thirty feet in height are present about three-fourths of a mile north of the last mentioned point, in the extreme northern part of section 27 and the southernmost part of section 22, on the east bank of the stream. The nature of the beds at this point, however, is largely obscured on account of slumping and the encroachment of vegetation upon the weathered slopes of the material. Many geodes occur in the beds and the weathered slopes of the deposit are strewn with specimens. Some of these have a diameter as great as eighteen inches. The following section of the Lower Warsaw was measured in a ravine which opens into Mud creek from the east about one-fourth mile north of these bluffs:

Section of Lower Warsaw beds in section 22, Baltimore township.

5. Limestone, massive, magnesian, yellowish, no geodes nor fossils noted .......................................................... 4

4. Shale, bluish, calcareous; grading upward into limestone ......... 2

3. Limestone, impure, buff, magnesian ............................ 1

2. Shale, calcareous, bearing several large geodes ............... 2

1. Shale, bluish, argillaceous; bearing rounded calcareous nodules near the top. Exposed .......................................................... 4

A section along the bed and banks of a creek emptying into
Skunk river from the south a short distance west of Webster's mill in the western part of section 4 of Jackson township, shows the Lower Warsaw in contact with the overlying St. Louis and the underlying Keokuk limestone. The section of the Keokuk at this point is described on pages 174 and 175 of this report.

**Section in western part of Jackson township.**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
<th>Feet</th>
<th>Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower St. Louis</td>
<td>Limestone, buff, dolomitic, massive, exposed along the bed of the creek</td>
<td>5-6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Limestone, dark gray, compact, dense, fine-grained, much brecciated and mashed; forming low mounds along the bed of the creek a short distance above</td>
<td>1 1/2-2 1/2</td>
<td></td>
</tr>
<tr>
<td>Lower Warsaw</td>
<td>Limestone, brownish, dolomitic, thin-bedded, locally arenaceous in part</td>
<td>1 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sandstone, soft, fine-grained, bluish</td>
<td>3 8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sandstone, bluish, fine-grained, filled with large angular fragments of white chert</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Limestone, ash-colored, soft, impure, shaly, arenaceous in the upper part</td>
<td>1 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shale, bluish, argillaceous</td>
<td>1 6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Concealed, probably soft shale</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Limestone, soft, gray, shaly, with bands of irregular siliceous segregations; exposed in a little gully near the main stream</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Limestone, brownish, dolomitic, medium-grained in middle part but fine-grained above and below. Shaly in lower part. Contact with Keokuk limestone below concealed</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

The following species were collected from bed 1: *Pustula biseriata* (Hall), *Spirifer tenuicostatus* Hall, and *Composita trinuclea* (Hall). Beds 7, 8 and 9 possibly represent the Spergen formation in an attenuated condition.

*Van Buren County.*—The Lower Warsaw is present in Van Buren county though it is somewhat thinner and less typically developed than at Warsaw, Illinois, the type locality.

The beds may be studied to good advantage in this county along Indian creek near Farmington, on Bear creek at Vernon, on Copperas creek above Bentonsport, in the north bluff of Des Moines river just below Bentonsport and on Potters branch near Bonaparte.

The Lower Warsaw is well exposed in the north bluff of Des Moines river one-fourth mile below the railroad station at Bentonsport. It yields numerous fossils throughout its exposure. A section of the underlying Keokuk beds at this locality has been described in a preceding chapter.
LOWER WARSAW FOSSILS AT BENTONSPORT

Section of Lower Warsaw beds one-fourth mile below Bentonspor{l.

<table>
<thead>
<tr>
<th>DES MOINES</th>
<th>FEET INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Sandstone, gray to whitish, weathering yellowish, bearing a few plant remains. Exposed</td>
<td>1 5</td>
</tr>
<tr>
<td>6. Concealed</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LOWER ST. LOUIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Limestone, brownish, dolomitic</td>
</tr>
<tr>
<td>4. Concealed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LOWER WARSAW</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Shale, bluish, argillaceous, with occasional layers of brownish impure limestone, containing a few imperfect siliceous geodes. Poorly exposed on slope of bluff</td>
</tr>
<tr>
<td>2. Limestone, gray, fine-grained, brittle, fucoidal, with occasional thin layers of coarse-grained bluish gray limestone in middle part and in the basal parts a few fine-grained impure layers which weather yellowish</td>
</tr>
<tr>
<td>1. Limestone, shaly, grayish weathering yellowish, filled with bryozoa</td>
</tr>
</tbody>
</table>

The fossils identified from beds 1, 2 and 3 of the Lower Warsaw are as follows:

List of fossils from bed 1 of Lower Warsaw beds near Bentonspor{l.

ANTHOZOA—
Triplophyllum dalei (M.-E. and H.)
Amplexus sp.
Monilopora sp.

BLASTOIDEA—
Metablastus wortheni (Hall)

CRINOIDEA—
Dorycrinus sp.
Barycrinus sp.
Barycrinus sp.

ECHINOIDEA—
Archaeocidaris sp.

BRYOZA—
Meekopora sp.
Fistulipora f. sp.
Stenopora sp.
Leiolema punctatum (Hall)
Leiolema zoliatum Ulrich
Fenestella serrulata Ulrich
Fenestella multipinosa Ulrich
Fenestella rudis Ulrich
Fenestella triseriata Ulrich
Fenestella tenax Ulrich
Fenestella exigua Ulrich
Fenestella sp.
Fenestella sp.
Fenestella sp.
Fenestella sp.
Hemitrypa proutana Ulrich
Hemitrypa nodosa Ulrich
Hemitrypa aspera Ulrich
Hemitrypa perstriata Ulrich
Hemitrypa cf. H. beedei Cumings
Hemitrypa sp.
Archimedes owenanus Hall f.

Archimedes negligens Ulrich
Archimedes sp.
Archimedes sp.
Polypora retrorsa Ulrich
Polypora halliana Prout
Polypora spinimodata Ulrich
Polypora sp.
Polypora sp.
Pinnatopora sp.
Rhombopecten attenuata Ulrich
Rhombopecten varians Ulrich
Bactropora simplex Ulrich
Streblotrypa cf. S. radialis Ulrich
Streblotrypa major Ulrich
Cystiodictya nitida Ulrich
Cystiodictya americana Ulrich
Cystiodictya sp.
Fibratopora trifolia (Rominger)
Glyptopora sagamella (Prout)
Glyptopora keyserlingi (Prout)
Glyptopora elegans (Prout)
Glyptopora sp.
Glyptopora sp.
Cylindropora sp.
Worstenopora spinosa Ulrich

BRACHIOPODA—
Schuchertella f. sp.
Dielasma sp.
Spiriferina sp.
Spirifer cf. S. pellaensis Weller
Spirifer tenuicoatus Hall
Brachothyris subearbiformis (Hall)
Syringothyris subeurispida Hall
Reticularia pseudolimesta (Hall)
List of fossils from bed 2 of Lower Warsaw beds near Bentonsport.

**ANTHOZOA—**
- Zaphrentis sp.
- Triplophyllum pellacensis (Worthen)
- Ampelis sp.
- Syringopora sp.
- Moniopora sp.
- *Zaphrentis* sp.
- *Triplophyllum* pellacensis (Worthen)
- *Ampelis* sp.
- *Syringopora* sp.
- *Moniopora* sp.

**ECHINOIDEA—**
- Archaeocidaris keokuk Hall
- Pholidocidaris irregularis (M. and W.)

**BRYOZOA—**
- Stenopora sp.
- *Leioclema punctatum* (Hall)
- *Fenestella serratula Ulrich*
- *Fenestella multipinnosa Ulrich*
- *Fenestella exigua Ulrich*
- *Fenestella sp.*
- *Fenestella sp.*
- *Hemitiryna sp.*
- *Archimedes sp.*
- *Polypora cf. P. varsoviensis Prout*
- *Polypora varsoviensis Prout*
- *Polypora sp.*
- *Polypora sp.*
- *Ptilopora sp.*
- *Rhombopora varians Ulrich*
- *Rhombopora transversalis Ulrich*
- *Rhombopora sp.*
- *Bactropol'a simplex Ulrich*
- *Taeniolycopodium ramosula Ulrich*
- *Cystodictya sp.*
- *PhractoplIoma trifolia (Rominger)*
- *Glyptopora sagemella var. f.*
- *Glyptopora sp.*
- *Cyclopora *f. sp.*

**BRACHIOPODA—**
- *Schuchertella f. sp.*
- *Productus ovatus Hall*
- *Productus setigerus Hall*

List of fossils from bed 3 of Lower Warsaw beds near Bentonsport.

**BRYOZOA—**
- Stenopora sp.
- *Leioclema punctatum* (Hall)
- *Fenestella serratula Ulrich*
- *Fenestella tenax Ulrich*
- *Fenestella multipinnosa Ulrich*
- *Archimedes neglexi Ulrich*
- *Archimedes ovatus Hall*
- *Polypora varsoviensis Prout*
- *Ptilopora f. sp.*
- *Rhombopora attenuata Ulrich*

**GASTROPODA—**
- *Orthonychia sp.*
- *Orthonychia sp.*
- *Polypora cf. P. varsoviensis Prout*
- *Polypora varsoviensis Prout*
- *Polypora sp.*
- *Polypora sp.*
- *Ptilopora f. sp.*
- *Rhombopora asperula Ulrich*
- *Cystodictya lineata Ulrich*
- *PhractoplIoma trifolia (Rominger)*

**PELECYPODA—**
- *Concardium sp.*
- *Schizodus sp.*
- *Schizodus sp.*
- *Schizodus sp.*
- *Aviculopecten f. sp.*
- *Aviculopecten sp.*
- *Aviculopecten sp.*
- *Aviculopecten sp.*
- *Lithophagus illinoiensis Worthen*
- *Cypriocardinia sp.*

**SCAPHOPODA—**
- *Laevidentalium sp.*

**GASTROPODA—**
- *Orthonychia sp.*

**TRILOBITA—**
- *Orthothetes keokuk (Hall)*
- *Rhipidomella dubia (Hall)*
- *Spirifer keokuk Hall*
- *Spiriferella neglecta (Hall)*
- *Reticularia setigera (Hall)*
- *Composita globosa Weller*
The following section is exposed along Indian creek a short distance back from its mouth, near Farmington:

Section on Indian creek near Farmington.

<table>
<thead>
<tr>
<th></th>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.</td>
<td>Loess</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Till, yellowish, arenaceous; passing locally into an incoherent stratified sand</td>
<td>2</td>
</tr>
<tr>
<td>5.</td>
<td>Shale, bluish, argillaceous, laminated; no geodes nor calcareous nodules</td>
<td>4</td>
</tr>
<tr>
<td>4.</td>
<td>Limestone, bluish, fine-grained, magnesian; pinching out laterally</td>
<td>4</td>
</tr>
<tr>
<td>3.</td>
<td>Shale, bluish, argillaceous, no geodes</td>
<td>2</td>
</tr>
<tr>
<td>2.</td>
<td>Limestone, bluish, fine-grained, magnesian; passing laterally into shale</td>
<td>1</td>
</tr>
<tr>
<td>1.</td>
<td>Shale, bluish, laminated, argillaceous; bearing geodes and calcareous nodules in lower part</td>
<td>4</td>
</tr>
</tbody>
</table>

Beds 1 to 5 represent the Lower Warsaw.

A similar section may be studied along Bear creek in the northeast quarter of section 11 of Henry township, about six miles northwest of the Indian creek locality.

Section of Lower Warsaw beds on Bear creek.

<table>
<thead>
<tr>
<th></th>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td>Shale, bluish, argillaceous; with occasional impure fossiliferous limestone flakes; more calcareous and bearing siliceous geodes in basal part</td>
<td>15</td>
</tr>
<tr>
<td>2.</td>
<td>Limestone, grayish, medium-grained, fossiliferous</td>
<td>2–19</td>
</tr>
<tr>
<td>1.</td>
<td>Shale, bluish, argillaceous; with thin seams of impure fossiliferous limestone. Exposed to bed of creek</td>
<td>11</td>
</tr>
</tbody>
</table>

The species collected from the various beds are as follows:

List of fossils from bed 1 of above section.

**Anthozoa**—

- *Triplophyllum dalei* (M.-E. and H.)
- *Monilopora beecheri* Grabau

**Bryozoa**—

- *Stenopora* sp.
- *Leiocelema punctatum* (Hall)
- *Fenestella rudis* Ulrich
- *Fenestella serratula* Ulrich
- *Fenestella multispinosa* Ulrich

**Bryozoa**—

- *Fenestella* sp.
- *Hemitrypa* sp.
- *Archimedes negligens* Ulrich
- *Rhombopora attenuata* Ulrich
- *Rhombopora varians* Ulrich
- *Bactropora simplex* Ulrich
- *Cystodictya lineata* Ulrich
- *Worthenopora spinosa* Ulrich

List of fossils from bed 2 of above section.

**Bryozoa**—

- *Stenopora* sp.
- *Fenestella multispinosa* Ulrich
- *Archimedes* sp.
- *Bactropora simplex* Ulrich
- *Cystodictya lineata* Ulrich

**Brachiopoda**—

- *Glyptopora michelinia* (Prout)
- *Worthenopora spinosa* Ulrich

- *Rhipidomella dubia* (Hall)
- *Spiriferina* sp.
List of fossils from bed 3 of above section.

**BRYOZOA—**
- Stenopora sp.
- Leiocelma punctatum (Hall)
- Fenestella exigua Ulrich
- Fenestella serrata Ulrich
- Fenestella tenax Ulrich
- Hemitrypa sp.
- Polypora retrorsa Ulrich
- Polypora varsoviensis Prout

**BRACHIOPODA—**
- Leiocelma punctatum (Hall)
- Fenestella erigua Ulrich
- Fenestella serrata Ulrich
- Hemitrypa sp.
- Polypora retrorsa Ulrich
- Polypora varsoviensis Prout
- Rhipidomella dubia (Hall)
- Spiriferina (species undescribed)
- Spirifer tenuecostatus Hall

Geodes do not occur at this place but they are common in the shale farther up the creek.

The following section of the Lower Warsaw is exposed along Copperas creek two miles northwest of Bentonspor.

**Section of Lower Warsaw beds along Copperas creek.**

1. Shale, bluish, nonfossiliferous; bearing imperfect geodes and discontinuous bands of siliceous material in lower part ...... 11
2. Limestone, fine-grained, impure, shaly in middle ...................... 2
3. Shale, bluish, weathering drab ........................................ 4
4. Drift ................................................................................. 1 1/2

At an exposure on Potter’s branch in the southeast one-fourth of the southeast quarter of section 9, Bonaparte township, eleven feet of Lower Warsaw shale, argillaceous above but calcareous below, is overlain by thirty-three feet of Spergen shales and limestones.

The following section is shown a few rods farther down in the north bank:

**Section on Potter’s branch.**

**LOWER WARSAW**

1. Limestone, bluish gray, unaltered, with shaly seams in upper and lower part. Exposed to bed of creek ...................... 4
2. Shale, bluish gray, subcrystalline, unaltered, fossiliferous .......... 2
3. Limestone, yellowish, dolomitic, vesicular, tough, massive.... 2
4. Shaly parting ................................................................. 8
5. Limestone, bluish gray, subcrystalline, unaltered, fossiliferous .... 2
6. Limestone, buff, massive, dolomitic, shaly in lower part .... 13 10

An outcrop of bluish Lower Warsaw shale appears in the east bank of Rock creek about one hundred yards above the railway bridge in the northwest quarter of section 21, Washington township, Van Buren county. It is nine feet in thickness and con-
tains thin intercalated flakes of limestone. Both the shale and the limestone are fossiliferous. A thin bed of fine-grained cream-colored limestone is exposed at the top of the section. The following species were collected from the shale:

**List of fossils from Lower Warsaw shale on Rock creek.**

<table>
<thead>
<tr>
<th>Bryozoa</th>
<th>Brachiopoda</th>
<th>Pelecypoda</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stenopora sp.</td>
<td>Worthenopora spinosa Ulrich</td>
<td>Cypriocardinia indianensis Hall</td>
</tr>
<tr>
<td>Leiolema punctatum (Hall)</td>
<td>Pustula biseriata (Hall)</td>
<td></td>
</tr>
<tr>
<td>Fenestella serratula Ulrich</td>
<td>Rhipidomella dubia (Hall)</td>
<td></td>
</tr>
<tr>
<td>Hemitrypa sp.</td>
<td>Spiriferina sp.</td>
<td></td>
</tr>
<tr>
<td>Archimedes sp.</td>
<td>Spirifer tenuecostatus Hall</td>
<td></td>
</tr>
<tr>
<td>Rhombopora attenuata Ulrich</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhombopora † asperula Ulrich</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cystodictya lineata Ulrich</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

About ten feet of bluish calcareous shale of a slightly lower horizon outcrops in the west bank near the mouth of the creek. Reddish siliceous segregations appear in this member.

**THE UPPER WARSAW BEDS**

**DESCRIPTION OF THE TYPE SECTION**

The Upper member of the Warsaw formation is typically developed near the town of Warsaw in Hancock county, Illinois, where it was examined and described by Hall* under the heading of "Warsaw, or Second Archimedes limestone." The most satisfactory exposures appear along a small tributary of Mississippi river a short distance northeast of the town. The upper layers of the Keokuk limestone, the entire section of the Lower and Upper Warsaw, the Spergen limestone, and the basal part of the St. Louis limestone are excellently exposed along this creek. The upper layers of the Keokuk limestone appear at the north of the creek, and along its bed for a short distance up stream. The Warsaw beds outcrop thence in the bed of the creek and along its bank continuously as far as a small waterfall beyond the first stone arch bridge. The basal limestone of the Upper Warsaw caps the ledge at the fall. Above this point the Upper Warsaw beds are exposed in the bed of the stream and along its banks for a considerable distance, finally giving way to the Spergen and St. Louis limestones.

The section of the Upper Warsaw, which was carefully measured in the bluffs below the first stone bridge, and along the

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* Geol. of Iowa, vol. 1, part 1, p. 97; 1858.
stream above the small waterfall, is given below, the succession being from above downwards:

Section of Upper Warsaw beds northeast of Warsaw.

| FEET | 5. Limestone, bluish, magnesian, locally arenaceous or shaly in part; the "arenaceous-magnesian limestone" of authors. Fossils scarce except in lower part | 3 to 7½ |
| 4. Shale, bluish, argillaceous; with interbedded layers and flakes of gray subcrystalline limestone, some layers of which are shaly. A fine-grained bluish fossiliferous sandstone near the middle | 18½ |
| 3. Limestone, bluish gray, lenticular, subcrystalline, locally dolomitic in part. Massive where fresh but weathering to thin layers | 0 to 3 |
| 2. Shale, bluish, argillaceous, with occasional thin layers of shaly, fossiliferous limestone | 7 |
| 1. Limestone, bluish, magnesian; layers thin and undulating in creek bed, but thicker and more even in bank of creek further down | 4 to 8 |

Bed 1 represents the basal member of the Upper Warsaw. At Keokuk, and in the Soap Factory Hollow section, two miles below Warsaw, this member is represented by an unaltered thin-bedded fossiliferous limestone. Evidently dolomitization has affected this bed locally and incompletely. Occasional seams in the dolomitic limestone are filled with the molds of fossils, mainly of bryozoans. It also bears a few small irregular and imperfect siliceous geodes lined with quartz or calcite, or both. Surfaces of the layers are pitted locally due to the weathering and removal of small pyrite nodules. The contact of this bed with the topmost shale member of the Lower Warsaw is gradational.

The uppermost part of bed 2 furnishes a clay product valued for molding purposes. It has been worked in a desultory manner just west of the first stone bridge. This bed bears few well preserved fossils except in the interbedded limestone layers.

Bed 3 may aptly be called the lenticular limestone member. The thickening and thinning appears to take place from the lower side only. In places it pinches and swells very abruptly and at one point in the bank of the creek it disappears completely for a distance of several yards. It is there replaced by shale. It is usually in the form of a massive ledge when fresh but weathers into thin layers. It is divided locally into two parts by a shaly parting. The surfaces of the layers are pitted and are blotched here and there with limonite, a condition which is
caused by the oxidation and weathering of pyrite nodules which are common in the fresh rock.

This bed of limestone is locally dolomitic in part, but the dolomite occurs at no definite level. At one point it is in the upper part, at another it is in the lower. Evidently the alteration was very local and imperfect. Where it is dolomitized the limestone carries molds of fossils only.

In bed 4 a conspicuous ten-inch layer of bluish fossiliferous sandstone with fucoidal markings appears seven feet ten inches below the top. Ten and one-half feet below the top there occurs an eight inch layer of limestone which thickens abruptly in the bed of the creek below Main street bridge. It attains a thickness of four feet at one point. It bears many spiral axes of *Archimedes wortheni* and may be designated the *Archimedes* limestone. The following detailed section will show the nature of the individual layers of this member:

### Layers of Bed 4.

| Shale, with thin layers of fossiliferous limestone interbedded. | 7 | 10 |
| Well exposed along creek between the bend and the falls of the north fork |  |
| Sandstone, fine-grained, bluish, fucoidal | 10 |
| Shale, bluish, argillaceous | 1 | 10 |
| Limestone, gray, filled with *Archimedes* and other fossils | 8 |
| Shale | 1 | 6 |
| Limestone, shaly | 1 | 3 |
| Shale | 10 |
| Limestone | 7 |
| Shale | 3 | 3 |

Bed 5 is typically represented by massive layers of arenaceous magnesian limestone, but in a ravine east of the high school it is shaly. The shaly facies is bluish and weathers into irregular chips. The arenaceous-magnesian facies becomes brownish when weathered.

The fossils collected from the individual members of the Upper Warsaw at this locality are listed below:

### List of fossils from bed 1 of the Upper Warsaw near Warsaw.

**Bryozoa**
- Steneopora sp.
- Fenestella serratula Ulrich
- Polyopora varsoviensis Prout
- Worthenopora spinosa Ulrich

**Brachiopoda**
- Productus sp.
- Productus setigerus Hall

- Pustula alternata (N. and P.)
- Pustula biseriata (Hall)
- Carnarotoechia mutata (Hall)
- Diclasma sp.
- Girtyella indianaensis (Girty)
- Spiriferina sp.
- Spirifer pellaensis Weller
- Spirifer tenuicostatus Hall
Brachythyris subcardiformis (Hall)
Reticularia setigera (Hall)
Eumetria verneuiliana (Hall)
Composita sp. ?

PELECYPODA—
Cypricardinia indianensis Hall ?

List of fossils from bed 2 of the Upper Warsaw near Warsaw

ANTHOZOA—
Triplophyllum dalei (M.-E. and H.)

BRYOZOA—
Stenopora sp.
Leioclemia punctatum (Hall)
Archimedes owenaeus Hall
Archimedes wortheni Hall

PELECYPODA—
Cypicardiinaia indianensis Hall ?

Lithophagus illinoisensis Worthen
GASTROPODA—
Orthonychia sp.

List of fossils from bed 3 of the Upper Warsaw near Warsaw

BRYOZOA—
Stenopora sp.
Archimedes unguispina (M.-E. and H.)

PELECYPODA—
Cystodictya lineata Ulrich
Cystodictya pustulosa Ulrich ?

GASTROPODA—
Orthonychia sp.

List of fossils from bed 4 of the Upper Warsaw near Warsaw.

ANTHOZOA—
Zaphrentis spinulifera Hall

BRYOZOA—
Pseudopecten planus Ulrich

Echinoidea—
Archaeocidaris sp.

BRYOZOA—
Fistulipora sp.
CHARACTER OF WARSAW BEDS

Rhombopora varians Ulrich
Rhombopora attenuata Ulrich
Rhombopora sp.
Bactropora simplex Ulrich ?
Cystodiictya sp.
Cystodiictya sp.
Glyptopora elegans (Prout)
Glyptopora michelinia (Prout)
Glyptopora sagenella (Prout)
Glyptopora sagenella var. calciculosa Ulrich ?
Glyptopora plumosa (Prout)
Cyclopora sp.
Worthenopora spinosa Ulrich
Worthenopora spatulata (Prout)
Worthenopora sp.

BRACHIOPODA-

Lingula varsoviensis Worthen ?
Orthotetes ? sp.
Productus siltonensis N. and P. ?
Pustula biseriata (Hall)
Rhipidomella dubia (Hall)
Tetracamera subcuneata (Hall)
Dielasma sp.
Girtyella turgida (Hall)

List of fossils from bed 5 of the Upper Warsaw near Warsaw.

BRACHIOPODA-

Lingula sp.
Streptorhynchus rugosum (Hall and Clarke)
Pustula biseriata (Hall)
Tetracamera subcuneata (Hall)
Dielasma sp.
Girtyella turgida (Hall)

The composite section of the Lower and Upper members of the Warsaw formation as they are developed at the type localities is given below:

**Genera section of Warsaw Beds at Warsaw and Soap Factory Hollow.**

**UPPER WARSAW**

<table>
<thead>
<tr>
<th>FEET</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.0</td>
<td>Limestone, bluish, magnesian</td>
</tr>
<tr>
<td>7.0</td>
<td>Shale, bluish, argillaceous, with interbedded layers of gray fossiliferous limestone and fine bluish sandstone</td>
</tr>
<tr>
<td>6.0</td>
<td>Limestone, bluish, lenticular</td>
</tr>
<tr>
<td>5.0</td>
<td>Shale, bluish, argillaceous, with thin flakes of fossiliferous limestone</td>
</tr>
<tr>
<td>4.0</td>
<td>Limestone, bluish, magnesian</td>
</tr>
</tbody>
</table>

**LOWER WARSAW**

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
</tr>
</tbody>
</table>
2. Limestone, cherty; impure, buff-colored and magnesian at Warsaw; thin-bedded, gray and nonmagnesian at Soap Factory Hollow
1. Limestone, drab, fine-grained, impure, magnesian. Fossils scarce in geodiferous phase at Warsaw but common in Soap Factory Hollow

The accompanying chart indicates the vertical distribution of the more characteristic species of the Warsaw fauna through the several members of the formation as developed at Warsaw and Soap Factory Hollow.

Table showing Range of Species in the Warsaw Formation at Warsaw and Soap Factory Hollow.

<table>
<thead>
<tr>
<th>Species</th>
<th>Lower Warsaw</th>
<th>Upper Warsaw</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5 6 7 8</td>
<td></td>
</tr>
<tr>
<td><strong>ANTHOZOA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zaphrentis spergenesis Worthen</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Zaphrentis cassedyi M.-E. and H.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zaphrentis spinulifera Hall</td>
<td>x x x x</td>
<td></td>
</tr>
<tr>
<td>Triplophyllum dalei (M.-E. and H.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amplexus sp.</td>
<td>x x</td>
<td></td>
</tr>
<tr>
<td>Monilopora becheri Grabau</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Monilopora sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aulopora sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CRINOIDEA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agaricocrinus wortheni Hall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uperocrinus nashvillae (Hall)</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Barycrinus sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BLASTOIDEA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pentremites conoideus Hall</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Schizoblastus granulosus (M. and W.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ECHINODERMATA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Archaeocidaris keokuk Hall</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>VERMES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spirorbis sp.</td>
<td>x f</td>
<td>x</td>
</tr>
<tr>
<td><strong>BRYOZOA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meekopora sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leioclema foliatum Ulrich</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leioclema punctatum (Hall)</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Cystodictya lineata Ulrich</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Cystodictya pustulosa Ulrich</td>
<td>x x x x</td>
<td></td>
</tr>
<tr>
<td>Glyptopora keyserlingi (Prout)</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Glyptopora elegans (Prout)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glyptopora michelinia (Prout)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glyptopora sagenella (Prout)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glyptopora sagenella (Prout)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 3 1/4 | 11 1/2 |
Table showing Range of Species in the Warsaw Formation at Warsaw and Soap Factory Hollow.—Continued.

<table>
<thead>
<tr>
<th>Species</th>
<th>Lower Warsaw</th>
<th>Upper Warsaw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glyptopora sagenella var. caliculosa Ulrich</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Glyptopora plumosa (Prout)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bactropora simplex Ulrich</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhombopora varians Ulrich</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Rhombopora attenuata Ulrich</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Fenestella serrulata Ulrich</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Fenestella limitaria Ulrich</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Fenestella triseriallis Ulrich</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Fenestella tenax Ulrich</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Fenestella multipinosa Ulrich</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Fenestella funicula Ulrich</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fenestella compressa Ulrich</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fenestella exigua Ulrich</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fenestella radius Ulrich</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Archimedes neglectus Ulrich</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Archimedes oenomus Hall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Archimedes worthesi Hall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemitrypa pateriformis Ulrich</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Hemitrypa proutana Ulrich</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Hemitrypa proutana var. nododorsalis Cumings</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Hemitrypa nodosa Ulrich</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Pneustrolia sacti-ludovici Prout</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Polyopora gracilis Prout</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Polyopora varsoviensis Prout</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyopora retorsa Ulrich</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Polyopora biseriata Ulrich</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyopora spininodata Ulrich</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Pilopora valida Ulrich</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Pilopora prouti Hall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pinatopora conferta Ulrich</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Worthenopora spinosa Ulrich</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Worthenopora spatulata (Prout)</td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

**Brachiopoda—**

<table>
<thead>
<tr>
<th>Species</th>
<th>Lower Warsaw</th>
<th>Upper Warsaw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lingula varsoviensis Worthen</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Orbiculoidea sp.</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Streptorhynchos rugosum (Hall and Clarke)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orthotetes keokuk (Hall)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productus setigerus Hall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productus ovatus Hall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productus altenensis N. and P. †</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Productus indianaensis Hall †</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Pustula alterata (N. and P.)</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Pustula biseriata (Hall)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhipidomella dubia (Hall)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camaroteocbia mutata (Hall)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tetraacamera subcaudata (Hall)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cragaensa subsolda Weiler</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Dicosta sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Girtyella turgida (Hall)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Girtyella indianaensis (Girty)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spiriferina sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spirifer rostellatus Hall †</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Spirifer cf. S. koekuk Hall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spirifer tenuicostatus Hall</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table showing Range of Species in the Warsaw Formation at Warsaw and Soap Factory Hollow.—Continued.

<table>
<thead>
<tr>
<th>Species</th>
<th>Lower Warsaw</th>
<th>Upper Warsaw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spirifer bifurcatus Hall</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Spirifer indianensis Weller ?</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Spirifer pellaensis Weller</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Brachythyris subbuculifera (Hall)</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Brachythyris subcardiformis (Hall)</td>
<td>x x x x x x</td>
<td>x</td>
</tr>
<tr>
<td>Spiriferella neglecta (Hall)</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Reticularia setigera (Hall)</td>
<td>x x x x x x</td>
<td>x</td>
</tr>
<tr>
<td>Reticularia pseudolineata (Hall)</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Eumetria verneuiliana (Hall)</td>
<td>x x x x x x</td>
<td></td>
</tr>
<tr>
<td>Chlothyridina parvirostris (M. and W.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Composita trinuclea (Hall)</td>
<td>x x x x x x</td>
<td></td>
</tr>
<tr>
<td>Composita globosa Weller</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td><strong>PELECYPODA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edmondia varsoviensis Worthen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edmondia illinoensis Worthen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schizodus cf. S. cirsus WORTHEN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schizodus sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schizodus sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aviculopecten sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aviculopecten sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aviculopecten sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aviculopecten sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lithophagus illinoensis Worthen</td>
<td>x x x x x x</td>
<td></td>
</tr>
<tr>
<td>Cypricardinia indianensis Hall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allorisma sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SCAPHOPODA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lævidentalium sp.</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td><strong>GASTROPODA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holopea proutana Hall</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Strophostylus earleyana Hall ?</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Platycteras equilateralis Hall ?</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Straparollus sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TRILICHTA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phillipsia ? sp.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### THE UPPER WARSAW IN IOWA

The Upper Warsaw thins abruptly to the north from the type section and is absent from the exposures within a distance not exceeding fifteen miles.

The section in the Mississippi river bluff back of the wholesale office of the Taber Lumber Company situated two miles below the Union station at Keokuk, Iowa, involves the upper part of the Keokuk limestone, which is exposed at the foot of
UPPER WARSAW AT KEOKUK

the bluff, the whole of the Lower and Upper Warsaw, the Spergen limestone and the lower and upper divisions of the St. Louis limestone. The Upper Warsaw is considerably thinner at this point than at Warsaw and has a total thickness of only twenty-two feet. The beds are described below:

Section two miles below Keokuk Union Station.

<table>
<thead>
<tr>
<th>ST. LOUIS</th>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Warsaw</td>
<td></td>
</tr>
<tr>
<td>Limestone, brownish, dolomitic</td>
<td>2¼</td>
</tr>
<tr>
<td>Spergen</td>
<td></td>
</tr>
<tr>
<td>Limestone, gray, with interbedded shale</td>
<td>4</td>
</tr>
<tr>
<td>Limestone, bluish, argillaceous</td>
<td>18</td>
</tr>
<tr>
<td>Lower Warsaw</td>
<td></td>
</tr>
</tbody>
</table>

The following species were collected from the Upper Warsaw at this place:

List of fossils from bed 1 of Upper Warsaw in above section.

<table>
<thead>
<tr>
<th>Bryoza —</th>
<th>Brachiopoda —</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leioclima punctatum (Hall)</td>
<td>Pustula biseriata (Hall)</td>
</tr>
<tr>
<td>Archimedes owenanus Hall</td>
<td>Rhipidomella dubia (Hall)</td>
</tr>
<tr>
<td>Archimedes, cf. A. owenanus Hall</td>
<td>Spirexina sp.</td>
</tr>
<tr>
<td>Fenestella serrata Ulrich</td>
<td>Spirexina cf. S. keokuk Hall</td>
</tr>
<tr>
<td>Fenestella tenax Ulrich</td>
<td>Spirexina tenuicostatus Hall</td>
</tr>
<tr>
<td>Hemitrypa plumosa Prout</td>
<td>Spiressella neglecta (Hall)</td>
</tr>
<tr>
<td>Polypora retrorsa Ulrich</td>
<td>Reticularia setigera (Hall)</td>
</tr>
<tr>
<td>Rhombopora attenuata Ulrich</td>
<td>Clothyridina parvirostris (M. and W.)</td>
</tr>
<tr>
<td>Cystodictya lineata Ulrich</td>
<td>Pelecypoda —</td>
</tr>
<tr>
<td>Cystodictya pustulosa Ulrich</td>
<td>Pinna subspatulata Worthen</td>
</tr>
<tr>
<td>Cyclopora sp.</td>
<td>Gasteropoda —</td>
</tr>
<tr>
<td>Worthenopora spinosa Ulrich</td>
<td>Orthonychia cf. O. acutirostre Hall</td>
</tr>
</tbody>
</table>

List of fossils from bed 2 of Upper Warsaw in above section.

<table>
<thead>
<tr>
<th>Anthozoa</th>
<th>Brachiopoda</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zaphrentis sp.</td>
<td>Productus ovatus Hall</td>
</tr>
<tr>
<td>Bryoza —</td>
<td>Rhipidomella dubia (Hall)</td>
</tr>
<tr>
<td>Fistulipora (†) sp.</td>
<td>Tetracameria subuneata (Hall)</td>
</tr>
<tr>
<td>Stenopora (†) sp.</td>
<td>Dielasma sp.</td>
</tr>
<tr>
<td>Leioclima punctatum (Hall)</td>
<td>Spirexina sp.</td>
</tr>
<tr>
<td>Archimedes wortheni Hall</td>
<td>Spirexina cf. S. keokuk Hall</td>
</tr>
<tr>
<td>Archimedes owenanus Hall</td>
<td>Spirexina tenuicostatus Hall</td>
</tr>
<tr>
<td>Archimedes sp.</td>
<td>Spiressella neglecta (Hall)</td>
</tr>
<tr>
<td>Fenestella tenax Ulrich</td>
<td>Reticularia setigera (Hall)</td>
</tr>
<tr>
<td>Fenestella serrata Ulrich</td>
<td>Pelecypoda —</td>
</tr>
<tr>
<td>Fenestella exigua Ulrich</td>
<td>Aviculopecten sp.</td>
</tr>
<tr>
<td>Fenestella triserialis Ulrich</td>
<td>Glyptopora sp.</td>
</tr>
<tr>
<td>Hemitrypa sp.</td>
<td>Cystodictya pustulosa Ulrich</td>
</tr>
<tr>
<td>Polypora varsoviensis Prout</td>
<td>Cystodictya lineata Ulrich</td>
</tr>
<tr>
<td>Rhombopora attenuata Ulrich</td>
<td>Worthenopora spinosa Ulrich</td>
</tr>
<tr>
<td>Glyttopora keyserlingi (Prout)</td>
<td>Brachiopoda —</td>
</tr>
</tbody>
</table>

A low bluff on B street near its intersection with Reid street, West Keokuk, shows seven feet of interbedded limestone and
shale containing *Archimedes wortheni* and other characteristic Upper Warsaw fossils. It is overlain directly by the brecciated nondolomitic basal bed of the St. Louis limestone which is here three and one-half feet thick (fig. 6). As a result of the disconformity at the base of the St. Louis the Spergen limestone is not present in this section. Inasmuch as the base of the Upper Warsaw is not exposed at this locality its total thickness could not be determined.

In the vicinity of Ballinger Siding, five and one-half miles north of Keokuk, the Spergen limestone rests upon shales which are believed to represent the Lower Warsaw. The outcrops along a small creek near the centre of section 25, Township 66 North, Range 5 West, show about twenty-five feet of bluish argillaceous shale underlying the Spergen limestone. The contact of the Spergen with the shales appears to be even and regular although a disconformity undoubtedly exists. Exposures along the banks of a small creek seven and one-half miles north of the city of Keokuk and just south of the town of Montrose show Spergen dolomitic limestone in contact with the Lower Warsaw in its typical development.

A similar though apparently less abrupt thinning of the Up-
per Warsaw beds takes place westward from Warsaw, Illinois. Exposures along Des Moines river and its tributaries show the Spergen limestone underlain by shales which probably represent an attenuated equivalent of the Upper Warsaw.

The following layers are exposed below the Spergen beds in the Deamude quarries located near the center of section 13 of Des Moines township, Lee county:

Section in Deamude quarries.

**Spergen Limestone**

**Upper Warsaw Beds**

<table>
<thead>
<tr>
<th>Layer Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Concealed, probably shale; <em>Archimedes wortheni</em> found on weathered slope</td>
<td>6 1/4</td>
</tr>
<tr>
<td>2. Limestone, bluish, lenticular, arenaceous-magnesian; weathering to thin layers</td>
<td>0-4 1/2</td>
</tr>
<tr>
<td>1. Shale, bluish, argillaceous, bearing a few calcareous nodules. Exposed</td>
<td>4</td>
</tr>
</tbody>
</table>

Bed 2 contains the following species:

- Bryozoa—
  - *Streblotrypa* sp.
- Brachiopoda—
  - *Lingula varsoviensis* Worthen
  - *Productus* sp.
  - *Girtyella indianensis* (Girty)
- Pelecypoda—
  - *Aviculopecten* sp.
- Gasteropoda—
  - *Conus* sp.
  - *Reticularia setigera* (Hall)
  - *Spiriferella neglecta* (Hall)
  - *Girtyella indianensis* (Girty)

The presence of *Lingula varsoviensis* and *Archimedes wortheni* in this exposure suggests the Upper Warsaw age of the beds.

In his report on Van Buren county\(^5\) Gordon reports fifty-five feet of shales above the Keokuk limestone and refers the upper part of these to the Warsaw of Hall. In the present report these are referred to the Lower Warsaw because of the lack in them of fossils indicative of their Upper Warsaw age. However, the possibility of their upper part representing the Upper Warsaw must be granted.

**THE SPERGEN FORMATION**

**Nomenclature**

The term Spergen was applied first as a formation name by Ulrich\(^6\) in 1904 although several authors in publications dating back to 1860 referred to the highly fossiliferous strata of this age at Spergen Hill, Indiana, as “Spurgen’s Hill beds”, “Sper-
gen Hill limestone", etc. The name Salem limestone as pro-
posed for this formation by Cumings7 in 1901 has appeared in
the literature on Mississippian geology many times, but the U.
S. Geological Survey now favors the use of Spergen.
This formation was recognized by the writer8 as a distinct
unit in the Mississippian column of Iowa several years ago.

AREAL DISTRIBUTION

The Spergen formation has a very restricted areal distribu-
tion in Iowa. In earlier reports it has usually been mapped as
St. Louis limestone. Exposures of rocks of this age appear
only in the southeastern part of the state, the most conspicuous
ones being in Des Moines river valley in Lee and Van Buren
counties. Small isolated outcrops appear at a few other local-
ities in Lee, Des Moines, Henry and Jefferson counties.

CHARACTER AND STRATIGRAPHIC RELATIONS

The Spergen is represented in southeastern Iowa by an at-
tenuated, near-shore facies, to which the name Belfast beds is
given, because of the excellent exposures of the formation near
the town of Belfast in Lee county.

Until recent years the Spergen has not been recognized in
Iowa owing to the fact that it was confused in some places with
the Warsaw formation and in others with the basal member of
the St. Louis limestone. This confusion was due in large part
to the failure of earlier workers to recognize the disconformi-
ties at the base and at the top of this formation. The apparent
tendency of the Spergen to grade laterally into the Warsaw or
the Lower St. Louis evidently is due to this relationship. The
Spergen as developed in the area in question has a wide range
in character, owing in part to original conditions of sedimenta-
tion and in part to differences in the degree of dolomitization.
It is not uncommon to find a cross-bedded crinoidal limestone
passing laterally into a massive brown dolomitic limestone, and
this again into a brownish arenaceous dolomite, which may in
turn give way to a fine-grained bluish sandstone. In Van Buren
county the formation contains a large proportion of shale. Such

differences clearly suggest near-shore conditions of deposition. This also is suggested by the limited areal extent of the formation in Iowa, and by its thinning to the northwest. It has not been found north of Jefferson county. As a result of the disconformity below the Spergen it may rest upon either the Upper or the Lower Warsaw. Owing to the hiatus above, it is in some places entirely cut out by the St. Louis limestone. The thickness of the formation thus ranges from almost nothing to thirty-five feet.

AREAL DESCRIPTION BY COUNTIES

Lee County, Iowa.—The most representative sections of the Spergen formation in Iowa are those in the quarries in the east bluff of Des Moines river south of the town of Belfast in Lee county. Several different exposures are described in this area in order to emphasize the variability of the beds. The formation is well exposed in the old Deamude quarry, located near the middle of section 13, Des Moines township. At the northeast end of the quarry opening the following section of the Spergen was measured:

Section of Spergen formation in Deamude quarry.  

<table>
<thead>
<tr>
<th></th>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Beds 1, 2 and 4 contain only fragmentary fossils but bed 3 yields molds of numerous species which are listed below:

List of fossils from bed 3 of Spergen formation in Deamude quarry.

**BRYOZOA**
- Fenestella serrulata Ulrich
- Hemitrypa sp.

**BRACHIOPODA**
- Productus altonensis N. and P. ?
- Pustula biseriata (Hall)
- Tetraehemera arctirostrata (Swallow)
- Dielasma sp.
- Girtyella indianensis (Girty)

**GASTROPODA**
- Spirifer tenuicostatus Hall
- Brachythiris subcardiformis (Hall)
- Spirilferella neglecta (Hall)
- Reticularia setigera (Hall)
- Eumetria verneuiliana (Hall)
- Orthonychia sp.
- Conularia sp.

At the mouth of a ravine forty yards southeast of the preceding section lower layers, which are believed to represent the Upper Warsaw, outcrop below the Spergen.
Section in a ravine at the Deamude quarry.

<table>
<thead>
<tr>
<th>Spergen</th>
<th>Feet</th>
<th>Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>8. Limestone, gray, crinoidal, cross-bedded, overlain by conglomeratic St. Louis limestone</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>7. Shale, drab, arenaceous with thin layers of arenaceous magnesian limestone; containing mica flakes</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>6. Limestone, arenaceous-magnesian, weathering yellowish, in layers about 6 inches thick</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>5. Shale, bluish, arenaceous; containing mica flakes</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>4. Limestone, bluish, arenaceous-magnesian, in layers 2 to 9 inches thick</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

Upper Warsaw

<table>
<thead>
<tr>
<th>Spergen</th>
<th>Feet</th>
<th>Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Concealed, probably shale in large part. <em>Archimedes wortheni</em> found on weathered slope</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>2. Limestone, bluish, lenticular, arenaceous-magnesian, weathering to thin layers, thickening and thinning abruptly on lower surface. Bearing a few fossils. Passing into shales at one point</td>
<td>0 to 4</td>
<td>6</td>
</tr>
<tr>
<td>1. Shale, bluish, argillaceous, bearing a few calcareous nodules. Exposed</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

A comparison of this section with the preceding one will illustrate the range in character of the Spergen in this region. Bed 8 of the last section corresponds to number 4 of the former. The lower beds of the Spergen in the two sections possess little in common.

Other excellent sections of the Spergen appear in the Des Moines river bluff along the Chicago, Rock Island & Pacific railway a short distance below Belfast. The most satisfactory exposures are in the old Fox quarry openings, and in the ravines which cut through the bluff at intervals between these, in the western part of section 12, Des Moines township. A detailed study of these sections brings to light some very puzzling features in the way of lithologic differences of the formation.

The first quarry opening, three-fourths of a mile below Belfast, presents the following section:

Section of Spergen formation in upper Fox quarry.

<table>
<thead>
<tr>
<th>Spergen</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Limestone, brownish, magnesian, with molds of brachiozoans</td>
<td>2</td>
</tr>
<tr>
<td>3. Shale, bluish, arenaceous</td>
<td>1 to 2</td>
</tr>
<tr>
<td>2. Limestone, dolomitic, bluish to brownish, arenaceous</td>
<td>5 to 7</td>
</tr>
<tr>
<td>1. Limestone, gray, fossiliferous, cross-bedded in upper part. Exposed</td>
<td>6</td>
</tr>
</tbody>
</table>

An irregular lens of unaltered gray fossiliferous cross-bedded limestone four inches to one foot thick and about ten feet long occurs at one point in bed 2.

A few yards south of the above exposure the following succession appears at the mouth of a ravine:
Section at mouth of ravine below Belfast.

4. Limestone, conglomeratic ................................................. 8 to 10

SPERGEN

3. Limestone, brownish, dolomitic, somewhat arenaceous, bearing small angular whitish chert fragments ........................................ 2
2. Shale, bluish, argillaceous .................................................. 3½ to 4
1. Limestone, heavy bedded, consisting of bluish dolomitic limestone, locally arenaceous, with interbedded seams and layers of grayish nondolomitic, fossiliferous limestone. Exposed ............. 11½

Twenty-five yards up the same ravine at a small waterfall the following section was measured:

Section of Sperrgen formation in ravine below Belfast.

4. Drift.

SPERGEN

3. Limestone, brownish, dolomitic, massive; with molds of fenestelloid bryozoans; thickening abruptly locally at the expense of the thin-bedded limestone beneath owing to uneven dolomitization ......................................................... 1 to 4 4
2. Limestone, gray, in the form of thin cross-bedded highly fossiliferous layers. The slope of the cross-bedding ranges from about 9 degrees to 20 degrees. Direction of slope, west, southwest, and southeast. At one point the lower one and one-half feet of this limestone bed passes abruptly into a massive dolomitic layer, which continues ten to fifteen feet, and thence grades gradually back into thin-bedded unaltered limestone ............................................. 2 to 6 6
1. Limestone, bluish, arenaceous-magnesian, in heavy layers when fresh but weathering into thinner layers ..................................... 5 6

The species listed below were collected from bed 2 of this section:

ANTHOZOA—Worthenopora spinosa Ulrich
           Monilopora beecheri Grabau
           Zaphrentis sp.
BLASTOIDEA—Productus indianensis Hall
           Productus altonensis N. and P.
           Pustula biseriata (Hall)
           Rhipidomella dubia (Hall)
           Tetraecamer a subcuneata (Hall)
           Tetraecamer a arctistrostra (Swallow)
           Girtyella turgida (Hall)
           Girtyella indianaensis (Girty)
           Spirifer tenuicostatus Hall
           Spirifer bifurcat us Hall
           Brachyth ris subscardiformis (Hall)
           Reticularia setigera (Hall)
           Eumetria verruculiana Hall
           Cliothyridina parvirostris (M. and W.)
           Composita triurce (Hall)

GASTROPODA—Orthonychia acutirostr e (Hall)

GASTROPODA—

BRACHIOPODA—

BRYOZOA—Tetracam e ra subcuneata (Hall)
           Fistulipora sp.
           Stemopora sp.
           Leioecena gracillimum Ulrich
           Fenestella serrata Ulrich
           Fenestella multispinosa Ulrich
           Amelitrypa sp.
           Polypora biseriata Ulrich
           Rhombopora bedfordensis Cumings
           Rhombopora varians Ulrich
           Rhombopora attenuata Ulrich
           Bactropora simplex Ulrich
           Cystodictya linearis Ulrich
           Glyptopora sagenella (Prout)
           Glyptopora sp.
           "Worthenopora spinosa Ulrich

Some interesting relationships of limestone and dolomite are shown in a quarry face in the bluff just south of the ravine men-
tioned above. In addition to layers of dolomite, which grade laterally into limestone, there occurs a lens of dolomite in a limestone bed. Two bowlder-like masses of dolomite appear in the same limestone nearby. The lens of dolomite has a rounded surface in the outcrop. It is seven and one-half feet long and has a maximum thickness of ten inches. It is of about the same texture as the limestone, and bears the same types of fossils, but it is bluish to brownish in color while the limestone is gray.

The contact of the upper cross-bedded limestone member (bed 2 of preceding section) with the dolomitic beds above and below is irregular owing to uneven dolomitization. It appears that the dolomitization of the Spergen must have taken place after all of the beds were deposited. The arenaceous limestones of the Spergen are believed to have been more susceptible to alteration than the purer limestones for they are dolomitic in nearly every exposure in which they appear.

The following succession is shown in a quarry opening about ninety yards below the last section:

Section in a quarry below Belfast.

<table>
<thead>
<tr>
<th>St. Louis</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Limestone, conglomeratic, in the form of a mound with less disturbed layers of brownish dolomitic limestone lapping up on its flanks</td>
<td></td>
<td>12 to 15</td>
</tr>
<tr>
<td>Spergen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Limestone, brownish, dolomitic with small scattered subangular quartz grains and occasional small angular fragments of whitish chert</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>2. Limestone, gray, crinoidal, filled with bryozoans; massive when fresh but weathered surfaces show thin cross-bedded layers. The lower part passes locally into dolomite indistinguishable from the dolomite below. At the north end of the opening the lower 3 feet of this bed is represented entirely by dolomite. This is very massive where it is dolomitic, although it was thin-bedded originally. At the south end of this opening there is a large lenticular layer of bluish dolomitic limestone near the middle of this member. It attains a maximum thickness of about 2 feet and is 25 to 30 feet long. Large irregular bowlder of dolomite and a smaller lens of dolomite also were noted in the upper part of this member</td>
<td></td>
<td>14 1/2</td>
</tr>
<tr>
<td>1. Limestone, arenaceous-magnesian, bluish when fresh but weathering brownish, bearing thin discontinuous seams of compact bluish dolomitic limestone. The arenaceous material is very fine-grained. Exposed</td>
<td></td>
<td>11</td>
</tr>
</tbody>
</table>

About ninety yards farther down stream there is another good exposure in a quarry opening.
SPERGEN BEDS BELOW BELFAST

Section in a quarry near the preceding one.

ST. LOUIS

3. Limestone, conglomeratic, marly in lower part .......... 15

SPERGEN

2. Limestone, bluish, arenaceous-magnesian, massive when fresh but weathering to thin layers and scaling off obliquely. Locally with shaly streaks ........................................ 9 10

1. Limestone, massive, bluish when fresh but weathering brownish; bearing molds of bryozoans. Exposed ................. 8 6

Bed 2 is correlated with bed 2 of the preceding section, in part at least. The upper parts of the beds were traced into each other but the transition of the lower beds is concealed by talus. The transition observed was abrupt. The limestone first graded into arenaceous material and thence became dolomitic. Fossils are scarce and poorly preserved in the dolomitic facies but are abundant in the cross-bedded limestone facies.

Two hundred and sixty yards farther down the following beds appear in the bluff:

Section in the Des Moines river bluff below Belfast.

ST. LOUIS

4. Limestone, much disturbed, some blocks dolomitic ........ 15

SPERGEN

3. Limestone, brownish, arenaceous, with chert fragments ........ 1

2. Limestone, gray, thin-bedded, crinoidal, shaly in lower part; resting on the irregular surface of bed beneath .................. 0 to 5

1. Limestone, dolomitic, slightly arenaceous; bluish when fresh but weathering brownish; in heavy layers which in lower part are separated by layers of bluish arenaceous shale. Exposed 18 1/2

At one point in this exposure bed 2 is cut out completely by the local thickening of bed 1. This relationship is believed to be due to uneven dolomitization.

A few yards farther downstream the following section appears in a quarry:

Section near the preceding.

ST. LOUIS

7. Limestone, conglomeratic, dolomitic and nondolomitic blocks indiscriminately mixed, marly toward the base ................. 11

SPERGEN

6. Limestone, gray, crinoidal, thin-bedded, slightly cross-bedded 4

5. Limestone, brownish, dolomitic, slightly arenaceous .......... 4 1/3

4. Shale, calcareous and arenaceous ................................... 2

3. Limestone, bluish, dolomitic, arenaceous ....................... 1 to 2

2. Limestone, gray, crinoidal ......................................... 4

1. Limestone, brownish, arenaceous-magnesian, in one massive ledge. Exposed ........................................ 10

Bed 3 differs greatly in thickness and lies upon the irregular surface of bed 2. Bed 2 passes laterally into dolomite at one point in the quarry face.
The quarries end at a ravine one mile below the station at Belfast. Beyond this point a few good natural exposures may be seen in the bluff. One such exposure occurs sixty rods below this ravine.

Section in bluff of Des Moines river one mile below Belfast.

<table>
<thead>
<tr>
<th>ST. LOUIS</th>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>10. Limestone, conglomeratic, poorly exposed.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Spergen

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. Limestone, bluish to brownish, with large rounded quartz grains and occasional angular chert fragments</td>
<td>2</td>
</tr>
<tr>
<td>8. Sandstone, fine-grained, bluish, shaly</td>
<td>2</td>
</tr>
<tr>
<td>7. Limestone, bluish, arenaceous-magnesian</td>
<td>5</td>
</tr>
<tr>
<td>6. Shale, bluish, arenaceous, bearing small mica flakes</td>
<td>1</td>
</tr>
<tr>
<td>5. Limestone, arenaceous-magnesian, shaly in upper part</td>
<td>3</td>
</tr>
<tr>
<td>4. Limestone, arenaceous-magnesian, shaly in upper part</td>
<td>3</td>
</tr>
<tr>
<td>3. Shale, bluish, arenaceous, with mica flakes</td>
<td>6</td>
</tr>
<tr>
<td>2. Limestone, bluish, arenaceous</td>
<td>6</td>
</tr>
<tr>
<td>1. Shale, bluish, argillaceous. Exposed at foot of bluff</td>
<td>6</td>
</tr>
</tbody>
</table>

Some very interesting sections occur on Mummi creek two and one-half miles west of Belfast. A short distance above the mouth of the creek, the following succession is shown in an east branch (SE.¼ sec. 33, T. 67 N., R. 7 W.).

Section in the east branch of Mummi creek.

<table>
<thead>
<tr>
<th>SPERGEN</th>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone, arenaceous-magnesian, bluish weathering yellowish to brownish; with thin discontinuous seams of bluish magnesian limestone which weather in relief. Massive when fresh, but weathering to thin layers. Weathered surface of a massive ledge in lower part shows indications of cross-bedding. Bearing molds of fenestelloid bryozoa.</td>
<td>19</td>
</tr>
</tbody>
</table>

Warsaw

Shale, bluish to black, argillaceous, more calcareous in upper part and grading into the beds above. No fossils found, but occasional bands of small imperfect siliceous geodes were noted. Exposed | 14½ |

About two hundred and thirty-five yards up the creek the section given below was measured in a small ravine in the east bank.

Section in small branch of Mummi creek near preceding section.

<table>
<thead>
<tr>
<th>LOWER ST. LOUIS</th>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Limestone, compact, buff, magnesian</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4. Limestone, buff, magnesian in the nodular layers</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>3. Limestone, yellowish, conglomeratic, magnesian; the structure partly obliterated by dolomitization; resting on the irregular surface of the bed beneath</td>
<td>2</td>
<td>6</td>
</tr>
</tbody>
</table>

Spergen

<table>
<thead>
<tr>
<th>Spergen</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Shale, drab, arenaceous, bearing small mica flakes</td>
<td>6</td>
</tr>
<tr>
<td>1. Limestone, arenaceous and magnesian, massive; a small amount of buff cherty magnesian limestone in upper part. Exposed</td>
<td>17</td>
</tr>
</tbody>
</table>
In a small branch about eighty yards north of the above described section, the conglomeratic and dolomitic basal limestone layer of the St. Louis succeeds twenty and one-half feet of arenaceous-magnesian Spergen limestone. About one foot of shale is exposed at the mouth of the branch beneath the Spergen. The weathering out of the shale undermines the massive limestone ledge for many feet, and several huge blocks of the latter have tumbled down into the bed of the creek. Some seams in the Spergen at this place are less arenaceous and are highly fossiliferous. These tend to weather out in relief and in many cases indicate the existence of cross-bedding in the original rock.

Two hundred yards farther upstream a section in the creek bank extends from the top of the Warsaw shale to the Upper St. Louis limestone. The Spergen is very much attenuated here, averaging only about one foot in thickness in the face of the bluff. The abrupt thinning of the Spergen in passing from the previously described Mumm creek sections to this point is undoubtedly due to pre-St. Louis erosion.

The Spergen limestone has a thickness of thirteen to fourteen feet in the east bank of Monk creek just northwest of Belfast. It is underlain by shales provisionally referred to the Warsaw and is overlain by the Lower St. Louis limestone. There is a possibility that the shales belong, in part at least, to the Spergen. In the absence of well preserved fossils their age cannot be determined definitely.

<table>
<thead>
<tr>
<th>Section in the east bank of Monk creek northwest of Belfast</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOWER ST. LOUIS</td>
</tr>
<tr>
<td>4. Limestone, conglomeratic, matrix calcareous above but shaly below</td>
</tr>
<tr>
<td>SPERGEN</td>
</tr>
<tr>
<td>3. Limestone, brownish, magnesian, soft, thin-bedded, bearing molds of fenestelloid bryozoa</td>
</tr>
<tr>
<td>2. Limestone, brownish, arenaceous-magnesian, in one massive ledge which shows faint indications of cross-bedding at one point, but composed of thin rotten layers a few yards downstream, where it is much weathered</td>
</tr>
<tr>
<td>WARSAW</td>
</tr>
<tr>
<td>1. Shale, argillaceous, dark blue to black where fresh but weathering drab; bearing efflorescence of a mineral which appears to be gypsum; containing a few small crushed imperfect siliceous geodes; somewhat calcareous in upper part and grading into the bed above. A few poorly preserved fossils in the upper part. Exposed</td>
</tr>
</tbody>
</table>

At and in the vicinity of the city of Keokuk the Spergen ranges from practically nothing to a little more than eight feet
in thickness. The St. Louis limestone lies directly upon the Upper Warsaw shale at an exposure in B street near its intersection with Reid street, but in the Mississippi river bluff back of the Taber lumber mill, two miles below the Union Station, the Spergen is represented by a layer of bluish gray sandy limestone which weathers brownish and is two and one-half to six feet thick. Upper Warsaw shales underlie the limestone while conglomeratic St. Louis limestone outcrops above it.

Good exposures of the Spergen and associated beds may be seen along a small creek in the northeast quarter of section 24 of Jackson township, about three-fourths of a mile northwest of Rand Park at Keokuk. The following section was measured at this locality.

**Section near Rand Park, Keokuk.**

<table>
<thead>
<tr>
<th>LOWER ST. LOUIS</th>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Limestone, for the most part conglomeratic; consisting chiefly of irregularly disposed blocks and subangular boulders of compact gray limestone; matrix shaly below but more calcareous above; bearing silified corolla of <em>Lithostrotion canadensis</em>. Upper two to three feet more evenly-bedded. A more regular layer of compact gray limestone ranging in thickness from a few inches up to 2 feet or more appears at the base. It rests upon an irregular and eroded surface of the Spergen</td>
<td>16</td>
</tr>
</tbody>
</table>

**SPERGEN**

| 2. Sandstone, grayish blue, fine-grained, with scattered subangular quartz grains ranging up to 1 mm. or more in diameter. This bed becomes somewhat yellowish on weathered surfaces. The upper half exhibits a tendency towards cross-bedding of the torrential type and the uppermost two feet is weathered into thin layers. Locally some of the arenaceous layers pass into a bluish compact magnesian limestone. The fronds of fenestelloid bryozoans so commonly observed in the Spergen are seldom seen here. The lower two feet of the formation is somewhat shaly and appears to pass gradually downward into the Warsaw shales below | 8 |

**WARSAW**

| 1. Shale, bluish, argillaceous | 12 |

Several outcrops of Spergen limestone appear along the north and south forks of a small creek near the center of section 25, Montrose township, five miles north of Keokuk. The greatest exposed thickness of the formation is ten feet. In some of the exposures the limestone is brownish, arenaceous and dolomitic. In others it consists chiefly of gray subcrystalline slightly altered limestone. The formation is shown at several points in contact with the disturbed facies of the St. Louis limestone. At a small fall in the creek a short distance below the confluence of
the two branches the Spergen is nine and one-half feet in thickness. The upper half consists of shale and the lower half of bluish to brownish arenaceous-magnesian limestone with abundant molds of fenestelloid bryozoans. The formation is here overlain by the basal disturbed layer of the St. Louis limestone one and one-half feet in thickness, and is underlain by the Lower Warsaw shale with an exposed thickness of four feet. Farther down the creek lower beds of the Lower Warsaw appear.

The Spergen limestone outcrops again just south of the town of Montrose along a small tributary of the Mississippi. It is ash-colored to brownish in color and arenaceous and dolomitic in character. Poorly preserved molds of fenestelloid bryozoans are the only important fossils. The formation here has a thickness of twenty-one feet. Thirty feet of geodiferous Lower Warsaw shales is exposed below it along the banks of the creek while conglomeratic St. Louis limestone of variable thickness appears above.

The Spergen appears in the following bluff section in the northern part of section 13 of Pleasant Ridge township:

\[
\text{Section in Pleasant Ridge township.}
\]

\[
\begin{array}{ll}
6. & \text{Limestone, magnesian, brownish; cross-bedded and laminated; impure and arenaceous toward the base. Impressions of fenestelloid bryozoans abundant} \quad \text{8 feet} \\
5. & \text{Shale, argillaceous, with intercalated layers of sandstone and magnesian limestone near the top} \quad \text{7 1/6 feet} \\
4. & \text{Limestone, magnesian, in a massive ledge} \quad \text{3 feet} \\
\end{array}
\]

\[
\text{WARSAW}
\]

\[
\begin{array}{ll}
3. & \text{Shale, bluish, argillaceous} \quad \text{2 feet} \\
2. & \text{Concealed} \quad \text{10 feet} \\
1. & \text{Shale, calcareous, in bed of creek.} \\
\end{array}
\]

\[
\text{Hancock County, Illinois.} - \text{The Spergen formation outcrops at a number of localities in this county. In the vicinity of Warsaw it is very thin, owing no doubt to the erosion interval which followed its deposition and preceded the incursion of the St. Louis sea (fig. 7).}
\]

In a small ravine tributary to the large creek a short distance east of the High School, the following section was measured:

\[
\text{Section near the High School at Warsaw.}
\]

\[
\begin{array}{ll}
\text{ST. LOUIS} & \text{FEET INCHES} \\
\text{Limestone, gray, compact; the disturbed basal layer of the St. Louis} \quad \text{2 feet} \\
\end{array}
\]
The following succession may be seen in an old quarry face in the south bank of the creek, about thirty yards northeast of the ravine section:

**Section in quarry near the preceding section.**

<table>
<thead>
<tr>
<th>STRATUM</th>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPERGEN</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Limestone, yellowish, magnesian, with occasional rounded sand grains</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPERGEN</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Limestone, gray, fossiliferous, thin-bedded</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WARSAW</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Limestone, magnesian; upper one foot brownish and massive; lower five feet bluish and shaly</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WARSAW</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Limestone, brownish, in two massive ledges. Exposed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The following section is exposed at the bend of the creek a short distance above the Main Street bridge:
The Spergen was formerly quarried extensively in the Mississippi river bluff one mile south of Sonora, Illinois. The formation consists of arenaceous-magnesian limestone and is twenty feet thick in the southernmost of the quarry openings, where it overlies bluish argillaceous shale presumably of Lower Warsaw age. It is succeeded above by six to twelve feet of conglomeratic St. Louis limestone. The latter pinches out a few rods north of this exposure and the Spergen is succeeded directly by sandstones and shales of Pennsylvanian age, which contain characteristic plant remains. The Sonora sandstone of Keyes9 represents the Spergen of the above described section.

The following section appears in the Fort Madison-Appanoose Stone Company quarry about two miles northeast of Niota, Illinois.

The contact of bed 1 with the Lower Warsaw may be studied in a ravine near by.

The Spergen attains a thickness of not less than twenty-five feet along a creek skirting the Pontusac road, about two miles east of Niota. All but the upper three feet of the formation at this place is a massive magnesian limestone. The upper three feet is made up of thinly laminated and cross-bedded gray limestone which bears brachiopods and numerous bryozoans. The contact with the Lower Warsaw is shown here also.

The Spergen outcrops in a somewhat different facies about one-half mile east of Niota on the west bank of a creek.

---

### Des Moines County, Iowa

The only exposures of the Spergen which are known to occur in Des Moines county appear on Long creek in section 12 of Augusta township. In an abandoned quarry on the property of Wm. Madlener, in the north bluff of the creek (SW 1/4 of SE 1/4 sec. 12), it has an exposed thickness of thirty-four and one-half feet. The beds are described in the accompanying section:

#### Section of Madlener quarry

<table>
<thead>
<tr>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Drift ................................................................. 1</td>
</tr>
<tr>
<td>Spergen</td>
</tr>
<tr>
<td>4. Limestone, buff, dolomitic .................................... 1</td>
</tr>
<tr>
<td>3. Shale, bluish, argillaceous ................................... 3</td>
</tr>
<tr>
<td>2. Limestone, buff, dolomitic, massive, filled with the molds of fenestelloid bryozoans and other fossils; with occasional streaks and patches of denser bluish dolomitic limestone .... 30 1/2</td>
</tr>
</tbody>
</table>

#### Lower Warsaw

1. Shale, bluish, argillaceous, with occasional siliceous segregations. Exposed .................................................. 12

The fossils identified from bed 2 of this section are as follows:

**List of fossils from Spergen formation in Madlener quarry.**

- Fenestelloid bryozoa (impressions) Spirifer bifurcatus Hall
- Productus altowensis N. and P. Spirifer tenuecostatus Hall
- Pustula biseriata (Hall) Reticularia setigera (Hall)
- Dielasma sp. Brachythiris subcardiformis (Hall)
- Spiriferina salemensis Weller Orthonychia neustrostre (Hall)

A bluff on the same bank of the creek three hundred yards farther down stream shows the following succession.
Van Buren County.—The Spergen is exposed at several localities along Des Moines river and its tributaries in Van Buren county. In the northeast quarter of section 3 of Farmington township it outcrops in the banks of Indian creek. An exposure of limestone five and one-half feet high which yields many characteristic Spergen fossils appears one hundred yards below the railroad bridge across the stream. The limestone is gray in color, slightly crinoidal and thinly bedded. Locally, parts of the bed grade laterally into heavier bedded bluish dolomitic limestone. Three feet of dolomitized conglomeratic St. Louis limestone overlies the Spergen.

The following beds of the Spergen are shown in the creek bank one-fourth mile below this exposure. St. Louis limestone appears above.

<table>
<thead>
<tr>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Van Buren County. — The Spergen is exposed at several localities along Des Moines river and its tributaries in Van Buren county. In the northeast quarter of section 3 of Farmington township it outcrops in the banks of Indian creek. An exposure of limestone five and one-half feet high which yields many characteristic Spergen fossils appears one hundred yards below the railroad bridge across the stream. The limestone is gray in color, slightly crinoidal and thinly bedded. Locally, parts of the bed grade laterally into heavier bedded bluish dolomitic limestone. Three feet of dolomitized conglomeratic St. Louis limestone overlies the Spergen. The following beds of the Spergen are shown in the creek bank one-fourth mile below this exposure. St. Louis limestone appears above.</td>
</tr>
<tr>
<td>5. Drift.</td>
</tr>
<tr>
<td>4. Limestone, soft, buff, dolomitic, filled with the molds of fenesteloid bryozoans and other fossils.</td>
</tr>
<tr>
<td>3. Concealed.</td>
</tr>
<tr>
<td>2. Shale, bluish, argillaceous, more calcareous in lower part; a few small imperfect siliceous geodes on slope.</td>
</tr>
<tr>
<td>1. Limestone, bluish, medium to coarse-grained, Orthotetes keokuk abundant. Exposed above level of water in creek.</td>
</tr>
<tr>
<td>Spergen</td>
</tr>
<tr>
<td>5. Limestone, bluish gray when fresh, weathering brownish; a few small angular chert fragments present at one point; filled with molds of bryozoans and other fossils. This bed is overlain disconformably by the St. Louis limestone except at the west end of the section where the Pennsylvanian sandstone rests upon the Spergen.</td>
</tr>
<tr>
<td>4. Limestone, arenaceous-magnesian, bluish; with molds of fenesteloid bryozoans and other fossils. Consists typically of a bluish dolomitic sandstone with irregular, discontinuous seams of fine-grained bluish dolomitic limestone. Locally this member passes completely into a fine-grained bluish sandstone, nearly barren of fossils. One large fish tooth was found in the sandstone. This facies tends to flake off obliquely to the weathered surface. The shaly portion at the top bears mica flakes.</td>
</tr>
<tr>
<td>3. Shale, bluish, argillaceous, slightly arenaceous in the basal part, and grading down into the bed below. Thin seams of bluish fine-grained sandstone in lower part.</td>
</tr>
<tr>
<td>2. Shale, calcareous, arenaceous in upper part; approaching an impure limestone below; ash-colored, grading into the bed above, bearing Spirifer sp., Conularia sp. and bryozoans.</td>
</tr>
<tr>
<td>Lower Warsaw</td>
</tr>
<tr>
<td>1. Shale, bluish, argillaceous. No fossils noted. Contact with the bed above mostly concealed. Exposed.</td>
</tr>
</tbody>
</table>
Other important exposures of the Spergen are shown along Reed creek in the northeast quarter of section 15, Bonaparte township. The following section is exposed in an abandoned quarry about half a mile above the mouth of the stream:

**Section in abandoned quarry on Reed creek.**

<table>
<thead>
<tr>
<th>Location</th>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST. LOUIS</td>
<td>5. Limestone, brownish, dolomitic, mashed and broken in lower part</td>
<td>15</td>
</tr>
<tr>
<td>SPERGEN</td>
<td>4. Limestone, brownish, arenaceous-magnesian</td>
<td>5 to 8</td>
</tr>
<tr>
<td></td>
<td>3. Sandstone, fine-grained, soft, bluish</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2. Concealed</td>
<td>6</td>
</tr>
<tr>
<td>WARSAW</td>
<td>1. Shale, bluish, argillaceous. Exposed to bed of creek</td>
<td>22½</td>
</tr>
</tbody>
</table>

Another exposure of the Spergen, twelve feet high, appears about two hundred yards farther upstream and is capped by drift. The formation as here exposed consists of fine-grained bluish sandstone the upper two-thirds of which is massive when fresh but weathers into thin layers. The lower third is thinly and irregularly bedded and locally is shaly.

The same beds appear again in the banks of the creek one hundred and twenty-five yards east of the above section. At this point the Spergen is represented dominantly by shale. Sixteen feet of bluish argillaceous shale with thin layers and discontinuous seams of bluish sandstone is overlain by drift.

A small exposure on Potters branch in the southeast quarter of section 9, Bonaparte township, shows the Spergen in contact with the Warsaw shales.

**Section on Potters branch.**

<table>
<thead>
<tr>
<th>Location</th>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPERGEN</td>
<td>Shale, argillaceous, bearing a few imperfect siliceous geodes</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Limestone, brownish, dolomitic</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Shale, arenaceous and calcareous, with a band of siliceous nodules near the middle; bearing fenestelloid bryozoans. Resting unevenly on the bed beneath</td>
<td>5 ¼</td>
</tr>
<tr>
<td>WARSAW</td>
<td>Shales</td>
<td>11</td>
</tr>
</tbody>
</table>

The following section of the Spergen is exposed in the south bank of Bear creek, in the northeast quarter of section 10, Henry township.

**Section of Spergen formation on Bear creek.**

<table>
<thead>
<tr>
<th>Description</th>
<th>Feet</th>
<th>Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Sandstone, bluish, fine-grained; blocks of St. Louis limestone on slope above</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>6. Shale, bluish, argillaceous</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>
5. Sandstone, fine-grained, yellowish; resting unevenly on the bed beneath; with angular white chert fragments in basal part ............................................................................. 1 to 2
4. Limestone, cream-colored, with irregular seams and nodules of whitish chert; weathering to polyhedral blocks ........................................ 2 6
3. Shale, bluish, argillaceous ................................................................. 2
2. Sandstone, fine-grained, bluish, calcareous, massive when fresh but weathering to shaly layers ..................................................... 2 3
1. Shale, bluish, argillaceous. To bed of creek .................................................. 6 6

A second exposure in the creek bank a little more than one-fourth mile east of the above section shows a considerable difference in the character of the above beds.

Section of Spergen formation east of preceding section.

<table>
<thead>
<tr>
<th>FILE</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.</td>
<td>Sandstone, fine-grained ................................................................. 1</td>
</tr>
<tr>
<td>5.</td>
<td>Limestone, cream-colored, bed 4 of preceding section ...................... 2 6</td>
</tr>
<tr>
<td>4.</td>
<td>Shale, bluish, argillaceous ............................................................... 6 6</td>
</tr>
<tr>
<td>3.</td>
<td>Limestone, brownish, dolomitic .......................................................... 1 2</td>
</tr>
<tr>
<td>2.</td>
<td>Shale, bluish, argillaceous ............................................................... 10 10</td>
</tr>
<tr>
<td>1.</td>
<td>Limestone, bluish when fresh but weathering yellowish; dolomitic; bearing fenestelloid bryozoans. Exposed above bed of creek .................................. 4</td>
</tr>
</tbody>
</table>

Considerable arenaceous limestone has been removed from the Spergen in the old Bear creek quarries which were located in the northwest quarter of section 11, Henry township. At present about three feet of arenaceous dolomite with impressions of fenestelloid bryozoans is exposed in the floor of the quarry. This is overlain by five feet of arenaceous shale which in turn is capped by drift. The limestone ledge which appears in the quarry has an exposed thickness of eight feet in the bank of the creek near by.

Henry County.—The only exposure of the Spergen formation observed by the writer in Henry county appears in the bed of a small branch of Mud creek about one and one-half miles northeast of the town of Lowell in Baltimore township. At this locality it is represented by a wedge-shaped bed of brownish to buff massive dolomitic limestone between the St. Louis limestone and the Warsaw shale. It is filled with molds of Productus altonensis and impressions of fenestelloid bryozoans. The maximum exposed thickness of the limestone is about four feet. It thins abruptly from this point downstream and within a few yards disappears completely, thus permitting the basal bed of the St. Louis limestone to succeed the Lower Warsaw shale directly.
Jefferson County.—The northernmost exposures of the Spergen formation observed by the writer in Iowa occur in Lockridge township of Jefferson county. Twenty-one feet of Spergen sandstone underlies an unusually complete exposure of the St. Louis limestone in the Cedar Bluff section on Skunk river, one-fourth mile east of the southwest corner of section 12. The base of the Spergen is not exposed. The section is as follows:

Section of Spergen formation in Cedar Bluff.

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Sandstone, gray with slight greenish tint, fine-grained, weathering yellowish, soft, incoherent</td>
<td>7</td>
</tr>
<tr>
<td>3. Sandstone, as above, thin-bedded, weathering yellowish</td>
<td>2</td>
</tr>
<tr>
<td>2. Sandstone, as above, with greenish tint, massive, soft</td>
<td>8</td>
</tr>
<tr>
<td>1. Sandstone, fine-grained, gray with greenish tint, with numerous small greenish patches and occasional thin buff dolomitic seams. Worthenopora spinosa, Stenopora sp., Polypora sp.</td>
<td>3</td>
</tr>
</tbody>
</table>

Fifteen and one-half feet of Spergen sandstone is exposed below the St. Louis limestone in an abandoned quarry in the north bank of Turkey creek, near the center of the northeast quarter of section 11, Lockridge township.

Section of Spergen formation on Turkey creek.

<table>
<thead>
<tr>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Sandstone, soft, weathering brownish, probably gray when fresh; less massive than bed below; bearing minute mica flakes; dolomitic below</td>
</tr>
<tr>
<td>1. Sandstone, gray with bluish tint when fresh, micaceous; in one great massive ledge; lower half dolomitic and showing oblique stratification lines on weathered surface. This also has small lenses and streaks of bluish dolomitic limestone free from sandstone; sand grains coarser in lower half. Bearing Worthenopora spinosa and other bryozoans. Exposed</td>
</tr>
</tbody>
</table>

The St. Louis Limestone

CHARACTER AND GENERAL RELATIONS

The St. Louis limestone is named from the city of St. Louis. This formation, like the Spergen, has been poorly understood in Iowa, owing to the great lateral range in its character, a range which is due to original differences in sedimentation, to differences in the degree of dolomitization, to the presence of a disconformity at the base and to extensive brecciation at some localities. According to the old definition the St. Louis in Iowa includes three distinct subdivisions, designated by Bain the Springvale, or basal member, the Verdi, and

the Pella. It is now known that the Pella member is formationally distinct. This bears a Ste. Genevieve fauna, and is separated from the true St. Louis beneath by a disconformity. Again it is now recognized that the arenaceous-magnesian limestone locally exposed above the Warsaw, and formerly included with the St. Louis, is a distinct formation and belongs to the Spergen limestone. Furthermore the type section of the Springvale as defined by Bain is believed to be of Keokuk age (see page 181) rather than St. Louis. Consequently this term should be abandoned. In its place the name Croton is substituted, since the lower division of the St. Louis is typically developed in the vicinity of that town in Lee county. The terms Croton and Lower St. Louis are used synonymously in this report. The Croton limestone is by far the more extensive of the two divisions of the St. Louis, for it extends far to the north, overlapping all the earlier divisions of the Mississippian except the Kinderhook, upon which it rests in Humboldt county (fig. 2, page 44). This relationship is believed to be due in part to greater uplift and erosion in the northern region prior to the Croton submergence and to nondeposition of the Warsaw and Spergen formations in the northern area. This division consists for the most part of massive, compact buff to brownish dolomitic limestone, but frequently these beds are found to grade laterally in short distances into dense, fine-grained gray nondolomitic limestone. Again, the two phases may have an interbedded relationship. Furthermore the Croton limestone is brecciated at many localities. At the close of Croton time, the sea retreated to the southward as a result of an elevation of the northern area. An intraformational disconformity between this division and the Verdi has been traced as far south as Alton, Illinois, but there is no evidence of it in the St. Louis section in Ste. Genevieve county, Missouri, where the formation has a greater thickness than in Iowa. The Croton limestone is about thirty feet in thickness.

Following a short interval of erosion at the close of Croton time the sea returned and deposition of limestone in the region began again. The returning seas, however, probably did not extend so far north at this time as during the Croton. The Verdi or Upper St. Louis limestones, which were formed at this time, are, for the most part, light gray in color and fine-grained
and compact in texture. But interbedded layers of granular to oölitic limestone occur at a few localities. This member is dolomitc at only a few places but locally the beds pass laterally in whole or in part into sandstone. Its thickness is nowhere more than thirty-five feet. The type section is in the old railroad quarries near Verdi in Washington county.

The fauna of both divisions of the St. Louis is meagre. The coral, *Lithostrotion canadensis*, which normally occurs in a zone at the very top of the Croton, is the most important horizon marker of that member. The fauna of the Verdi is more varied, consisting of several species of *Productus*, a few other brachiopods and occasional gastropods and pelecypods.

The unstable conditions of the St. Louis were terminated by a greater and more widespread uplift than that which occurred in this region during preceding Mississippian time. However, the duration of the erosion interval which followed the uplift could not have been great, for the deposits of the returning Ste. Genevieve sea, which must have rivalled that of the early St. Louis in size, have not been found in Iowa to rest upon formations older than the Croton.

*Fig. 8.—Brecciated Lower St. Louis limestone overlying regularly bedded Spergan limestone. Near Colchester, Illinois.*
The brecciated and disturbed facies of the St. Louis limestone received considerable attention from the writer in the course of field work in southeastern Iowa. The brecciation is confined almost entirely to the St. Louis limestone as revised, although locally the succeeding Pella beds are slightly affected. The underlying Spergen beds nowhere share in the fracturing. The disturbance may involve beds only a few feet in thickness at any horizon, or it may affect the whole formation from top to bottom. Where it is confined to beds only a few feet in thickness it is usually very local and the disturbed facies passes laterally into undisturbed layers within short distances. Where it is more general, however, the beds are affected over a much larger area, but even there the signs of disturbance eventually die out and give place to evenly lying beds showing no signs whatever of brecciation. The tendency of the beds to grade laterally into material of an entirely different character within short distances is very confusing and this coupled with the puzzling features produced by variations in the intensity of dolomitization at different localities complicates the situation considerably.

By previous workers it has usually been assumed that the brecciated character of the St. Louis limestone is an original feature which was produced by disturbed conditions during deposition. Thus, C. H. Gordon\textsuperscript{11} offers the following possible explanations:

1. Wave action upon a rock-bound coast.
2. Systematic alternation of vigorous and quiet action of wind waves in connection with tidal oscillation in regions where the sea bottom is subjected to wave action at low tide.
3. Wave action especially facilitated by the development of coral reefs.

The second of these, according to Gordon, best suits the facts. Again, Bain\textsuperscript{12} in his discussion of the Verdi limestone of Washington county expresses himself as follows:

"The Verdi contains the record of a time of considerable disturbance. Shore formations and open sea deposits succeed each

\textsuperscript{12} Iowa Geol. Survey, vol. V, p. 150; 1896.
other in rapid alternation. Huge blocks of the previously formed limestone were torn from their beds and buried in the sands, apparently at the foot of a series of cliffs; or they were beaten upon each other and reduced, in part, to fragments of varying degrees of coarseness, and in part to finest powder that eventually cemented the fragments together. Considering the turbulent conditions under which the beds were formed, it is not strange that fossils are rare."

In his report on the geology of Henry county, Savage interprets the disturbed St. Louis in much the same way. Quoting from him:13

"The second or middle division is recognized by the extreme variableness of its beds and its generally disturbed condition. It consists of irregular layers of sandstones and shales with an occasional bed of brecciated limestone near the upper portion. It is a record of a time of great disturbance and of rapidly changing conditions. It is for the most part a deposit near the margin of some troubled sea. The presence of local layers which thin out rapidly in a short distance, the pockets of sand and shale, the numerous lenticular beds, and the general irregular appearance of the strata indicate a vigorous wave action. The ripple marks which are beautifully preserved in the sandstone at numerous points, and the local development of oolitic limestone testify to the close proximity of an old shore line."

The most important outcrops of the St. Louis from the standpoint of brecciation are located at Montrose in Lee county and along the creeks tributary to Des Moines river in Van Buren county.

The brecciation effects in the formation may be grouped into three main types. In the first the disturbed portions assume the form of small mounds or reefs of limestone blocks, usually in a calcareous or sandy matrix, with undisturbed layers lapping up on the flanks and filling in the depressions. These appear at all horizons in the formation, but are most characteristic of the basal Croton and basal Verdi. In the second type the brecciation is developed along one bed of the Lower St. Louis owing to differential movements. The latter type is accompanied in a few cases by tongue-like extensions of broken limestones which are forced into the beds below, especially where the underlying layers are soft shales. The third type embraces

the major part if not the entire formation over an area of differ­ing but usually limited extent. In this type the disturbance has been produced by mashing on a large scale and the breccia­tion is in many places associated with small overthrust faults and folds. The Pella beds also are involved to a slight extent in this disturbance but in no instances have the underlying for­mations been found to exhibit signs of brecciation.

Regarding the origin of the brecciation, at least three periods of disturbance are believed to have been involved in its produc­tion. The mounds or reef-like masses of the first type are be­lieved to have been formed under conditions of violent wave action possibly induced by local shallowing of the sea during deposition. The presence in the formation of local disconform­ties, of stratified breccia, and of cross-bedded limestone sands supposedly formed by the grinding up of layers already depos­i­ted is in favor of this view. Other features which suggest wave action at the time of deposition are contemporaneous erosion phenomena, wave-marks and cross-bedding.

The brecciation of the second type was formed as a result of deformation. The importance of this cannot be definitely eval­uated since its effects are in many cases overshadowed by the disturbance of the third type. That this disturbance is distinct from the third is suggested by the fact that there is evidence of dolomitization having intervened between the two. Thus, the reefs produced by the first disturbance and the shattered areas and fracture lines produced by the second are in numerous in­stances either wholly undolomitized or are very imperfectly altered while the undisturbed limestone about them is uniform­ly dolomitized. This relationship supports the theory that dolo­mitization succeeded the first and second periods of disturbance and that the brecciated areas were more resistant to alteration. But a later disturbance involves both the poorly dolomitized areas and the uniformly dolomitized ones and a later series of fractures cuts the earlier ones. The latter relationship is shown by the displacement of calcite veinlets which occupy the older fractures. (See page 257.)

Furthermore, the fact that dolomitization apparently nowhere affects the topmost limestone layers of the St. Louis nor any layers of the Pella indicates that the alteration took place prior
to the close of the St. Louis. Now since the brecciation of the second type is known to have taken place still earlier and appears to be confined to the Lower St. Louis it seems probable that this shattering may be related to the uplift which brought this division to a close.

The third period of disturbance was by far the most important. To this is ascribed the extensive mashing and shearing effects and the overthrust faulting and folding on a small scale so common in the formation. These were influenced to a large extent by the effects of the preceding disturbances, and at the same time they obscured to a large degree the evidence of these earlier activities. That the deformation which produced the later disturbances is post-Pella but pre-Pennsylvanian in age is indicated by the fact that blocks of Pella limestone have been found sheared down into basal Pella shales and sandstones and thus preserved at a locality where Pennsylvanian sandstone rests directly upon these basal beds. (See page 292.)

The general parallelism of the strike of the faults and of the tilted layers formed at this time with certain folds in the region, notably the Bentonsport anticline, which trends approximately N. 68°W., suggests a common mode of origin of these two types of deformation.

Moreover, it seems probable that both the last period of brecciation and the folds are closely related to the extensive uplift and tilting to the southwest which affected the region in late Mississippian time. It is well known that the Mississippian formations were profoundly eroded prior to the deposition of the Pennsylvanian beds. The belted arrangement of the Mississippian areas in southeastern Iowa was brought about largely by this period of erosion as is shown by the fact that Pennsylvanian beds are now found resting upon truncated Mississippian formations of all ages. That the present boundaries of the formations do not represent old shore lines seems certain. The strata at many localities consist of limestone up to the very margins and exhibit no shore facies.

AREAL DISTRIBUTION

The areal distribution of the St. Louis limestone is greatest in southeastern Iowa, where it forms a broad belt, with occa-
sional Pennsylvanian outliers, extending from central Lee county northward through Henry county and into northeastern Jefferson and southern Washington counties, thence northwestward through Keokuk county and into southwestern Iowa and southeastern Poweshiek counties. Southwest of this belt there are long, linear southeasterly trending areas of St. Louis limestone along the larger streams, notably Skunk and Des Moines rivers and their larger tributaries, which have cut down through the Coal Measures. The Des Moines river exposures appear in southwestern Lee, Van Buren, Wapello, southwestern Mahaska and eastern Marion counties while those related to the Skunk are chiefly in the northern half of Mahaska county. In southern Lee county there is an imperfect outlier, elliptical in outline, extending from Keokuk northward to Montrose. In west-central Story county there is an irregular inlier of St. Louis limestone surrounded on all sides by Pennsylvanian strata.

The most northerly exposures of the St. Louis in Iowa are in Webster and Humboldt counties where there are several small isolated exposures chiefly along Des Moines river and its tributaries.

The St. Louis limestone has a widespread distribution in southern Iowa beneath the Coal Measures as is indicated by artesian well records.

AREAL DESCRIPTION BY COUNTIES

Lee County.—A section exposed in the Mississippi river bluff two miles below the Keokuk Union Station ranges from Keokuk limestone up to the base of the Des Moines sandstone. The St. Louis limestone is well exposed at several points near the brow of the bluff. One of the most typical sections appears a short distance below the planing mill of the Taber Lumber Company. The formation is about thirty-two feet thick at this point and there is evidence of an intraformational disconformity in the upper part. The lower or Croton division here is eighteen to twenty-three feet thick and consists for the most part of massive disturbed layers of dark gray magnesian limestone which weathers brownish. The lower part is somewhat conglomeratic and some of the limestone pebbles in this part are compact, white and unaltered. The matrix and many of the pebbles, on the other hand, are mag-
nesian and weather brownish. About one foot of drab sandstone of Spergen age is exposed at the base at one point.

The contact of the Verdi member with the Croton is very irregular. The Verdi is greatly disturbed and consists essentially of conglomeratic, compact, dense whitish limestone with a calcareous matrix. The maximum thickness is fourteen feet.

In a ravine back of the wholesale office of the Taber Lumber Company the St. Louis limestone is overlain disconformably by ten feet of Des Moines sandstone. The St. Louis is conglomeratic throughout its thickness of thirty feet. A very irregular contact line separates the conglomeratic, compact white Verdi limestone above from a conglomeratic gray limestone, with blocks and layers of brownish magnesian limestone, below. Near the base of the St. Louis there is a bed composed of cemented grains and pebbles of limestone.

The basal Pennsylvanian sandstones are in disconformable contact with the Croton member of the St. Louis in a bluff section a short distance northwest of Rand Park at Keokuk as indicated in the following section:

Section in a bluff northwest of Rand Park, Keokuk.

Des Moines
Sandstone, whitish and with carbonaceous seams below, but yellowish above; cross-bedded and irregularly stratified. Weathered surfaces pitted and cavernous. A few eroded corals and quartz pebbles in basal part; resting on a very uneven and irregular surface of the Lower St. Louis ........................................ 11 to 12

Lower St. Louis
Limestone, compact, gray, conglomeratic, with calcareous matrix; reef-like and structureless. One block measures 4 by 8 feet. Maximum thickness ................................................................. 18 to 19

The Upper Warsaw shale, with intercalated layers of bluish and gray fossiliferous limestone underlies the St. Louis at this place, but the total thickness could not be ascertained owing to poor exposure.

Several exposures of Lower St. Louis limestone appear in the south part of the town of Montrose along a small creek which flows into Mississippi river. The following bluff section was measured a short distance below the wagon bridge.

Section in the south part of Montrose.

4. Drift.
Lower St. Louis
3. Limestone, conglomeratic; more regularly stratified above. A layer near the middle bears small irregular quartz grains .... 6 6
2. Irregular blocks and layers of limestone in a shaly matrix.
The blocks in the lower part are brownish and magnesian but
the limestone in the upper part is whitish or ash-colored 6

SPERGEN
1. Sandstone, gray, calcareous, with a few irregular and discon-
tinuous seams of compact gray limestone. Close inspection
reveals the presence of fenestelloid bryozoans and other fossils
in this member. Exposed 6

A few rods north of the bluff section described above there is
another good exposure of the Lower St. Louis in a quarry face.
At the base of the section is the Spergen formation, consisting
of four feet seven inches of fine-grained bluish sandstone over-
lain by two feet four inches of arenaceous shale. In the middle
of the quarry face there is a mound of conglomeratic and dis-
turbed limestone and on the flanks of this are more regularly
bedded layers of limestone (fig. 9).

Fig. 9.—Reef-structure in Lower St. Louis limestone near Montrose.

The mound evidently represents a reef built up by vigorous
wave action in Lower St. Louis time. The disturbance probab-
ly took place after the basal limestones had been deposited and
consolidated.

Several exposures of the St. Louis limestone in the interior of
Lee county have been described by Keyes.14 The more import-

ant of these are on the east branch of Sugar creek. The following description from Keyes is of an outcrop on this stream in the northeast quarter of section 20, T. 68 N., R. 5 W.

Section of St. Louis limestone on east branch of Sugar creek (After Keyes).

<table>
<thead>
<tr>
<th>Bed</th>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.</td>
<td>Concealed</td>
<td>5</td>
</tr>
<tr>
<td>5.</td>
<td>Limestone, hard, bluish white; breaking with conchoidal fracture</td>
<td>3</td>
</tr>
<tr>
<td>4.</td>
<td>Sandstone, light brown, soft, saccharoidal</td>
<td>10</td>
</tr>
<tr>
<td>3.</td>
<td>Limestone, fine, white, chertlike</td>
<td>1</td>
</tr>
<tr>
<td>2.</td>
<td>Limestone, soft, or calcareous sandstone grading downward into next</td>
<td>10</td>
</tr>
<tr>
<td>1.</td>
<td>Limestone, brecciated, roughly stratified</td>
<td>10</td>
</tr>
</tbody>
</table>

It will be observed that the formation as exposed here contains considerable sandstone.

Excellent exposures of the St. Louis appear in the southwestern part of the county near Belfast. In the Deamude quarries, located near the center of section 13, Des Moines township, the formation is typically developed. The occurrence of the Spergen and Upper Warsaw beds at this locality has been described on a previous page. (See pages 213 and 215.)

The succession of beds in the St. Louis at the northeast end of the quarry is given below:

Section of St. Louis limestone in Deamude quarry.

**Upper St. Louis**

3. Limestone, conglomeratic, light gray, consisting of subangular blocks rudely stratified. The matrix is of a lighter gray color. Rests irregularly on the surface of the bed beneath .......... 9½

**Lower St. Louis**

2. Limestone, compact, massive, brownish on weathered surface, magnesian; locally passing laterally into unaltered limestone. 6½

1. Limestone, conglomeratic. Cross-bedded Spergen limestone below ......................................................... 10 to 14½

At one point in this part of the quarry a small outlier of Pennsylvanian sandstone occurs. This appears to occupy a small valley cut into the St. Louis. The contact is concealed.

Bed 1 has a marly matrix which is more prevalent in the lower part. Some of the blocks have a fine contorted stratification and many show stylolytic structure on their surfaces. The conglomerate consists of confusedly mingled angular and subangular blocks of compact dark gray limestone; gray somewhat shaly fossiliferous limestone; gray subcrystalline limestone filled with worm castings; compact brownish magnesian limestone; and drab fine-grained soft impure limestone. Where the blocks are
not greatly disturbed they are rudely stratified. This bed thickens abruptly at one point and bed 2 arches up over it.

Bed 2 is bluish gray when fresh but weathers brownish. At one point it passes abruptly into a thin-bedded gray limestone. To the southwest in the quarry face this bed shares in the general disturbance. At this point it is only imperfectly changed to dolomite, and contains a few chert nodules. No fossils were found.

Bed 3 is composed of blocks of a rather soft gray subcrystalline limestone and of compact gray limestone. These blocks vary from a fraction of an inch to several feet in diameter. At one point this bed forms a tongue-like extension down through bed 2 apparently as a result of shearing.

The St. Louis limestones outcrop at a number of points in the Des Moines river bluff just below Belfast. Reference has been made to several of these in the description of the Spergen as developed there. The following section of the Lower St. Louis appears in the bluff about one and one-third miles south of Belfast.

Section of Lower St. Louis Limestone below Belfast.

<table>
<thead>
<tr>
<th>LOWER ST. LOUIS</th>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sandstone, fine-grained, bluish; upper surface slightly undulating</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The disturbed facies of the St. Louis is seen at the same horizon only a few yards beyond.

An excellent section may be seen on Mumm creek in the southern middle part of section 33, Van Buren township, two and one-half miles west of Belfast and a little north of that village. This section includes the Warsaw, an attenuated equivalent of the Spergen and both members of the St. Louis.
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**Section on Mumm creek.**

**UPPER ST. LOUIS**

11. Limestone, gray, compact, conglomeratic, rudely stratified; with occasional pockets of carbonaceous shale and irregular lines of fine-grained whitish sandstone at the very base. Resting on the irregular surface of the bed beneath. Three specimens of *Lithostrotion canadensis* were obtained from a seam of carbonaceous shale at the base. These were angular, and showed no evidence of abrasion .................................................. 6

**LOWER ST. LOUIS**

10. Limestone, brownish, tough, magnesian, bearing the silicified coralla of *Lithostrotion canadensis* ....................... 5 6 to 1 5

9. Limestone, buff, magnesian, brittle, tending to scale off obliquely; bears a few rounded chert concretions ..................... 5 2

8. Limestone, gray, compact, dense, unaltered here, but dolomitic at the bend farther up the creek ........................................ 1 5

7. Limestone, bluish, magnesian, soft, weathering yellowish .......... 3 1

6. Limestone, buff, magnesian, in two layers of about equal thickness ................................................................. 2 9

5. Limestone, yellowish to brownish, dolomitic; disturbed and conglomeratic, especially in lower part; more evenly bedded above; passing gradually downward into the bed below; bearing pebbles and irregular patches of unaltered compact gray limestone. Lower surface extremely irregular ............ 3 to 5

4. Shale, bluish, calcareous, with imbedded pebbles of compact gray limestone; of very variable thickness; resting on the uneven surface of the bed below, and followed unevenly by the bed above .................................................. 1 to 3

3. Limestone, gray to buff or yellowish, magnesian; conglomeratic and disturbed. Some pebbles of unaltered gray compact limestone ................................................................. 2 to 3 1/2

**SPERGEN**

2. Limestone, bluish, arenaceous-magnesian ...................... 2 3 to 1 4

**WARSAW**

1. Shale, bluish, argillaceous, more calcareous towards the top where it carries fish remains, *Comularia* sp. and *Oribitoidia* sp. Argillaceous part bears a few small imperfect siliceous geodes. Exposed ................................................................. 8 10

Concealed to bed of creek .................................................. 3

About seven hundred yards farther up, the stream bends abruptly from the north to an easterly direction. A fine exposure is afforded here in the west bank immediately below the bend.

**Section on Mumm creek above the preceding section.**

**DES MOINES**

8. Concealed to brow of hill; surface strewn with blocks of brownish sandstone.

**UPPER ST. LOUIS**

7. Limestone, light gray, compact; some layers granular to oolitic ........................................................................... 12

6. Concealed, probably brecciated limestone with shaly matrix... 4

5. Limestone, gray, compact, conglomeratic, rudely stratified .... 12 1/4

**LOWER ST. LOUIS**

4. Limestone, massive, magnesian, weathering brownish; bearing a few silicified coralla of *Lithostrotion canadensis*. Very undulating and uneven ................................................................. 3

3. Limestone, buff, magnesian, massive, structureless; little trace of bedding; flaking off obliquely; slightly receding. At one
point a small cave extends back ten to fifteen feet. Highly fossiliferous in basal part. 4½ to 5½

2. Limestone, yellowish to brownish, magnesian; in one massive ledge; resting on the undulating and hummocky surface of bed below; usually projecting. 2 to 3¾

1. Limestone, bluish, magnesian, in thin, undulating layers; arching up over mounds in creek bed. Exposed to bed of creek. 2 5/6

The following forms occur as molds in bed 3:

- Girtyella indianensis (Girty)
- Spirifer (species undescribed)
- Brachythiris altomensis Weller
- Myalina sp.
- Myalina sp.
- Myalina sp.
- Aviculopecten sp.
- Aviculopecten sp.
- Aviculopecten sp.
- Modiomorpha sp.
- Conocardium sp.
- Bellerophon sp.

Another excellent exposure of the St. Louis occurs two hundred yards east of the above mentioned bend in Mumm creek (fig. 10). The description of this exposure follows:

Section two hundred yards east of preceding one.

### Upper St. Louis

- 6. Limestone, gray, dense, compact, unevenly stratified; exposed. 7 1/4
- 5. Limestone, gray, compact. 5 2/3
- 4. Limestone, compact, gray, with small white kaolinic patches; in thin layers separated by laminated calcareous shale, which weathers yellowish. 2
- 3. Limestone, gray, compact, with seams of gray granular lime-
MISSISSIPPIAN STRATA OF IOWA

stone; locally oolitic in part; disturbed and structureless at one point, but passing laterally into evenly bedded limestone .......................... 12

2. Limestone, gray, compact, conglomeric, rudely stratified; lower portion with calcareous matrix; upper portion with shaly matrix; imperfectly dolomitized locally. At one point a tongue-like mass about fifteen feet wide appears in the lower part. This is filled with angular blocks of limestone many of which differ physically from those in the adjacent walls. They consist of compact light gray limestone, of light gray oolitic limestone, and of bluish fine-grained shaly limestone. The matrix is shaly and the breccia has weathered back slightly, thus emphasizing the outline of the mass ........................................ 12

LOWER ST. LOUIS

1. Limestone, dolomitic, bluish gray when fresh but weathering brownish, massive; bearing a few rounded chert concretions; bedding very uneven and disturbed. At one point a distinct depression about six feet deep and six feet wide extends into this member and is filled with the conglomeratic limestone of the bed above. A few yards to the southeast two other such tongues appear. These are broader but less deep ......................... 2 to 10

Bed 5 of the above section yields the following species:

<table>
<thead>
<tr>
<th>Species</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Streptorhynchus ruginosum (Hall and Clarke)</td>
<td>Girtya indianaensis (Girty)</td>
</tr>
<tr>
<td>Orthotetes sp.</td>
<td>Sp. pellensis Weller</td>
</tr>
<tr>
<td>Productus ovatus Hall</td>
<td>Composita trinuclea (Hall)</td>
</tr>
<tr>
<td>Productus tenuicostatus Hall</td>
<td>Streblopria sp.</td>
</tr>
</tbody>
</table>

Good exposures of the upper St. Louis limestone may be seen along the east branch of Monk creek in the southeast quarter of section 36, T. 67 N., R. 7 W., one and one-fourth miles northeast of Belfast. The relation of conglomeratic mounds to the evenly-bedded facies is shown here on a small scale. Well up in the section a single large partly silicified corallum of Lithostrotion canadensis was found. Imperfect ripple marks were noted on the surface of a limestone layer a short distance farther up the branch. The mounds of limestone appear to be but little altered to dolomite, while the evenly bedded layers on the flanks are nearly everywhere uniformly altered.

One of the most complete and representative exposures of the St. Louis limestone in southeastern Iowa appears along the bed and banks of a small creek emptying into Des Moines river in the lower edge of the town of Croton (T. 67 N., R. 7 W.). The section described below begins up the creek nearly one mile from its mouth but the more important outcrops of the St. Louis are in section 20 near the town.

Section along a creek at Croton.

<table>
<thead>
<tr>
<th>Feet</th>
<th>Section along a creek at Croton.</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.</td>
<td>Limestone, gray, compact, lower part arenaceous .......................... 9</td>
</tr>
<tr>
<td>13.</td>
<td>Sandstone, fine-grained, yellowish .................................. 4½</td>
</tr>
</tbody>
</table>
ST. LOUIS STRATA AT CROTON

UPPER ST. LOUIS
12. Limestone, gray, granular, in some places slightly oolitic; middle part cross-bedded. At the very base there is locally a conglomeratic layer several inches thick. The lower part of the granular limestone passes laterally into gray compact, subcrystalline evenly bedded limestone which bears small pelecypods. The upper surface of this layer shows symmetrical wave ripples, which have a general north-south trend. They measure three to five and one-half inches from crest to crest and are one-half inch to one and one-half inches deep. This member forms a series of mounds of disturbed limestone at one point in the creek bed .................................10 to 13 1/2

11. Limestone, bluish, magnesian, thinly bedded; somewhat shaly; slightly fossiliferous; resting on uneven undulating surface of bed beneath ..................................................2

10. Limestone, conglomeratic, gradually less disturbed and more evenly bedded towards the top. More evenly bedded layers arching up over mounds of conglomeratic limestone which consists of pebbles and blocks of compact gray limestone; gray subcrystalline, brittle limestone; light gray slightly oolitic limestone and a few small blocks of fine-grained sandstone. The matrix is for the most part calcareous but locally it is sandy. Some blocks show stylolyphic structure. Some of the matrix is of a lighter gray color than the blocks. Occasional blocks bear worm castings and some have irregular patches of kaolin. Locally clayey in upper part. The more evenly bedded material towards the top consists of dense, compact gray limestone, and of gray subcrystalline limestone. This part is slightly fossiliferous ..................................................13

LOWER ST. LOUIS
9. Limestone, massive, compact, dolomitic, gray when fresh but weathering yellowish. Locally bearing remnants of compact unaltered gray limestone. The Lithostrotion canadensis zone 0 to 2

8. Limestone, dolomitic, buff, massive, tough; flaking off obliquely. Basal part fossiliferous ..................................................4 1/4 to 5

7. Limestone, grayish weathering buff, dolomitic; locally passing wholly or in part into dark gray conglomeratic limestone ..............1 1/3 to 12/3

6. Limestone, bluish, dolomitic, weathers soft and buff, filled with structures resembling worm castings ..................................................3 to 4

5. Limestone, brownish, dolomitic, tough; with discontinuous seams of unaltered limestone in upper part .................................2 3/3 to 1

4. Limestone, drab, subcrystalline, rather compact, brittle; bearing small, irregular patches of kaolin and numerous small chert concretions with nuclei of greenish clay. Somewhat fossiliferous. Lithostrotion proliferus and Springaporidae sp. most common fossils. Differing in thickness on account of hummocky and irregular surface of the bed beneath. This bed arches up over the mounds below, and fills some of the depressions, thus levelling up the irregular surface. Contains worm castings. Locally passes laterally into dolomitic limestone ..................................................2 3/3 to 3

3. Limestone, disturbed, conglomeratic; consisting of blocks, pebbles and subangular bowlders of compact gray limestone; gray subcrystalline limestone; brownish dolomitic limestone and rather soft buffish, impure limestone, in a calcareous to shaly matrix. Locally evenly bedded layers appear for a few yards, but these abut abruptly against conglomeratic limestone on either side. In one mound the matrix is sandy. In places the conglomeratic limestone assumes the form of mounds and hummocks, with the evenly bedded limestone above lapping up over the elevations and filling in the depressions. Locally the conglomeratic limestone is imperfectly dolomitized and discolored yellowish. The calcareous matrix seems to be the first to be affected. Occasional blocks in the
conglomerate are slightly fossiliferous. Blocks show stylolytic structure. Exposed ........................................ 12 to 13

2. Limestone, compact, dense, gray; dolomitic in basal part. Upper part with thin wavy concretionary stratification, the wavy layers of which conform to the irregular surface of the limestone below .................................................. 1 to 1 2/3

WARSAW

1. Shale, bluish, argillaceous; exposed ........................................ 5 5/6

The Spergen formation apparently was removed by erosion prior to the deposition of the St. Louis. Fossils collected from beds 3, 4, 10 and 11 were identified as follows:

List of fossils from bed 3 of the St. Louis at Croton.

Syringopora sp.
Eumetria verneuiliana (Hall)
Modiomorpha ? sp.
Leperditia carbonaria Hall

List of fossils from bed 4 of the St. Louis at Croton.

Zaphrentis sp.
Lithostrotion proliferum Hall
Syringopora sp.
Fenestella serratula Ulrich
Fenestella sp.
Cystodictya sp.

List of fossils from bed 10 of the St. Louis at Croton.

Lithostrotion proliferum Hall
Spirifer cf. S. pellaensis Weller
Straparollus sp.

List of fossils from bed 11 of the St. Louis at Croton.

Productus ovatus Hall
Spirifer cf. S. pellaensis Weller

The conglomeratic mounds in beds 3 and 10, representing the basal parts of the Lower and Upper St. Louis, respectively, are believed to be due to disturbed conditions during deposition, although later fracturing undoubtedly has modified the original relationship somewhat.

A section of the St. Louis limestone in the bluff of Des Moines river a little more than one mile below Croton, in section 29 of the same township, shows some variations from the one at Croton. The succession is as follows:

Section one mile below Croton.

DES MOINES

13. Sandstone, yellowish, soft, capping the hill ......................... 1 to 2

PELLA

12. Concealed. Loose blocks of limestone on the slope of the con-
One hundred and forty yards below the above described section, twenty feet of massive soft sandstone, whitish when fresh but weathering yellowish, rests directly upon bed 6 of the preceding section. This sandstone doubtless is of Pennsylvanian age, although no plant remains were found in it. Massive beds of sandstone here bend up over a thick dome of the same material to give the appearance of a massive arch.

Van Buren County.—Exposures of the St. Louis limestone in Van Buren county are confined to the valley of Des Moines river and its tributaries. Along Indian creek west of Farmington it outcrops at a number of points. Beginning three and one-half miles west of Farmington, a series of sections were studied along the banks of the creek, continuing almost to its mouth.

Below the Van Aucken quarry in the northwest one-fourth of
the northeast quarter of section 5, T. 67 N., R. 8 W. there is a
good exposure of the Upper St. Louis.

Section of Upper St. Louis limestone in and near Van Auken quarry.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Limestone, gray, granular to compact, locally cross-bedded in part; a layer 1 foot 6 inches thick near top consists of dense compact gray limestone. Rolled calcareous algae on surface of bed. The lower 4 feet consists of compact gray limestone.</td>
</tr>
<tr>
<td>2.</td>
<td>Limestone, gray, compact; weathering to light gray layers 2 to 10 inches in thickness; with shaly partings in upper part. No fossils noted.</td>
</tr>
<tr>
<td>3.</td>
<td>Limestone, gray, compact; consisting of a single layer showing thin irregular stratification, the irregular surface of the individual lamelae being imparted to the layers immediately above. Bears a few small pelecypods.</td>
</tr>
<tr>
<td>4.</td>
<td>Limestone, gray, compact, weathering to a lighter gray, cleaving easily into thin layers; bearing seams of fissile shale towards the top.</td>
</tr>
<tr>
<td>5.</td>
<td>Shale, fissile, rather bluish when fresh, weathering drab; upper part more calcareous and passing into an impure fissile limestone. No fossils noted.</td>
</tr>
<tr>
<td>6.</td>
<td>Limestone, dark gray, subcrystalline and compact; rather brittle when fresh but becoming tough when weathered; locally filled with small sinuous tubular branching fucoids which resemble worm castings; bearing large calcareous algae some of which have a maximum diameter of over 5 inches. Upper surface bearing a few large vertically compressed sinuous pipes which represent large fucoids. Separated from the bed above by a shaly parting 1 inch thick.</td>
</tr>
<tr>
<td>7.</td>
<td>Limestone, gray, subcrystalline and compact; in rather heavy ledges; cherty in upper part; upper surface undulating and irregular. Overlain disconformably by basal sandstone of the Pella. Contains numerous shells of a large Bellerophon 2½ to 4½.</td>
</tr>
</tbody>
</table>

In the northwest quarter of section 4 of the same township a small reef appears in the Upper St. Louis limestone. This is shown in a small quarry opening in the east bank of Indian creek a short distance south of the Chicago, Burlington and Quincy railway bridge. The reef is fifteen feet wide and six and one-half feet high. The lower three feet of the reef consists of subangular blocks of granular limestone in a calcareous matrix. The upper three feet consists of angular and subangular blocks of granular to oolith limestone and of compact gray limestone filled with a branching bryozoan. The matrix of the upper part is in some places a conglomeratic limestone consisting of small limestone pebbles in a calcareous matrix and in others a gray limestone with the same species of branching bryozoan as above. On the flanks of this reef-like structure is granular cross-bedded limestone. The layers of this abut abruptly into the reef and were not found to contain the bry-
ozoan so common in the reef. No beds are exposed above the reef with the exception of one thin layer which extends part way over it on the north side.

Associated with the bryozoan in the reef are occasional specimens of a small Conularia. Some of the blocks of granular oolitic limestone in the upper part of the reef contain calcareous algae. These were not noted in the adjacent evenly bedded limestone. This reef structure doubtless is original in large part. Some of the disturbance, however, may be due to later mashing.

There is a good exposure of the Upper St. Louis and the topmost members of the Lower St. Louis on the White farm in the southeast quarter of section 33, T. 68 N., R. 8 W. This appears in the north bank of Indian creek two hundred and twenty-five yards above an abrupt bend of the creek to the north, and two and one-half miles west of Farmington.

Section of St. Louis limestone on Indian creek.

<table>
<thead>
<tr>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Drift, yellowish, sandy.</td>
</tr>
<tr>
<td>UPPER St. Louis</td>
</tr>
<tr>
<td>6. Limestone, dark gray, granular, with occasional thin layers of compact gray limestone</td>
</tr>
<tr>
<td>5. Limestone, dark gray, subcrystalline; with small rounded sand grains included; locally passing into brecciated limestone; in places thin-bedded and shaly. Rests on the undulating surface of the bed beneath and is separated from it by a shaly parting</td>
</tr>
<tr>
<td>4. Limestone, dark gray, brecciated, consisting of angular and subangular pebbles and blocks of compact gray limestone, and gray subcrystalline limestone in a calcareous matrix. Upper part less disturbed and more evenly stratified. In some places filled with fusoid-like markings resembling worm castings. Irregular lenses of buff dolomitic limestone were noted at two points in this bed and at one place a rounded boulder of dolomite 8 inches in diameter occurs. This bed rests on the very irregular surface of the bed below as a result of uneven dolomitization. The pseudo-disconformity at the base of this bed is very striking (fig. 11)</td>
</tr>
<tr>
<td>3. Limestone, drab, dolomitic, conglomeratic, matrix constituting a large part of rock. Pebbles rounded and subangular. A few flinty masses occur. Lower part more massive and seeming to grade downward into the bed beneath. Upper part showing no stratification and flaking off obliquely to surface. The upper surface is very irregular and undulating. A few blocks with worm burrows were noted in the upper part. At one point two irregular lenses of unaltered compact gray limestone appear in this bed 2 feet and 3 feet 6 inches respectively below the top</td>
</tr>
<tr>
<td>LOWER St. Louis</td>
</tr>
<tr>
<td>2. Limestone, dolomitic, bluish gray when fresh but weathering brownish; bearing silicified corolla of Lithostrotion canadensis.</td>
</tr>
</tbody>
</table>
Imperfectly preserved ripple marks on upper surface trend N 60° E. These measure 3 to 4 inches from crest to crest and ¼ to ½ inch in height. They are so poorly preserved that it cannot be determined whether they are symmetrical or not.

1. Limestone, bluish gray when fresh but weathering brownish, dolomitic, the topmost part of the fossiliferous bed. Exposed in bed of creek

A very instructive exposure appears in the east bank at the point where the creek bends abruptly to the north, two hundred and twenty-five yards below the preceding section. Both members of the St. Louis are considerably disturbed here, owing to shearing, mashing and overthrust faulting on a small scale. The Upper St. Louis attains a thickness of eleven and one-half feet and is gray, brecciated and nondolomitic. The Lower St. Louis has an exposed thickness of fourteen and one-half feet and is brownish and dolomitic.

The reverse faulting is best developed in a massive member four feet thick at the top of the Lower St. Louis. The overlying and underlying softer limestones appear to have accommodated themselves to the compressive stresses chiefly by mashing. In the largest fault the massive limestone on the north side of the break appears to have been raised almost vertically about four feet, then as a result of compression the upthrown
side was made to overlap the downthrown side about ten feet while the softer beds above and below yielded by mashing. The strike of the fault is approximately N. 80° E. Several other small faults and shear zones with nearly vertical displacement appear in the bluff nearby.

Other interesting exposures of the Lower St. Louis in contact with the Upper St. Louis are shown a short distance farther down the creek in the southeast one-fourth of the southeast quarter of section 33 where the valley bends again to the eastward. The Lower St. Louis is for the most part evenly bedded and undisturbed, but at one point a large lenslike mass of brownish structureless limestone is enclosed within a blue magnesian limestone bed, which at this point thickens greatly. The limestone of the lens seems to grade into the blue magnesian limestone on the flanks. The lens has a maximum thickness of five feet and is thirty feet wide. It is believed to have been formed during the deposition of the formation.

A bluff section in the south bank of Indian creek just below the bridge of the Chicago, Burlington and Quincy Railroad, in the northeast quarter of section 3, T. 67 N., R. 8 W., shows the Des Moines sandstone in contact with the St. Louis.

Section on Indian creek in section 3.

Drift.

**DES MOINES**
Sandstone, grayish, carbonaceous; bearing many plant remains; imperfectly stratified; locally passing in part into carbonaceous shale. Exposed ................................................. 7
Sandstone, gray, carbonaceous, soft; resting on the oxidized and decomposed surface of the bed beneath; receding slightly beneath the bed above. Imperfectly stratified .................... 2

**LOWER ST. LOUIS**
Limestone, disturbed; layers undulating. Stratification obliterated in some places by brecciation. Some layers dolomitic and buff. Other layers and blocks which are interstratified and mingled with the dolomitic limestone consist of compact gray limestone. Dolomitization appears to have been very imperfect. The lower 1 to 3 feet is shaly, and grades downward into the bed beneath. Locally very much discolored by iron stains, and decomposed in places, especially in upper part, due to reaction with sulphate solutions from the bed above.

At points where the limestone is decomposed and iron-stained it bears small crystals of gypsum, probably formed by the reaction of limestone with iron sulphate solutions from the sandstones above.
Shale, bluish, calcareous, weathering into irregular chips; grading gradually upwards into the beds above and resting on the undulating surface of the bed beneath ................................................. 1 1/3 to 4
Limestone, dense, bluish gray, dolomitic, showing faint stratification .................................................................................................................. 2
Limestone, bluish, arenaceous and dolomitic, tough, porous; fossils poorly preserved; concealed at this point, but with an exposed thickness of 7 feet beneath the east end of the railroad bridge near by.

An exposure on the north bank of the creek just north of the railway, two hundred yards below the preceding section, again shows the Des Moines sandstone and Lower St. Louis in contact. The Des Moines is represented by thirteen feet of light gray medium to coarse-grained sandstone locally discolored yellowish or reddish. It is massive below but thin-bedded above. A slight development of basal conglomerate appears at the base, where pebbles of chert were observed. Locally at the contact there are thin films and small crystals of gypsum.

The Lower St. Louis has an exposed thickness of fifteen feet. It is greatly disturbed and imperfectly dolomitized. At several places in the bluff limestone blocks of certain horizons were found sheared down several feet into lower layers with a different physical character. The dip of some of the deformed layers is as great as thirty-five degrees. At several points pockets of Des Moines sandstone were found in the limestone several feet below the contact. These evidently represent the fillings of solution cavities formed prior to Des Moines sedimentation. That the disturbance of the St. Louis limestone took place prior to Des Moines time is indicated by the lack of deformation in the sandstone of this age.

In another exposure in the south bank of the creek, two hundred and fifty yards downstream, the basal Des Moines sandstone, which is here five and one-half feet thick, rests directly upon the Spergen formation. However, farther along the bluff to the east the lowermost beds of the St. Louis appear between the other formations.

The exposures of St. Louis limestone along Reed creek in Bonaparte township are very important in that they illustrate some of the remarkable lateral variations in the formation due to the variable conditions of deposition and to differences in the degree of deformation.

Near the middle of the north line of section 14, T. 68 N., R. 8 W., a bluff on the south side of the creek is seventy-five feet high and about two hundred yards long. In this bluff are exposed complete sections of the Pella and St. Louis formations. The Lower St. Louis is much more brecciated and mashed than
the overlying beds (figs. 12 and 13). It is probable that the presence of a shaly bed in the lower part of this member is largely responsible for this relationship since the limestone layers above appear to have been mashed and sheared down into this less resistant bed. However, deformation and mashing
have gone on locally in the Upper St. Louis and Pella. In these beds the disturbance tends to follow shear zones.

The Pella limestone, with a maximum thickness of twenty-one and one-half feet, caps the bluff. Below this comes fourteen feet of basal Pella sandstone with intercalated beds of shale and limestone and under it lies the St. Louis. The section of the Pella at this locality is described in a later chapter of this report (p. 291). The Pella limestone forms a sharp cliff while the underlying basal Pella sandstone and the conglomeratic Upper St. Louis below weather to a more gentle slope which terminates below in a sharp escarpment produced by the erosion of the more resistant Lower St. Louis limestone.

Near the middle of the bluff the following members appear in the St. Louis:

<table>
<thead>
<tr>
<th></th>
<th>Section on Reed creek.</th>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UPPER ST. LOUIS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Limestone, buff, dolomitic, with small scattered sand grains</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>3. Limestone, buff, dolomitic, massive</td>
<td>2¾</td>
<td></td>
</tr>
<tr>
<td>2. Limestone, compact; originally gray, but now altered to buff dolomite with irregular remnants of limestone. Slightly disturbed but not conglomeratic</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td><strong>LOWER ST. LOUIS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Limestone, brownish, dolomitic, mashed and deformed, shaly in lower part</td>
<td>28</td>
<td></td>
</tr>
</tbody>
</table>

Several remarkable shear zones appear near the east end of the bluff. The Pella limestone is considerably less disturbed along these zones than are the underlying strata. Along the most pronounced line of movement blocks of Pella limestone are sheared downward for at least ten feet into the soft shales and sandstones below. This tongue-like extension of mashed limestone weathers in relief, thus forming a prominent feature in the face of the bluff. On the east side of the tongue the sandstone is but little disturbed but on the west side the layers are bent down as much as three feet. At points where all members of the Lower St. Louis are involved in the crushing the shaly bed in the lower part is locally greatly reduced in thickness and numerous tongues of mashed limestone extend down through it. At several points angular blocks of limestone several feet in length are kneaded far down into the shaly material below. Some of these shale-enclosed blocks and broken layers are highly tilted.

About 200 yards farther up the creek a second bluff section
appears on the opposite bank. The succession of strata here is essentially the same as in the preceding section except that the basal Pella sandstone is much thicker and the lowermost bed of the Lower St. Louis is not exposed. At the south end of the bluff this member attains a maximum exposed thickness of twenty-nine feet. A few pockets of bluish shale were noted in the basal part.

The Lower St. Louis is greatly disturbed here on account of faulting, crushing and shearing. Shear zones and small overthrust faults appear at several points in the bluff. Most of these have a steep dip and the displacement is slight, the maximum being not more than five feet. Their strike is approximately N. 55° W. and the upthrow side is on the north. (See fig. 14.)

The following section was measured in this bluff:

<table>
<thead>
<tr>
<th>Section on Reed creek two hundred yards above preceding one.</th>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>PELLA</td>
<td></td>
</tr>
<tr>
<td>6. Limestone, gray, fine-grained</td>
<td>18</td>
</tr>
<tr>
<td>5. Shale</td>
<td>3½</td>
</tr>
<tr>
<td>4. Sandstone, fine-grained, soft, bluish, massive below but thin-bedded and shaly above; lower part containing pebbles of limestone and chert. Resting on the uneven surface of the bed below</td>
<td>24 to 35</td>
</tr>
<tr>
<td>UPPER ST. LOUIS</td>
<td></td>
</tr>
<tr>
<td>3. Limestone, consisting typically of angular to rounded blocks</td>
<td></td>
</tr>
</tbody>
</table>
of gray to buff dolomitic limestone in a gray impure sandy matrix. The limestone bears small patches of kaolin and small nodules of chert. Many of the blocks contain sinuous tubes resembling worm burrows. Occasional specimens of *Lithostroton proliferum* were noted.

**LOWER ST. LOUIS**

2. Limestone, massive, brownish, dolomitic

1. Limestone, brownish, dolomitic; much disturbed and mashed

The Lower St. Louis appears in its normal development in a cut along the Chicago, Rock Island and Pacific railway in the western part of section 23, T. 68 N., R. 7 W., a short distance below the mouth of Slaughters branch. A considerable thickness of sandstone appears in the slope above. The lower portion of this sandstone is believed to represent the Upper St. Louis while the upper portion probably belongs to the base of the Pella. The section follows:

*Section below the mouth of Slaughters branch.*

Pella

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.</td>
<td>Limestone, gray, brecciated; capping brow of hill</td>
</tr>
<tr>
<td>4.</td>
<td>Concealed</td>
</tr>
<tr>
<td>3.</td>
<td>Sandstone, light gray, thin-bedded</td>
</tr>
</tbody>
</table>

**UPPER ST. LOUIS**

2. Sandstone, soft, yellowish, bearing occasional rounded and subangular blocks of compact gray dolomitic limestone

**LOWER ST. LOUIS**

1. Limestone, brownish, disturbed, imperfectly dolomitized

The St. Louis is again exposed on Slaughters branch in the northwest quarter of section 23, about one-fourth mile above the point where the railway crosses the creek. Approximately twenty feet of Pella limestone and sandstone caps the section while the Spergen and Warsaw beds appear below the St. Louis.

*Section on Slaughters branch.*

Pella

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.</td>
<td>Limestone capping brow of hill</td>
</tr>
<tr>
<td>10.</td>
<td>Concealed</td>
</tr>
<tr>
<td>9.</td>
<td>Limestone, compact, gray, somewhat speckled; passing wholly or in part into sandstone</td>
</tr>
<tr>
<td>8.</td>
<td>Limestone, dense, compact, gray, showing fine lamination</td>
</tr>
<tr>
<td>7.</td>
<td>Sandstone, light gray, fine-grained, bearing angular chert fragments. Lower part grading in part into compact gray lime- stone; locally shaly</td>
</tr>
</tbody>
</table>

**UPPER ST. LOUIS**

6. Limestone, gray, granular to compact; upper part showing fine laminations on weathered surfaces

5. Concealed, slope covered by yellowish shales

4. Limestone, lower portion compact, gray and disturbed; upper portion more evenly bedded and consisting of massive buff imperfectly dolomitized limestone

**LOWER ST. LOUIS**

3. Limestone, brownish, dolomitic, with bluish shale bed three feet thick in basal part
A disturbed phase of the lower beds of the Lower St. Louis member appears along Potters branch, one and one-fourth miles northeast of Bonaparte, in the NW. 1/4 sec. 10, T. 68 N., R. 8 W. At several points the upper limestone layers appear to have been forced down into the lower shaly beds. Locally small mounds of limestone are exposed. The limestone was much fractured during at least two periods of disturbance and the fracture lines are sealed with veinlets of calcite. In several instances bands of limestone immediately adjacent to the fractures of earlier age are gray and unaltered although the rock elsewhere is brownish and dolomitic. It appears that the first disturbance here took place prior to dolomitization and that the limestone adjacent to the fractures was less susceptible to alteration, owing to its more crystalline condition or some other cause, than the surrounding rock. The fractures of later age in many instances cut across the earlier ones and their associated limestone bands, which are in such cases usually slightly displaced. The limestone is uniformly dolomitized adjacent to these younger breaks, a relationship which suggests that they were formed subsequent to dolomitization. The first period of fracturing is believed to have occurred at the close of Croton time, while the second probably occurred at the close of the Pella.

A short distance farther up the creek the following bluff section is shown in the south bank.

**Section in Potters branch.**

<table>
<thead>
<tr>
<th>PELLA</th>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>8. Sandstone, soft, yellowish, incoherent. Exposed</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>UPPER ST. LOUIS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Limestone massive, gray, subcrystalline, stylolytic, badly fractured; shaly parting at contact with bed below</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>6. Limestone, buff, magnesian, soft, grades into bed beneath</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>LOWER ST. LOUIS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Limestone, buff, magnesian; in one massive ledge</td>
<td>2 to 3</td>
<td></td>
</tr>
<tr>
<td>4. Limestone, buff, magnesian, brittle; tending to flake off obliquely</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>3. Limestone, buff, magnesian; in one heavy ledge; bearing small chert nodules</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>2. Limestone, dense, dark gray; blotched with patches of lighter gray magnesian limestone; bears irregular seams and nodules of chert</td>
<td>4 to 6</td>
<td></td>
</tr>
<tr>
<td>1. Limestone, buff, magnesian, in rather thin layers. Exposed to bed of creek</td>
<td>2</td>
<td>6</td>
</tr>
</tbody>
</table>
The following species were collected from bed 7 of the above section:

- Lithostrotion proliferum Hall
- Syringopora sp.
- Productus ovatus Hall
- Girtyiella indianaensis (Girty)
- Spirifer sp.
- Eumetria verneuiliana Hall
- Straparollus sp.
- Bellerophon sp.

There is an excellent exposure of the undisturbed facies of the Lower St. Louis limestone in an abandoned quarry at the mouth of Rock creek in the northwest quarter of section 21, Washington township, and in the Des Moines river bluff a short distance above. This phase is followed above by disturbed Upper St. Louis limestone which in turn is overlain by the Pella formation. The section follows:

### Section at the mouth of Rock creek.

<table>
<thead>
<tr>
<th>PELLA</th>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>12. Limestone, gray, fine-grained</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>11. Sandstone, fine-grained, massive, more calcareous and approaching brecciated limestone locally in upper part</td>
<td>11</td>
<td>8</td>
</tr>
</tbody>
</table>

### Upper St. Louis

- 10. Limestone, gray, compact, fine-grained, brecciated........5 to 8
- 9. Sandstone, soft, fine-grained, bluish, locally with pebbles of limestone in lower part. Lower six inches in some places consists of arenaceous limestone.................. 2
- 8. Limestone, buff, dolomitic; brecciated...................... 8 to 12

### Lower St. Louis

- 7. Limestone, buff, dolomitic, the *Lithostrotion* camadensis zone 0 to 1½
- 6. Limestone, buff, dolomitic, in two massive ledges, with fucoid markings resembling worm burrows in two thin zones .......... 7
- 5. Limestone, compact, gray, with shaly seams .................. 2
- 4. Limestone, compact, bluish, dolomitic, weathering yellowish .... 4
- 3. Limestone, buff, dolomitic, tough .................................. 2
- 2. Limestone, dense, with slight bluish tint, checking into irregular blocks ............................................. 2
- 1. Sandstone, fine-grained, bluish, calcareous; receding. Exposed 3

An even more typical exposure of the undisturbed Lower St. Louis limestone appears in the bank of Rock creek approximately one-third of a mile north of the quarry just described (fig. 15).

### Section in the bank of Rock creek.

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>12. Drift to brow of hill ........................................................................ 12</td>
<td></td>
</tr>
<tr>
<td>11. Limestone, gray, compact, dense, brecciated .................................. 3</td>
<td></td>
</tr>
</tbody>
</table>

### Upper St. Louis

- 10. Limestone, buff, dolomitic, tough, massive, overhanging, upper surface irregular ................................................. 1 to 2½
- 9. Limestone, buff, dolomitic; tough ............................................. 1 6
- 8. Limestone, buff, dolomitic; brittle, flaking off parallel to the face of the bluff; bearing small chert nodules in upper part.... 7
- 7. Limestone, soft, bluish, dolomitic, fucoid markings in middle part ................................................................. 3 3
A bed of sandstone is exposed in the south bank of Des Moines river approximately two and one-half miles below the town of Keosauqua. This has been referred to by C. H. Gordon\textsuperscript{15} as the Keosauqua sandstone, which he regarded as a phasal development of the limestone designated in this report as the Verdi or Upper St. Louis.

The present study makes the reference of these beds in part to the basal Pella and in part to the upper portion of the Verdi appear more plausible. In the above mentioned bluff we have three to four feet of brecciated Pella limestone which is underlain by five to twenty-one and one-half feet of fine-grained massive yellowish sandstone. This in turn is followed below by rudely stratified conglomeratic limestone with a bluish sandy

\textsuperscript{15} Jour. Geol. vol. III, p. 304; 1895.
matrix. Locally this limestone is represented by sandstone containing blocks and pebbles of limestone. This bed ranges to more than fourteen feet in thickness. At the base is a brownish conglomeratic limestone ten feet thick which is believed to represent the basal beds of the Verdi. The massive sandstone of variable thickness below the Pella limestone is referred to the basal Pella while the underlying sandy conglomeratic limestone very probably belongs to the Upper St. Louis.

The Upper St. Louis is exposed on the west fork of Thatcher creek, about one hundred and fifty yards above its junction with the east fork near the middle of the west line of section 1, T. 68 N., R. 10 W. The formation at this locality contains a bed of sandstone.

Section on Thatcher creek.

PELLA

4. Sandstone, soft, light gray when fresh but weathering yellowish; fine-grained, massive. Locally structureless but elsewhere exhibiting cross-bedding. Slightly overhanging. Exposed .................................................. 10 to 12

UPPER ST. LOUIS

3. Limestone, compact, gray, rather brittle; in heavy layers when fresh but weathering to thin layers and flakes. Bears Leperditia sp. and shells of a small pelecypod. Apparently lenticular ................................................................. 2 to 4

2. Sandstone, fine-grained, soft, bluish, calcareous. Thinnest where limestone above is thickest and vice versa ............... 1 to 4

1. Limestone, light gray, soft, massive, structureless, flakes parallel to face of bluff; with occasional stylolitic seams and a few patches of greenish material. Exposed ..................... 6

At the north end of this bluff section all of the above beds are involved in a disturbance which was accompanied by considerable shearing and brecciation. The movement appears to have been due to compression which caused the converging of two blocks over a wedge-shaped mass. A tongue of mashed and brecciated Pella limestone about twenty-five feet broad is sheared down into the disturbed area although this member has been removed by erosion elsewhere in the bluff.

There is a second exposure of the same strata on the east fork of Thatcher creek just below the wagon bridge and a short distance above the junction with the west fork. Beds 1 and 2 of the preceding section are represented here by a continuous bed of sandstone with an exposed thickness of twelve and one-half feet.

At the Price quarry on Price creek in the southwest quarter...
of section 20, T. 69 N., R. 10 W., the Lower St. Louis shows evidence of its shallow water origin in the form of strongly developed cross-bedding and contemporaneous erosion phenomena.

*Section in the Price quarry.*

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Drift, yellowish, sandy, oxidized. Maximum thickness</td>
<td>10</td>
</tr>
<tr>
<td><strong>UPPER ST. LOUIS</strong></td>
<td></td>
</tr>
<tr>
<td>5. Limestone, buff, dolomitic, in rather thin layers</td>
<td>2</td>
</tr>
<tr>
<td>4. Limestone, buff, dolomitic, compact, disturbed, brecciated and conglomeratic. At one point this member bears at the top a bed of medium-grained gray sandstone one foot thick. Resting irregularly on bed below</td>
<td>5 8</td>
</tr>
<tr>
<td><strong>LOWER ST. LOUIS</strong></td>
<td></td>
</tr>
<tr>
<td>3. Limestone, compact, gray, tough, unaltered. Preserved as a small lens at one point only</td>
<td>0 to 10</td>
</tr>
<tr>
<td>2. Limestone, fossiliferous; in places cherty; imperfectly dolomitic. Represented at some points by compact gray limestone with molds of fossils and at others by dense bluish magnesian limestone weathering buff. Locally this bed appears to fill small channels in the bed below. One such channel is three feet deep and about twenty-four feet wide. This member is evenly bedded while the member below is cross-bedded</td>
<td>0 to 2½</td>
</tr>
<tr>
<td>1. Limestone, in the form of one massive ledge in quarry face, arenaceous, magnesian; filled with rather coarse sand grains; bluish when fresh but weathering buff, cross-bedded; locally exhibiting a tendency towards thin lamination</td>
<td>7</td>
</tr>
</tbody>
</table>

The cross-bedding in bed 1 is on a large scale. The heavy sloping massive layers are truncated by the bed above. A short distance down the creek, in the south bank, twelve feet of cross-bedded limestone is shown at the horizon of bed 1. It is overlain by drift. The upper two feet is fossiliferous and more thinly laminated. Below these inclined layers is a blue soft limestone with fucoid markings resembling worm castings. It has an exposed thickness of two feet.

In the quarry at the mouth of Price creek, in the eastern part of section 20, the Upper St. Louis is thicker than usual and is somewhat different lithologically from other exposures in this part of the state.

*Section in quarry at mouth of Price creek.*

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>8. Drift.</td>
<td></td>
</tr>
<tr>
<td><strong>PELLA</strong></td>
<td></td>
</tr>
<tr>
<td>7. Limestone, gray, fractured</td>
<td>6</td>
</tr>
<tr>
<td>6. Sandstone, soft, fine-grained; resting upon the irregular surface of the bed below</td>
<td>6 8</td>
</tr>
<tr>
<td><strong>UPPER ST. LOUIS</strong></td>
<td></td>
</tr>
<tr>
<td>5. Limestone, gray, rather soft, in two massive ledges, fractured, styloytic; with thin shaly seams near the middle which bear a few fossils such as <em>Syringopora</em> sp., <em>Orthotetes</em> sp., <em>Zaphrentis</em> sp.</td>
<td>11 9</td>
</tr>
</tbody>
</table>
4. Limestone, buff, magnesian, dense and massive above but softer and thin-bedded below ........................................... 3½ to 5
3. Limestone, consisting of interbedded layers of compact and granular gray limestone ......................................... 4 1/3 to 5 1/3
2. Limestone, brecciated, buff, magnesian; shaly in upper part; poorly exposed ........................................... 8

LOWER ST. LOUIS
1. Limestone, buff, magnesian, bluish when fresh; fucoidal markings in a zone about six inches below the top. Lower three feet arenaceous and cross-bedded. Upper part massive. To bed of creek ........................................................................ 8 6

The Upper St. Louis is exposed in the south bank of Chequest creek at the bend about one-half mile above its mouth (NE.1/4 of SW.1/4 sec. 27, T. 69 N., R. 10 W.). It is here represented in part by sandstone as in the Thatcher creek section.

**Section on Chequest creek.**

<table>
<thead>
<tr>
<th></th>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Beds ranging from the Lower St. Louis limestone to the Des Moines sandstone are exposed in the Kilbourne bluff, in the east bank of Lick creek near its mouth, in the southwest quarter of section 1, T. 69 N., R. 10 W. The section is as follows:

**Section in Kilbourne bluff.**

<table>
<thead>
<tr>
<th></th>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.</td>
<td></td>
</tr>
</tbody>
</table>
| DES MOINES
  6. Shale, drab in basal part and carbonaceous above ............... 28
| PELLA
  5. Slope, strewn with blocks of limestone ............................... 5
  4. Limestone, gray, resting on the uneven surface of the bed below ........................................... 3
| UPPER ST. LOUIS
  3. Limestone, granular to compact, thin-bedded, much fractured; contact with bed below irregular ........................................... 6 to 8½
  2. Limestone, dense, compact, gray, brecciated, no semblance of original structure preserved. Resting on the irregular surface of the bed beneath ........................................... 3½ to 8½
| LOWER ST. LOUIS
  1. Limestone, buff, magnesian, massive. Exposed ...................... 16 1/4
The upper surface of bed 2 is very irregular. Mounds of conglomerate limestone locally extend several feet up into bed 3. Inasmuch as bed 3 does not arch up over these mounds but tends to fill in the depressions between them and is not itself conglomeratic it is believed that the disturbed character of bed 2 is original.

A bed resembling closely bed 3 of the preceding section is exposed in the east bluff of Des Moines river one and one-half miles southeast of Kilbourne. This bed rests directly upon the Lower St. Louis. It is possible that bed 2 of the Kilbourne bluff section is absent here, but this cannot be proven definitely. See the following section:

Section southeast of Kilbourne.

<table>
<thead>
<tr>
<th></th>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pella</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Sandstone, fine-grained</td>
</tr>
<tr>
<td>3.</td>
<td>Concealed</td>
</tr>
<tr>
<td>Upper St. Louis</td>
<td></td>
</tr>
<tr>
<td>2. Limestone, gray, granular to compact. Lower portion consisting of thin-bedded, granular and compact limestone which is somewhat cross-bedded where it is undisturbed. Upper portion consisting of a breccia of compact gray limestone in a calcareous matrix. Maximum measured thickness</td>
<td>14 2/3</td>
</tr>
<tr>
<td>Lower St. Louis</td>
<td></td>
</tr>
<tr>
<td>1. Limestone, buff, magnesian. Exposed</td>
<td>20</td>
</tr>
</tbody>
</table>

Des Moines County.—In the report on the geology of Des Moines county Keyes\(^{16}\) describes the distribution and character of the St. Louis as follows:

"The chief exposures of this formation are in the extreme southwestern corner of the county where it underlies an area of perhaps thirty square miles. It covers most of the uplands of Augusta township and probably nearly one-half of Danville township. A small area also occurs in the western part of Union township. The outcrops are principally on Long and Cedar creeks and on the Skunk river."

The exposures are small and the formation is similar in development in all respects to that in the adjacent counties of Lee and Van Buren.

Henry County.—The St. Louis limestone constitutes the bed rock over a much larger area in Henry than in any other county in Iowa. In the extreme western and southern borders there are narrow, irregular strips of Des Moines sandstones with oc-

\(^{16}\) Iowa Geol. Survey, vol. III p. 447; 1895.
casional small adjacent outliers. Small outliers of this forma-
tion occur also in Center township near the middle of the county
and in the extreme southeastern part. The Keokuk limestone
and Lower Warsaw shale outcrop along Skunk river in the
south-central part of the county and along Mud creek, a tribu-
tary of this stream in the southwestern part. These are the
only important known exceptions to the universal extent of the
St. Louis as the surface rock of Henry county.

Nearly all of the important exposures of the formation are in
the southern part of the county, the more typical outcrops being
along Big Cedar, Little Cedar, Brush and Big creeks.

The most complete section observed by the writer in Henry
county occurs along Big creek in section 7 of Baltimore town-
ship. Both divisions of the St. Louis appear in a high bluff just
above the wagon bridge in the southwest quarter of this section.
The Croton member is very much mashed and brecciated and
is imperfectly dolomitized. It has a thickness of about thirty-
five feet. The lower part is shaly and at the base of the section
there are carbonaceous seams. At both the east and west ends of
the bluff there appears more evenly bedded and less disturbed
brownish dolomitic limestone, which abuts into the disturbed
phase. Near the east end of the bluff the Upper St. Louis is
exposed in the form of two beds of gray limestone. The lower
bed is three to four feet thick and consists of fine-grained, dense
much brecciated and partly dolomitized limestone. It has a
rough upper surface and rests on the irregular surface of a
soft brownish dolomitic limestone layer of Croton age contain-
ing silicified specimens of Lithostrotion canadensis. The upper
bed consists of granular to compact thin-bedded slightly frac-
tured limestone seven feet in thickness.

A few rods upstream from the above described bluff section
the following succession is shown near the mouth of a small
ravine:

<table>
<thead>
<tr>
<th>Section on Big creek.</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PELLA</strong></td>
<td></td>
</tr>
<tr>
<td>7. Concealed; slope to top of hill overspread with blocks of Pella limestone</td>
<td>3</td>
</tr>
<tr>
<td>6. Limestone, exposed</td>
<td>1/3</td>
</tr>
<tr>
<td>5. Concealed; upper part of slope strewn with blocks of Pella limestone; lower part with blocks of fine-grained sandstone</td>
<td>9½</td>
</tr>
<tr>
<td><strong>UPPER ST. LOUIS</strong></td>
<td></td>
</tr>
<tr>
<td>4. Limestone, granular to compact, no fossils noted</td>
<td>7½</td>
</tr>
</tbody>
</table>
3. Limestone, fine-grained, compact, gray to buff; imperfectly
dolomitized; little disturbed; contacts above and below poorly
shown .......................................................... 3

LOWER ST. LOUIS
2. Limestone, buff, massive, dolomitic, probably the \textit{Lithostrotion}
canadensis zone .............................................. 4
1. Limestone, buff, massive, dolomitic .......................... 5

A third important exposure is shown above the bend of the
creek near the center of section 7. The Lower St. Louis has an
exposed thickness of thirty-five feet at one point. The lower
part is mashed and deformed but the higher layers are only
slightly brecciated. The Upper St. Louis is twelve feet thick
and consists of two members very similar in character to those
in the above described bluff section farther down stream.

A good exposure of the St. Louis is present in a meander
scarp of Big creek, near the center of section 6 of Center town­
ship.

\textit{Section of St. Louis limestone on Big creek.}

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>8. Drift, yellowish brown clay containing gravel</td>
<td>2</td>
</tr>
</tbody>
</table>

UPPER ST. LOUIS
7. Limestone, compact, gray, slightly brecciated; massive below
but thin-bedded and nodular above; with rounded limestone
pebbles in upper part ........................................ 4 6
6. Sandstone, gray, fine-grained, soft .......................... 8
5. Limestone, light gray, granular, bearing \textit{Lithostrotion pro­}
\textit{liferum}, \textit{Composita trinuclea}, \textit{Spirifer} sp. and \textit{Girtyella indi­}
\textit{cans} .......................................................... 1 8
4. Limestone, buff, dolomitic, soft, rather thin-bedded; weather­
ing to thin irregular chips. A layer near the top is filled with
worm castings .................................................. 7 6

LOWER ST. LOUIS
3. Limestone, dolomitic, buff, in one massive ledge. The \textit{Litho­}
\textit{strotion canadensis} zone .................................. 3 6
2. Limestone, buff, dolomitic, in rather thin layers; resting on
the irregular hummocky surface of the bed beneath ........... 3
1. Limestone, gray, brecciated. The lower part is locally evenly
bedded, buff and dolomitic .................................... 15

The following beds of the St. Louis are exposed in the Win­
ter quarry, located near the railway bridge over a branch of
Big creek, in the southeast quarter of section 17, Center town­
ship:

\textit{Section of St. Louis limestone in the Winter quarry.}

<table>
<thead>
<tr>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. Drift .................................................. 4</td>
</tr>
</tbody>
</table>

UPPER ST. LOUIS
8. Limestone, soft, shaly; mostly concealed at present ........... 6
7. Limestone, fine-grained, compact, gray; breaking with sub­
conchoidal fracture; slightly brecciated ........................ 10
6. Sandstone, fine-grained, bluish, shaly ........................ 4 to 5
5. Limestone, fine-grained, dense, gray; in some places arenace-
MISSISSIPPIAN STRATA OF IOWA

4. Sandstone; in part fine-grained, gray, calcareous, massive; with irregular stratification lines; in part shaly and laminated; resting on the uneven, eroded surface of the bed below 1½ to 2½

3. Limestone, light gray, compact, fine-grained, dense; usually badly mashed and brecciated but in places little disturbed; with occasional reddish chert nodules; resting on the uneven surface of the bed beneath 3 to 3½

LOWER ST. LOUIS

2. Limestone, buff, dolomitic; weathering into rather thin irregular layers; with small irregular patches of unaltered gray limestone and an occasional nonsilicified specimen of Lithostrotion canadensis 2½

1. Limestone, buff, dolomitic, in rather thin layers; obscure worm tubes noted at one point in upper part; bearing occasional rounded chert nodules: containing Brachythyris altamensis, Ariolopcten sp. and other fossils. Exposed 5

Another excellent exposure of the Croton limestone is located approximately one mile east of the town of Lowell, in the west bluff of Mud creek, near the wagon bridge. This division is less disturbed at this locality than usual and consists of massive buff to brownish dolomitic limestone about thirty-five feet in thickness. It is underlain by shales of Lower Warsaw age.

The character of the St. Louis limestone in the northeastern part of Henry county is well brought out by the following description by Savage of a quarry exposure in Scott township.

"Twenty miles directly north of the Lowell exposure and separated from it by almost the length of the county, there is an interesting quarry in the Se.¼ of section 4, of Scott township, about one mile northeast of the town of Winfield. At this place an exposure just north of the road on land owned by Mr. G. W. Wilson shows the following succession of layers:

Section.

5. Clay of a reddish brown color containing gravel 5

4. Bed of fine-grained, fissile limestone, light gray in color, the layers one to three inches in thickness, and containing but few fossils 4

3. Bed of rather soft, fine-grained standstone 6½

2. Bed of bluish gray limestone, the layers three to eight inches in thickness near the top, but increasing to as much as twelve inches near the base. The layers are separated by shaly partings which contain numerous fossils 10

1. Yellowish brown magnesian limestone perforated with irregularly shaped cavities; to the base of the exposure 2

Number 1 in the above section is of a stronger yellow color than the magnesian limestone usually met with over the county. It is less compact and contains a greater number of cavities which resemble water worn passages. No traces of fossils were

found in the rocks of this member. Number 2 is a bed of gray limestone. The narrower layers are somewhat shaly and weather easily into thin fragments, but the thicker portions are compact and durable. The shaly bands are very fossiliferous and among them the following forms are abundant:

- **Zaphrentis spinulosa** E. and H.
- **Lithostrotion canadensis** var. proliferum Hall
- **Syringopora** sp. undet.
- **Archaeocidaris** sp. spines and plates
- **Fenestella** sp.
- **Dielasma formosa** † Hall
- **Spirifer keokuk** Hall
- **Elumetria marcyi** Shumard
- **Athyris subquadrata** † Hall

Beds 1 and 2 of the above section probably represent the Croton while the overlying beds are believed to be of Verdi age.

Another section of interest, located in the northwestern part of the county, two miles west of Wayland, also is described by Savage.18

### Section of St. Louis limestone west of Wayland (after Savage).

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.</td>
<td>Bed of brown sandstone, rather hard and coarsely granular</td>
</tr>
<tr>
<td>5.</td>
<td>Layer of white fine-grained nonfossiliferous limestone</td>
</tr>
<tr>
<td>4.</td>
<td>Soft fine-grained sandstone</td>
</tr>
<tr>
<td>3.</td>
<td>Layers of light colored limestone, eight to ten inches in thickness, containing no fossils</td>
</tr>
<tr>
<td>2.</td>
<td>Band of clay or marl containing very numerous casts of a fossil which somewhat resembles a species of <em>Athyris</em></td>
</tr>
<tr>
<td>1.</td>
<td>Layers of light gray nonfossiliferous limestone down to the level of the stream</td>
</tr>
</tbody>
</table>

**Jefferson County.**—The mantle rock is underlain over the greater part of Jefferson county by the Des Moines formation. The St. Louis as mapped by Udden,19 appears in the northeastern part of the county where it has been uncovered by Skunk river and its tributaries; over a small area in the extreme northwestern part of the county; as small inliers in the eastern, south-central, and southwestern parts; and as ribbon-like areas along Cedar creek and its tributaries in the southeastern part.

One of the most complete sections in the entire county may be studied in the Cedar Bluff of Skunk river just southeast of the mouth of Rattlesnake creek and one-fourth mile east of the southeast corner of section 12, Lockridge township. The St. Louis is underlain here by fine-grained, bluish sandstone of Spergen age with an exposed thickness of twenty-one feet.

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18 Idem, p. 276.
### MISSISSIPPIAN STRATA OF IOWA

**Section of St. Louis limestone on Skunk river.**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.</td>
<td>Drift</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>UPPER ST. LOUIS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.</td>
<td>Limestone, gray to light gray, less brittle and dense than the bed below, containing <em>Productus ovatus</em>, <em>Composita trinuclea</em>, <em>Allorisma sinuata</em></td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>12.</td>
<td>Sandstone, soft, fine-grained, bluish, incoherent</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>Sandstone, gray, calcareous, fine-grained, in a single layer</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Limestone, gray, compact, fine-grained, brittle, middle and upper parts with ribbon-like stratification</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>9.</td>
<td>Shaly parting</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Limestone, compact, dark gray, fine-grained; rather heavily bedded; slightly disturbed in upper part</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>7.</td>
<td>Limestone, compact, gray, nodular; in the form of rounded pellets, ranging from size of pea up to size of walnut, in a shaly matrix. Filled with <em>Composita trinuclea</em></td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Limestone, gray, compact, fine-grained, brittle; weathering into thin flakes; locally brecciated and mashed down into the bed below; with stylolytic seams. Lower contact poorly exposed but appears to be irregular where mashing has not taken place. <em>Spirifer cf. S. pellaensis</em> and <em>Composita trinuclea</em>.</td>
<td>5 to 6</td>
<td></td>
</tr>
<tr>
<td><strong>LOWER ST. LOUIS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Limestone, yellowish to brownish, dolomitic, much decayed; shale in lower and upper parts; of differing thickness due to mashing down of limestone above</td>
<td>4½ to 7½</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Limestone, brownish, tough, massive, dolomitic; with small fragments and nodules of chert; indistinctly stratified; contact with bed below is an irregular wavy line; slightly vesicular; in one massive layer</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>3.</td>
<td>Limestone, gray tough, dolomitic, hard; weathering buff and soft; in layers 2 to 18 inches thick; receding slightly beneath bed above. Upper surface irregular. Top layer thins and thins from above; shaly and arenaceous in lower part and grading down into the bed below</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>2.</td>
<td>Shale, bluish, argillaceous, with seams of light gray more calcareous shale</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Limestone, compact, buff, dolomitic; in a single layer. Probably the base of the Lower St. Louis</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

An excellent section of the Lower St. Louis occurs in an old quarry opening in the north bank of Turkey creek near the center of the northeast quarter of section 11, Lockridge township. It is here underlain by fifteen and one-half feet of Spergen sandstone.

**Section of Lower St. Louis limestone on Turkey creek.**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UPPER ST. LOUIS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>Slope, covered with loose blocks of gray nondolomitic limestone</td>
<td></td>
</tr>
<tr>
<td><strong>LOWER ST. LOUIS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Limestone, gray, dolomitic, weathering brownish, poorly exposed</td>
<td>3</td>
</tr>
<tr>
<td>7.</td>
<td>Limestone, gray weathering buff, soft, dolomitic, much rotten, structureless</td>
<td>4</td>
</tr>
<tr>
<td>6.</td>
<td>Limestone, dark gray weathering buff; tough; massive below but thin-bedded above; projecting</td>
<td>2½</td>
</tr>
<tr>
<td>5.</td>
<td>Shale, bluish, weathering buff; arenaceous and dolomitic above but calcareous below</td>
<td>4½</td>
</tr>
<tr>
<td>4.</td>
<td>Limestone, compact, dense, dove-colored, brittle; with fine</td>
<td>4 ½/6</td>
</tr>
</tbody>
</table>
The following section is exposed in a quarry and in the ravine nearby in the southwest one-fourth of the southeast quarter of section 3, Lockridge township.

Section of St. Louis limestone in section 3, Lockridge township.

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPPER ST. LOUIS</td>
<td></td>
</tr>
<tr>
<td>12. Sandstone, gray, calcareous</td>
<td>1</td>
</tr>
<tr>
<td>11. Sandstone, fine-grained, soft, shaly</td>
<td>3</td>
</tr>
<tr>
<td>10. Limestone, gray, compact</td>
<td>1 to 2½</td>
</tr>
<tr>
<td>9. Limestone, compact, gray, nodular; filled with a Composita</td>
<td>6</td>
</tr>
<tr>
<td>8. Limestone, gray, compact, brecciated</td>
<td>3 to 5½</td>
</tr>
<tr>
<td>7. Shale, bluish, calcareous; of variable thickness owing to mashing</td>
<td>1 to 3</td>
</tr>
<tr>
<td>6. Limestone, brownish, dolomitic, tough; with reddish, quartzose masses</td>
<td>6</td>
</tr>
</tbody>
</table>

| LOWER ST. LOUIS |
| 5. Limestone, gray, compact, containing Lithostrotion prolifera, Syringopora sp. and Composita trinuclea | 2 |
| 4. Limestone, gray, dolomitic, slightly vesicular, massive; worm burrows in 6 inch zone at top | 5 |
| 3. Shaly parting | 8 |
| 2. Limestone, gray weathering yellowish, dolomitic, tough, massive; irregularly bedded owing to mashing and deformation | 7 |
| 1. Shale, bluish, dolomitic, weathering buff. Exposed | 4 |

Other characteristic exposures appear in Round Prairie township. The accompanying section is exposed in the bluff at the south end of the bridge over Cedar creek, near the middle of the south line of section 33.

Section of St. Louis limestone on Cedar creek.

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPPER ST. LOUIS</td>
<td></td>
</tr>
<tr>
<td>10. Drift, to brow of hill</td>
<td>6</td>
</tr>
<tr>
<td>9. Limestone, gray, fine-grained, compact</td>
<td>1</td>
</tr>
<tr>
<td>8. Concealed</td>
<td>1</td>
</tr>
<tr>
<td>7. Sandstone, gray weathering buff; massive in middle but thin-bedded above and below</td>
<td>7</td>
</tr>
<tr>
<td>6. Shale, soft, buff, dolomitic</td>
<td>8</td>
</tr>
</tbody>
</table>

| LOWER ST. LOUIS |
| 5. Limestone, gray, fine-grained, compact, brittle, non-dolomitic; |
containing *Lithostrotion prolifera*, *Spirifer* sp., and other fossils ................................................................. 1 7 to 2

4. Limestone, gray, weathering buff, dolomitic, with occasional rounded chert nodules; rather soft above. Bears the following fossils: *Girtyella indiana*, *Spirifer* sp., *S. pella*, *Composita trimocula* and *Strepardo* sp. ................................................................. 4

3. Limestone, gray, dolomitic, weathering buff; in two heavy layers ................................................................. 2 8

2. Limestone, gray, arenaceous, thin-bedded; cross-bedded below; bearing *Lithostrotion prolifera* ................................................................. 4 2

1. Limestone, gray, subcrystalline, non-dolomitic. Exposed to level of water in creek ................................................................. 1 6

A good exposure of the St. Louis occurs in the north bank of Cedar creek a short distance east of the southwest corner of section 34 of the same township.

Section of St. Louis limestone on Cedar creek in section 34.

<table>
<thead>
<tr>
<th>Upper St. Louis</th>
<th>Feet</th>
<th>Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Limestone and sandstone interbedded, the sandstone predominating below and the limestone above. Sandstone soft, fine-grained and gray; limestone gray, compact, dense and slightly brecciated. At the top no sandstone appears and the limestone is filled with small sinuous tubes of calcite. Some of the limestone layers exhibit a tendency towards lamination ............................................. 23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Limestone, gray, fine-grained; filled with dark brecciated chert ................................................................. 1 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Sandstone, gray, calcareous, weathering yellowish, very irregularly bedded. Locally filled with small angular fragments of whitish chert ................................................................. 4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lower St. Louis</th>
<th>Feet</th>
<th>Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Limestone, light gray, fine-grained; weathering to irregular angular blocks. Bears <em>Lithostrotion canadensis</em> in calcareous form. This and the bed below are undulating and much disturbed ................................................................. 1 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Limestone, dark gray, dense, compact, tough, brecciated. Exposed to water level ................................................................. 4 6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

At the meander scarp of the large meander, a short distance east of this point, in the northeast quarter of the southwest quarter of section 34, the Pella limestone, with a basal sandstone three to four feet in thickness, rests upon bed 5 of the preceding section.

Numerous other outcrops of the St. Louis limestone in Jefferson county have been described by Udden\(^{20}\) but inasmuch as the general character of the formation is much the same as in the exposures described above further space will not be given to them here.

Wapello County.—The beds in Wapello county which were mapped and described as St. Louis by Leonard\(^{21}\) are believed

\(^{20}\) Iowa Geol. Survey, vol. XII, pp. 368-386; 1901.

to be everywhere of Pella age. They were so identified by him with the exception of a layer of soft sandstone, which was seen below the limestones at two localities, and which he referred to the Verdi. According to the observations of the writer this sandstone is more probably of basal Pella age and it is so regarded in this report.

Louisa County.—In the report on Louisa county submitted by Udden reference is made to only one locality where rocks believed to be of St. Louis age outcrop. I quote from his description:

"On the left bank of Honey creek in the Se.1/4 of the Sw.1/4 of Sec. 32, Tp. 73 N., R. 3 W., some twenty rods north of the boundary of the county, there is a limestone breccia of greenish gray color composed of fragments of varying sizes, interbedded in a calcareous matrix of the same color. Some of the limestone blocks contain fragments of crinoid stems and other unrecognizable fossils. There are also seen in them some small cavities filled with a bright green clay. The breccia is only three or four feet high in the bank and rests on an uneven surface of the lower formation, which is yellow and weathered. An unconformity is here indicated. The rock extends only a few rods along the stream. A little farther down some reddish shaly beds appear on the same side of the creek. These are apparently continuous with the geode-bearing horizon of the Augusta (Osage), exposed nearby. The limestone breccia on this creek is entirely unlike anything else seen in the county. Doctor Bain, who visited the locality in company with the author, inclines to the opinion that it represents the St. Louis stage. If such is the case there are possibly some more outliers of the same formation under the drift in the southwest part of the county, where the bed rock occurs in wells at a considerably higher level than that of the Burlington limestone in the nearest outcrops."

Washington County.—Beds of St. Louis age cover the southern part of the county with the exception of small areas in the southwestern part which are buried by the Des Moines formation.

The type section of the Verdi member is located in this county at an abandoned quarry one-half mile south of Verdi station, in the eastern part of section 9 of Brighton township. The succession of beds there is as follows:

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MISSISSIPPIAN STRATA OF IOWA

Section one-half mile south of Verdi.

6. Drift, reddish, with decayed granite boulders ........................................ 4½ to 11

DES MOINES

5. Sandstone, coarse-grained, yellowish, soft ........................................ 0 to 6½

VERDI

4. Limestone, compact, gray, finely brecciated ..................................... 1/3

3. Limestone, ash-gray, fine-grained, rather soft, brecciated; thin-bedded and laminated above; locally little disturbed and heavily bedded below. Filled with stylolitic structure along fractures. Small pelecypods and Leperditia abundant in laminated layer at very top ........................................ 9½

2. Sandstone, gray, fine-grained, soft, incoherent, shaly; thickens and thins owing to mashing down of limestone above .................. 1 to 2½

1. Sandstone, massive, fine-grained, gray, soft, weathering yellowish; with mashed irregular lentils of compact gray limestone. Exposed ........................................ 7

In an exposure two hundred yards north of the preceding section in the west bluff of a small creek which parallels the railroad the Lower St. Louis appears. It consists of twenty feet of sandstone, dolomitic and shaly below, with a large lentil of compact gray limestone, about five feet thick in the middle and fifty feet long, in the upper part. A thin seam of finely brecciated limestone near the top of the lens is filled with a small brachiopod resembling Girtyella. Below the dolomitic shales comes four feet of thin-bedded, laminated buff dolomitic limestone with thin light gray to whitish chert bands.

The following fossils were collected from bed 3 of the above described quarry section.

Orthotetes 1 sp.
Pustula alternata (N. and P.)
Girtyella indianaensis (Girty)
Spirifer cf. S. pellinensis Weller
Composita trinuclea (Hall)
Edmondia 1 sp.

Aviculopecten sp.
Aviculopecten sp.
Allorisma sinuata McChesney 1
Laevidentalium 1 sp.
Bellerophon sp.
Leperditia carbonaria Hall

The Lower St. Louis is exposed in the vicinity of Brighton mill, one mile slightly east of north of the town of Brighton, in the southwest quarter of section 20, Brighton township. The following section appears in the Skunk river bluff at the mill and in the banks of a small creek just south of the mill.

Section at and near Brighton mill.

7. Drift to brow of hill .................................................. 3

UPPER ST. LOUIS

6. Limestone, gray, compact, brecciated; not well exposed .................. 8

5. Sandstone, gray, fine-grained, massive, calcareous .......................... 5

4. Sandstone, yellowish, soft, incoherent; filled with small angular fragments of whitish chert ........................................ 2 to 3
ST. LOUIS BEDS, NEAR COPPOCK

LOWER ST. LOUIS
3. Concealed ................................................................. 3
2. Shale and limestone; thin layers of dark gray compact, dense limestone weathering buff, intercalated with layers of shale... 13/4
1. Shale, bluish, argillaceous, with thin sandy seams ............................. 14

In a quarry one-half mile south of the Brighton mill a bed believed to represent an upward continuation of number 6 of the preceding section is overlain unevenly by sandstone and shale, viz.:

Section one-half mile south of Brighton mill.

4. Drift ................................................................. 4
3. Shale, bluish, argillaceous ........................................................... 1
2. Sandstone, gray, fine-grained, thin-bedded, calcareous; weathering yellowish on surface; slightly cross-bedded; with thin seams and lenses of compact gray limestone in lower part. Resting on the uneven surface of the bed beneath ..................... 5
1. Limestone, gray, fine-grained, compact, dense, brittle; breaking with subconchoidal to splintery fracture; in heavy, massive layers. Lower part slightly brecciated locally; with occasional small nodules of chert. Leperditia zone at top 4 to 6 inches thick. Bed 6 of preceding section. Exposed ........................................ 5

The fossils listed below are from bed 1:

Zaphrentis sp.
Syringopora sp.
Orthotetes † sp.
Productus ovatus Hall †
Girtyella indianaensis (Girty)
Spirifer sp.

Composita trinuclea (Hall)
Allorisma sp.
Sphonotus sp.
Myalina † sp.
Straparollus sp.
Leperditia carbonaria Hall †

An exposure in a ravine one hundred yards south of the quarry section shows the shale bed, number 3, to be overlain by five and one-half feet of interbedded shales and limestones filled with characteristic Pella fossils. It is probable therefore that the sandstone bed, number 2, of the quarry section represents the basal member of the Pella formation. Bed 1 undoubtedly represents bed 3 of the Verdi section.

An exposure in an abandoned quarry along the Chicago, Burlington and Quincy railway one-half mile northeast of Coppock probably represents a shaly facies of the Lower St. Louis. No fossils were found.

Section northeast of Coppock.

3. Limestone, brownish, dolomitic, with shaly and sandy seams; much decayed and rotted, and with solution cavities ............... 8
2. Shale, dolomitic and arenaceous, buff, poorly exposed ............ 12
1. Sandstone, fine-grained, gray weathering yellowish. Exposed ....... 3

Bain23 has described other exposures of the St. Louis along

Crooked creek in the southeastern part of the county and on Skunk river between the Brighton mill and the west county line.

Keokuk County.—The St. Louis limestone underlies the greater part of Keokuk county. Osage formations appear in the northeastern part and as isolated inliers in the St. Louis in the southern half of the county. Areas of Pennsylvanian project into the county on the west and southeast and there are small scattered outliers in the interior. Elsewhere the St. Louis is the bed rock.

The St. Louis as developed in Keokuk county has been subdivided by Bain into three members designated as the Springvale, the Verdi, and the Pella. He reports the Pella beds as being sparingly present.

His type section of the Springvale is at the old Springvale mill on South Skunk river in section 34, Warren township. The writer has pointed out on an earlier page (p. 181) that the shaly beds exposed here are more probably of Keokuk age, as are the shaly beds in the "granite" quarry northwest of Ollie, which were referred by him to the Springvale. It is apparent, however, that in a few instances, the beds elsewhere in the county designated by him as Springvale are of true Lower St. Louis age.

One of the most typical sections of the Upper St. Louis appears in a cut of the Minneapolis and Saint Louis railway one and one-half miles west of Ollie, in Jackson township. The following description of this is modified after Bain.

### Section of Upper St. Louis limestone west of Ollie.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
<th>Feet</th>
<th>Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Drift, reddish</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Limestone, gray, compact, with subconchoidal fracture, laminated; in the form of large lenses in the upper part of the sandstone member below</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>Sandstone, fine-grained, yellowish, of differing thickness due to limestone lenses in upper part. With rounded blocks of limestone in lower part</td>
<td>2 1/2</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>Limestone, compact, gray, not everywhere present</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Limestone, brecciated, with shaly and sandy matrix</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Limestone, gray, fine-grained</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Limestone, gray, compact, finely brecciated; upper part locally undisturbed</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Limestone, gray, compact; locally slightly brecciated. Exposed</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

A layer of limestone at the very top of bed 1 is filled with a small species of a Pelecypod and a small Leperditia. The fossils of this bed and of bed 7 are as follows:

**List of fossils from bed 1 of above section.**

- Stenopora sp.
- Productus ovatus Hall
- Spirifer cf. S. pellencis Weller
- Schizodus sp.
- Mediocorpha sp.
- Allorisma sp.
- Allorisma sp.
- Lervidentalium sp.
- Bellerophon sp.
- Bellerophon sp.
- Bucanopsis sp.
- Straparollus sp.
- Leperditia cf. L. carbonaria Hall.

**List of fossils from bed 7 of above section.**

- Orthotetes kaskaskiensis Weller
- Spirifer pellencis Weller
- Composita trinuclea (Hall)

Ninety yards east of the above section, twenty-one feet of Lower St. Louis limestone is exposed in the bluff of a small creek which parallels the railway on the north.

**Section ninety yards east of the preceding section.**

4. Drift.

**LOWER ST. LOUIS**

3. Limestone, brownish, soft, dolomitic, a thin-bedded chipstone; with occasional chert nodules and a few poorly preserved fossils .......................................................... 12

2. Limestone, brownish, dolomitic; massive above, but thinner bedded and rotted below ........................................................................................................ 4

1. Limestone, shaly and arenaceous, bluish to buff; massive in lower part. Exposed ....................................................................................................... 5

About one hundred yards east of this point another bluff on this branch shows Lower St. Louis in contact with the Upper. Twenty and one-half feet of dolomitic limestone, which is poorly exposed in its upper part, is succeeded by six feet of massive basal Verdi sandstone. This is overlain by two and one-half feet of shaly sandstone which is succeeded in turn by three feet of gray limestone.

Another interesting section appears one-fourth mile farther east in the north bank of the branch a short distance north of the railroad and about one and one-fourth miles west of Ollie.

**Section in creek bed west of Ollie.**

9. Drift, with loose blocks of gray limestone ........................................... 2

**UPPER ST. LOUIS**

8. Limestone, gray, compact, fine-grained, brecciated. Bed 1 of railway cut section ......................................................................................................... 7
MISSISSIPPIAN STRATA OF IOWA

7. Sandstone, very soft, incoherent, shaly ........................................ 2
6. Sandstone, gray weathering buff, in one massive ledge; calcareous and irregularly stratified in lower part ............................... 5

LOWER ST. LOUIS
5. Limestone, buff, dolomitic; with occasional seams and lenses of gray compact limestone. Contact with bed above irregular and undulating .............................................. 1/3 to 1
4. Limestone, buff, fine-grained, dolomitic; soft and shaly in middle part; flaking off obliquely; with zone of worm borings four inches thick in lower part ................................................. 2
3. Limestone, gray, shaly, laminated ................................................... 3 to 5
2. Limestone, dark gray, fine-grained, dense ........................................ 8 to 12
1. Limestone, soft, buff, dolomitic. Exposed ...................................... 1

Additional exposures in which the Verdi member of the St. Louis appears prominently are described by Bain (1) in a quarry located in the northeast quarter of section 12, T. 74 N., R. 12 W.; (2) in the bank of Cedar creek south of Sigourney (T. 75 N., R. 12 W., sec. 10, Se.1/4 Sw.1/4); (3) in a railway cut north of Hedrick and near Showman station; and (4) in the Atwood quarry (T. 75 N., R. 13 W., sec. 8, Ne.1/4).

The best evidence at hand supports the view that the Lower St. Louis limestone rests upon shaly beds of Keokuk age in this part of the state although the writer has not observed any direct contacts.

In the “granite” quarry, which is located in the southeast quarter of section 10, Jackson township, typical Keokuk limestone is overlain by cherty dolomitic shale ten feet in thickness. The fauna of this shaly member indicates that it also is of Keokuk age, although Bain referred it to the St. Louis. The following beds of Verdi limestone are exposed three hundred yards south of this quarry.

Section of Verdi limestone near the “granite” quarry.

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Drift ...............................................................</td>
<td>1</td>
</tr>
<tr>
<td>UPPER ST. LOUIS</td>
<td></td>
</tr>
<tr>
<td>4. Sandstone, fine-grained, gray, massive ........................</td>
<td>3</td>
</tr>
<tr>
<td>3. Limestone, gray, compact, in single layer .....................</td>
<td>6</td>
</tr>
<tr>
<td>2. Limestone, gray, fine-grained, finely brecciated ............</td>
<td>10</td>
</tr>
<tr>
<td>1. Limestone, gray, compact. Exposed ................................</td>
<td>7</td>
</tr>
</tbody>
</table>

Barometric measurements indicate that bed 1 of this section lies about twenty-two feet above the top of the highest member of the Keokuk in the “granite” quarry. It is believed that this interval is occupied by the Lower St. Louis limestone.

Bain reports the occurrence of St. Louis limestone in con-

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27 Idem, p. 273.
tact with the Augusta limestone (presumably Keokuk) in the Connor quarry, in the southeast quarter of section 15, Sigourney township.

His section is given below:

*Section in the Connor quarry (After Bain).*

<table>
<thead>
<tr>
<th></th>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Limestone, coarse, subcrystalline. Exposed at water's edge.</td>
<td>4</td>
</tr>
<tr>
<td>2. Limestone, yellow, soft, magnesian; apparently arenaceous in part. Exposed</td>
<td>10</td>
</tr>
</tbody>
</table>

Bed 2 was referred by Bain to the St. Louis and bed 1 to the Augusta. At the time of the writer's visit bed 1 was not exposed. Bed 2 is partly concealed but it resembles the Lower St. Louis limestone. Bain\(^28\) says further:

"About two and one-half miles west of Connor's quarry (Tp. 75 N., R. 12 W., sec. 18, Se. 1/4 Se. 1/4), the Augusta limestone, having its usual characteristics, rises above the water four feet. Both above and below this point the St. Louis limestone is well developed."

**Mahaska County.—**According to Bain\(^29\) the Verdi member of the St. Louis and the Pella beds are the only Mississippian formations exposed in Mahaska county. They outcrop at intervals along the valleys of North Skunk, South Skunk and Des Moines rivers, which flow in a southeasterly direction across the county in the northeastern, middle and southwestern parts respectively. Both the Verdi and the Pella members were mapped by Bain as St. Louis without differentiation. The Verdi in this area contains a large proportion of sandstone.

At Roberts mill, on North Skunk river, (T. 76 N., R. 14 W., sec. 4, Nw. 1/4 Ne. 1/4) Bain\(^30\) found twelve feet of poorly exposed interbedded sandstone and limestone of Verdi age. He also reports six feet of interbedded Verdi limestone and sandstone as being exposed at McBride's mill in the southwest quarter of section 15 of the same township. These beds are overlain by fossiliferous marls and limestones of Pella age.

The Verdi beds as shown in the valley of Des Moines river in the southwest quarter of section 14, T. 75 N., R. 14 W., have an

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\(^{29}\) *Idem*, p. 333 ff.

\(^{30}\) *Idem*, p. 324.
exposed thickness of thirty-five feet and consist of soft yellow cross-bedded sandstones which are capped locally by limestone. An exposure showing the Verdi limestone and sandstone overlain by the Pella beds appears in the valley of Spring creek and in the Des Moines river bluff nearby in the northwest quarter of section 4, T. 75 N., R. 15 W.

Other interesting exposures of the Verdi along Des Moines river are described by Bain\(^3\) as being present at and above Bellefountaine in the western part of Scott township. In section 18 he found eight feet of white calcareous sandstone overlain by twelve feet of fine-grained bluish sandstone. Southward, in section 19, fifteen feet of limestone with irregular, cross-bedded sandstone layers of Verdi age is overlain by more than one hundred feet of Des Moines sandstones and shales.

**Marion County.**—The Verdi beds are the lowest member of the St. Louis exposed in Marion county. So far as the writer is aware outcrops of these beds are confined to the valleys of South Skunk river and its tributary, Thunder creek, in the northeastern part of the county.

The following section is typical of the Thunder creek exposures. It is located in the east bluff of an old meander in the creek which is now abandoned as a result of an artificial cut-off in the northeast quarter of section 26, T. 77 N., R. 18 W.

### Section of Verdi beds on Thunder creek.

<table>
<thead>
<tr>
<th></th>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Drift</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4. Shale, marly; with thin irregular layers of fine-grained gray limestone. Exposed</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>3. Limestone, gray; with included rounded pebbles and grains of compact gray limestone and dark flint</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>2. Shale, bluish, argillaceous, weathering buff</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>1. Sandstone, yellowish, massive; with thin interbedded layers of compact gray limestone which weather in relief</td>
<td>27</td>
<td>6</td>
</tr>
</tbody>
</table>

**Poweshiek County.**—The geological map which accompanies Stookey's\(^2\) report on the geology of Poweshiek county shows an area of St. Louis limestone in the southeastern part of the county. Inasmuch as no descriptions of outcrops in this area are given it is not known whether this represents the true St. Louis or the Pella since both were mapped as St. Louis in the reports issued at that time.

Descriptions are given of exposures of both Pella and Verdi limestones in Sugar Creek township in the southwestern part of the county. Stookey's statements regarding the Verdi are as follows:

"In the northwest quarter of the southwest quarter of section 36, Sugar Creek township, in the east bank of the river near the Stilwell bridge, eight feet of rather heavily bedded, compact limestone is exposed. It represents the middle phase of the Saint Louis stage, known from the typical exposures at Verdi in Washington county, as the Verdi beds. No fossils were noticed. Above the limestone exposure the drift is intermingled with fragments of limestone, indicating the extension of these beds upwards. Elsewhere, as in Washington county, the Verdi beds are characteristically brecciated, and in Keokuk county they alternate with beds of sandstone. The phase represented here is the compact cherty form of the limestone which to the southeast is found associated with sandstone."

The stratigraphic relations of the St. Louis in this county are not entirely clear, owing apparently to the lack of outcrops showing this formation in contact with underlying deposits. It is possible that it rests upon the Kinderhook locally as indicated by Stookey's geological map of the county. However, Norton identifies strata below the St. Louis as Osage in his records of deep wells at Grinnell.

Marshall County.—With the exception of one small exposure in Bangor township, provisionally referred to the St. Louis by Beyer, the bed rock over Marshall county is of Des Moines and Kinderhook age. Beyer's description of the doubtful beds follows:

"In Bangor township in the SW.1/4 SW.1/4 of sec. 16, a heavily bedded, close-textured limestone is quarried in the bottom of Honey creek. The rock is of a dark, ash-gray color and contains some small, cherty concretions. Iron pyrites occur in bands and sheets in certain layers. The rock breaks with an uneven or hackley fracture, and some blocks give a metallic chink when struck with a hammer. No fossils could be found. Lithologically, these beds have a very close resemblance to the lithographic facies of the Saint Louis limestone as exhibited at the quarries north of Ames on the Skunk river, and at Web-

---

Story County.—The highest consolidated rocks in Story county are everywhere of Des Moines age except for an irregular inlier in the vicinity of Ames, in the western part. This owes its development to a local doming of the rocks and subsequent erosion.

In the report on the Geology of Story county, Beyer says:

"The chief outcrops occur along the Skunk and its immediate tributaries between Ames and Soper's mill, and along Onion creek, in Franklin township. The beds exposed consist, in the main, of impure limestone, but arenaceous layers and calcareous shales are usually also present."

One of the most typical exposures of the St. Louis in this area is in the southwest quarter of section 25, Franklin township. Beyer's description of this follows:

Section of St. Louis limestone on Skunk river (After Beyer).

<table>
<thead>
<tr>
<th>Depth (Feet)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-10</td>
<td>Drift</td>
</tr>
<tr>
<td>4</td>
<td>Limestone, earthy, yellow; very much disintegrated and rubbly; bedding planes almost eliminated</td>
</tr>
<tr>
<td>3</td>
<td>Limestone, fossiliferous</td>
</tr>
<tr>
<td>2</td>
<td>Limestone, similar to 4; bedding planes apparent, but showing tendency to become marly and assume a fissile structure in places</td>
</tr>
<tr>
<td>1</td>
<td>Limestone, buff to gray-buff when unweathered and massive; layers from ten to twenty inches in thickness; compact, lithographic in texture, fracture conchoidal to uneven; and earthy when weathered (exposed)</td>
</tr>
</tbody>
</table>

He reports that a fenestelloid bryozoan and a syringoporid coral occur in the upper half of the exposure. From the fossiliferous bed he identified a cyathophyllloid coral and several brachiopods.

Additional exposures of the St. Louis are to be found in the banks of Skunk river at Hannom's mill in the southwest quarter of section 23, Franklin township. The following section of an escarpment in the south bank was described by Beyer:

### Section on Skunk river at Hannom’s mill (After Beyer).

<table>
<thead>
<tr>
<th>Bed</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Soil and bouldery wash</td>
</tr>
<tr>
<td>5</td>
<td>Limestone, residual and concretionary</td>
</tr>
<tr>
<td>4</td>
<td>Limestone, arenaceous, yellowish gray to blue-gray, thinly-bedded and much fractured; in places argillaceous, while in others tends towards the massive; and fissility is apparently a function of weathering; small cherty concretions present</td>
</tr>
<tr>
<td>3</td>
<td>Sandstone, grayish blue, friable; shaly below</td>
</tr>
<tr>
<td>2</td>
<td>Limestone, impure, grayish buff; uneven to earthy fracture; compact and heavy-bedded</td>
</tr>
<tr>
<td>1</td>
<td>Limestone, gray-buff, compact; almost lithographic in character</td>
</tr>
</tbody>
</table>

The fossiliferous zone of the preceding section occurs in bed 1 at this locality and is at an elevation nearly twenty-five feet lower. The latter relationship probably is due to the arch which exists in the Ames area.

Beyer states that north of Hannom’s mill the St. Louis is concealed by Pleistocene deposits as far as Soper’s mill, in the southeast quarter of section 6, Milford township, where he found the following section:

### Section on Skunk river at Soper’s mill (After Beyer).

<table>
<thead>
<tr>
<th>Bed</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Drift, pale yellow, bluish below, unoxidized and unbleached</td>
</tr>
<tr>
<td>3</td>
<td>Limestone, rubbly, with occasional heavy ledges</td>
</tr>
<tr>
<td>2</td>
<td>Limestone, cherty, concretionary, cavernous; some of the larger caverns coated with calcite crystals, which consist of complicated combinations of the scalenohedron and rhombohedron; also smaller quartz-decorated caverns</td>
</tr>
<tr>
<td>1</td>
<td>Limestone, gray-buff, compact; heavy, but irregularly bedded; some of the layers two feet in thickness</td>
</tr>
</tbody>
</table>

No fossils were found in these exposures but the strata were regarded as representing the St. Louis.

The following beds are exposed near the mouth of Onion creek. The section is revised from Beyer’s by the writer.

### Section of St. Louis limestone near the mouth of Onion creek.

<table>
<thead>
<tr>
<th>Bed</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Limestone, brownish, dolomitic, impure</td>
</tr>
<tr>
<td>5</td>
<td>Limestone, brownish, heavy bedded; forming a projecting ledge</td>
</tr>
<tr>
<td>4</td>
<td>Limestone, shaly, containing <em>Productus ovatus</em> and <em>Fenestella multipinosa</em></td>
</tr>
<tr>
<td>3</td>
<td>Sandstone, yellowish, buff to gray buff; close textured, and bedding planes not apparent; the upper 15 inch layer more indurated than the lower part; nonfossiliferous</td>
</tr>
<tr>
<td>2</td>
<td>Sandstone, bluish gray to yellowish gray; irregularly bedded; containing <em>Modiomorpha</em> sp.</td>
</tr>
<tr>
<td>1</td>
<td>Sandstone intermixed with shale, thinly and evenly bedded; exposed</td>
</tr>
</tbody>
</table>

A similar exposure showing the same layers appears a short distance farther up the creek.
Webster County.—The Pella beds were included with the St. Louis in the geological report on Webster county,\textsuperscript{36} therefore the areal distribution of the St. Louis as now delimited cannot be definitely determined without additional field work. The areas mapped as St. Louis by Wilder are small isolated patches chiefly along Des Moines river and its tributaries and in the valleys of Soldier creek and Lizard creek, in the central and north-central parts of the county. A small inlier in the east-central part also is indicated on the map. Elsewhere the country rock is of Pennsylvanian and Permian age.

The more important exposures in which St. Louis beds appear are located in the abandoned Miller quarry on Soldier creek; in the east bluff of Des Moines river in the southeast quarter of section 7 and across section 18, Cooper township; and along Lizard creek west of Fort Dodge. All of these sections have been described by Wilder\textsuperscript{37} but they were revisited and examined by the writer.

The Miller quarry is located just below the stone bridge over Soldier creek in Fort Dodge. The revised section follows:

\begin{table}
\centering
\begin{tabular}{ll}
\hline
\textit{Section in the Miller quarry.} & \textit{FEET INCHES} \\
\hline
7. Drift & \textit{..................................................................................................} 1 \\
\hline
\textbf{Upper St. Louis} & \\
6. Limestone, lenticular, gray, compact, brecciated, fossils scarce and poorly preserved & \textit{...........................................} 0 to 1 \textbf{6} \\
5. Sandstone, fine-grained & \textit{.................................} 3 to 6 \\
4. Sandstone, fine, calcareous, in a single layer & \textit{.................................} 1 \textbf{6} \\
\hline
\textbf{Lower St. Louis} & \\
3. Limestone, massive, dolomitic in lower part; less disturbed than the beds below & \textit{.................................} 3 \textbf{6} \\
2. Concealed & \textit{...........................................} 7 \textbf{6} \\
1. Limestone, yellowish, tough, dolomitic, in mashed undulating layers. Exposed in bed and bank of creek near by & \textit{.........................} 4 \\
\hline
\end{tabular}
\end{table}

The beds are arched up in the quarry. The contact of beds 3 and 4 is irregular, indicating a disconformity. The exposure gives evidence of small cavities in the limestone which are filled with sandstone.

Wilder\textsuperscript{38} states that "a little above Miller's quarry, on Soldier creek, the St. Louis limestone gives place to Coal Measure shales. One-half mile farther up Soldier creek in Cooper town-

\textsuperscript{37} Idem, p. 78. See also vol. XXVIII, map in pocket and pp. 139-147, 163, 164; 1918.
\textsuperscript{38} Idem, p. 79.
ship, section 19, NE. 1/4, the limestone again comes to the surface and appears for 200 feet in the creek bed”.

Still farther up Soldier creek in the southwest quarter of section 17, the St. Louis is overlain by gypsum beds which are believed to be of Permian age.

At one point seven feet of massive gypsum overlain by thirty feet of red sandy shale appears in the bank of the creek. The gypsum comes down to the water’s edge. “One hundred yards farther down stream, at the water level and for three feet above it, the St. Louis limestone is exposed”. Within another hundred yards the limestone gives way to Coal Measure shale.

The east bluff of Des Moines river in section 7 of Cooper township shows the following beds:

<table>
<thead>
<tr>
<th>Section on Des Moines river in section 7, Cooper township.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Upper St. Louis</strong></td>
</tr>
<tr>
<td>4. Sandstone, fine-grained, soft, incoherent, marly above</td>
</tr>
<tr>
<td>3. Sandstone, fine-grained, gray, calcareous, in one heavy layer</td>
</tr>
<tr>
<td><strong>Lower St. Louis</strong></td>
</tr>
<tr>
<td>2. Limestone, gray weathering buff, massive, zone of worm</td>
</tr>
<tr>
<td>burrows in lower and middle parts. A thin flint layer near the top</td>
</tr>
<tr>
<td>1. Concealed to level of water in the river</td>
</tr>
</tbody>
</table>

A few yards down stream a massive layer of finely brecciated compact gray limestone three feet thick comes above the level of bed 4. Drift overlies the limestone. Farther up the river, around the bend Wilder found Coal Measure shales resting upon ten feet of St. Louis limestone. Several other exposures of limestone along the river between this point and the north boundary of the county are described by the same writer. He says: “The striking peculiarity of the limestone in the northern part of the county is the great amount of drusy quartz and flint that it carries, most of it in the upper brecciated layers. Frequently the masses weigh 200 pounds. Calcite is also abundant.”

Small exposures of the St. Louis along Des Moines river below Fort Dodge are described by Wilder from sections 5, 8 and 16 of Pleasant Valley township. Elsewhere the Coal Measures appear along the valley.

The Lizard creek sections are most important from the stand-

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39 Idem, p. 82.
point of Pella stratigraphy but the St. Louis beds outcrop at a few points at the base of the exposures.

In a bluff section near the center of section 24, Douglas township, approximately thirteen feet of limestone, sandstone and shale of this age is over lain by more than fifty feet of strata referred to the Pella. A description of the individual beds is given below:

**Section on Lizard creek.**

<table>
<thead>
<tr>
<th>PELLA</th>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. Marl. Like bed below but free from red areas</td>
<td>6</td>
</tr>
<tr>
<td>8. Gray marl blotched with red. Bears <em>Spirifer pellaensis</em>, <em>Pugnoides ottowma</em>, <em>Composita trinuclea</em> and other fossils</td>
<td>34</td>
</tr>
</tbody>
</table>

**UPPER ST. LOUIS**

| 7. Limestone, drab, compact, shaly and laminated | 3    |
| 6. Shale, drab, argillaceous | 3    |
| 5. Sandstone | 2    |

**LOWER ST. LOUIS**

| 4. Limestone as in bed 2 | 0 to 2/3 |
| 3. Shaly parting | 1/2 |
| 2. Limestone, gray, dolomitic, tough; undulating owing to mashing. Bearing impressions of *Sigillaria* | 2/3 |
| 1. Sandstone, fine-grained, gray, thin-bedded. Exposed | 3    |

Lees and Thomas⁴⁰ found thirty feet of St. Louis limestone exposed in the bluff of South Lizard creek just above the junction of the two branches of the Lizard, one mile west of the above section. The beds dip eastward, that is, downstream. One hundred feet upstream ten feet of green sandy marl grading up into gray sandstone underlies the limestone. Below a gap of six feet they found a two foot bed of limestone.

**Humboldt County.**—So far as the writer is aware only the Lower St. Louis is represented in these northernmost exposures of the formation in Iowa. It apparently rests everywhere on the Kinderhook formation, all of the pre-St. Louis Mississippian formations except the basal deposits having wedged out to the south of this area. The exposures are all in the form of small isolated patches along Des Moines river and its east and west forks.

An excellent opportunity of observing the contact of the St. Louis and Kinderhook limestones is afforded in the banks of a small creek a short distance southwest of the creamery at Rutland, in section 29, Rutland township.

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⁴⁰ Iowa Acad. Sci., vol. XXV, p. 692; 1918.
The contact of the Kinderhook and St. Louis is again shown at the point where this small creek joins the west fork of Des Moines river, just above the dam at the old mill site. At this point about four feet of the Kinderhook oolite is exposed above the bed of the creek. This is overlain by three feet of gray tough St. Louis dolomite which weathers yellowish. At one point in the exposure this dolomite grades laterally, in part at least, into unaltered gray brecciated limestone.

This contact is again shown in the river bank about seventy-five yards below the dam. Three feet of Kinderhook oolite is succeeded by two feet of yellowish St. Louis limestone in undulating layers, and this again by four feet of dense gray thin-bedded unaltered limestone of the same formation, which locally is mashed into mounds of breccia.

Where the St. Louis is disturbed the Kinderhook also shows considerable fracturing and slight brecciation.

Several other exposures between this point and the bridge show a similar relationship. The upper light gray limestone is five and one-half feet thick at one point. Where it is only slightly brecciated it tends to assume a massive appearance and in places is almost lithographic in fineness.

In the abandoned quarry and in the bank of a creek twenty yards west of the creamery at Rutland eight feet of St. Louis limestone is exposed. The lower two feet consists of disturbed, hummocky limestone but the upper six feet is made up of mashed layers of yellowish dolomitic limestone with seams and patches of gray dense unaltered limestone.

A small isolated exposure occurs along the West Fork of Des Moines river near the center of section 23, Avery township. Here the St. Louis is represented by undulating, slightly brecciated layers of gray dense limestone. A moundlike mass of
structureless brownish dolomite which occupies the middle part of the outcrop contains small remnants of gray limestone.

Macbride shows on his geological map of Humboldt county a small area of St. Louis in the valley of the Des Moines in the northern part of section 17, Avery township. The limestone in the vicinity of Gilmore City in western Humboldt and eastern Pocahontas counties which was referred to the St. Louis by Macbride is believed to be of Kinderhook age.

A small exposure of the St. Louis appears south of the town of Humboldt in the east bank of the West Fork of Des Moines river. In an abandoned quarry back of the slaughter house, south of the center of section 12, Corinth township, two feet of yellowish dolomitic limestone is succeeded above by two feet of gray to drab calcareous shale and this in turn by two feet of dense gray slightly brecciated limestone. A short distance farther downstream massive yellowish dolomitic St. Louis limestone rises ten feet above the water's edge.

The most complete section of the St. Louis in the county appears at the mill in the east bluff of the East Fork of Des Moines river at Dakota City. The section is as follows:

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Limestone, dolomitic, dense; gray when fresh but weathering yellowish or brownish: Exposed above level of water</td>
<td>2 FEET</td>
</tr>
<tr>
<td>2</td>
<td>Thin interbedded layers of fine-grained gray sandstone and limestone</td>
<td>3 1/4 FEET</td>
</tr>
<tr>
<td>3</td>
<td>Limestone, brownish, soft, dolomitic; in layers 2 inches to 1 foot in thickness</td>
<td>3 1/4 FEET</td>
</tr>
<tr>
<td>4</td>
<td>Limestone, soft, brownish, dolomitic; massive and structureless and showing evidences of brecciation</td>
<td>8 FEET</td>
</tr>
<tr>
<td>5</td>
<td>Drift</td>
<td>1 FEET</td>
</tr>
<tr>
<td>6</td>
<td>Drift</td>
<td></td>
</tr>
</tbody>
</table>

No fossils were noted in any of the beds.

A very sharp flexure is shown in the strata near the middle of the exposure. The beds are bent down three feet in the space of six feet although they are essentially horizontal on each side. The axis of the flexure trends approximately northwest-southeast. Similar beds are exposed in the Welch quarry and in the river bank near by in the west bluff of the same stream in the southeast quarter of section 31, Grove township.

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41 Iowa Geol. Survey, vol. IX, pp. 131, 132; 1898.
The following section is modified after Macbride's description of an outcrop of St. Louis which appears in the east bank of Des Moines river, near the south line of the county.

Section in east bank of Des Moines river.

<table>
<thead>
<tr>
<th></th>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Limestone, gray, weathering yellowish, in bed of river</td>
</tr>
<tr>
<td>2.</td>
<td>Concealed</td>
</tr>
<tr>
<td>3.</td>
<td>Limestone, gray, fine-grained</td>
</tr>
<tr>
<td>4.</td>
<td>Limestone, gray, dolomitic, weathering yellowish</td>
</tr>
<tr>
<td>5.</td>
<td>limestone, compact, gray</td>
</tr>
<tr>
<td>6.</td>
<td>Shale seam with pockets of clay</td>
</tr>
<tr>
<td>7.</td>
<td>Limestone, yellowish, dolomitic, brecciated</td>
</tr>
<tr>
<td>8.</td>
<td>Limestone, soft, buff, dolomitic</td>
</tr>
</tbody>
</table>

The quarry section in the city of Humboldt which Macbride describes as showing the St. Louis overlying the Kinderhook is concealed at present. But mounds of gray St. Louis limestone are exposed along the streets in the northwest part of the town. A particularly good outcrop may be studied three blocks north of Main street and one block west of the high school.

The Ste. Genevieve Formation

NOMENCLATURE

The name Ste. Genevieve was given by Shumard to a limestone formation typically developed in the Mississippi river bluffs near Ste. Genevieve, Missouri. This formation is represented in Iowa by the Pella beds of earlier reports. The Pella formation, so named by Bain because of its exposure near the town of Pella in Marion county, was formerly regarded as the topmost member of the St. Louis limestone. In the year 1900, however, Nickles and Bassler correlated the Pella beds with the Ste. Genevieve formation upon the basis of the bryozoan element of their fauna. The Ste. Genevieve affinities of the

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fauna were later pointed out by Weller,45 and the correlation was definitely established by Weller and Van Tuyl,46 as a result of further field and faunal studies.

AREAL DISTRIBUTION

The formation has a limited areal distribution due in part to erosion in late Mississippian time prior to the deposition of the Pennsylvanian beds and in part to post-Pennsylvanian denudation. The most representative sections are along the tributaries of Des Moines river in Lee, Van Buren, Wapello, Mahaska and Marion counties. These deposits have also been recognized locally in southeastern Iowa in Henry, Jefferson, Washington, Keokuk and Poweshiek counties. To the northwest of the last named county the Pella beds, if present, are concealed by Des Moines sandstone as far as Webster county where several exposures of the formation appear.

On the areal geology map of the state of Iowa the Pella formation is grouped with the St. Louis limestone and the Spergen formation under the name of "St. Louis limestone."

LITHOLOGIC CHARACTER AND THICKNESS

The Pella formation is most typically developed in southeastern Iowa where it normally consists of a thin basal sandstone followed by a bed of shale about five feet in thickness, and this again by approximately twenty-five feet of compact thinly bedded limestone. To the northwest the limestones give way to shale. In Webster county, in north-central Iowa, the formation is represented almost entirely by shale, which is there about fifty feet in thickness.

STRATIGRAPHIC RELATIONS

The Pella beds rest disconformably upon the St. Louis limestone wherever their contact has been observed in Iowa. In most of the exposures where the contact is shown the basal sandstone of the formation succeeds the Verdi limestone member but at a few localities it overlies the Croton, or Lower St. Louis limestone. The formation is overlain disconformably by either Des Moines sandstone or Pleistocene deposits.

At the close of Pella time the sea withdrew from the Upper Mississippi Valley again and this region remained a land area until the close of the Mississippian period. A great warping began to the north at the time of this emergence and continued probably to the end of the Mississippian. This resulted in a tilting of the Mississippian and earlier formations to the southwest and was accompanied by the development of small northwest-southeast anticlines and synclines and by extensive brecciation of the hard, brittle St. Louis limestone.

Consequent upon this uplift erosion proceeded rapidly during the remainder of Mississippian time and the tilted beds were partly truncated, thus giving rise to a series of northwest-southeast belts of formational outcrops in Iowa, some of which were later buried by the Coal Measures.

This southwestward tilting of the beds in Iowa was related to a widespread late Mississippian deformation which involved also eastern Nebraska, eastern Kansas and Missouri, and outlined a great southwestwardly pitching geosyncline which was later occupied by the early Pennsylvanian sea as it advanced along a narrow trough from the southwest and gradually spread to the margin of the basin.

**AREAL DESCRIPTION BY COUNTIES**

*Lee County.*—The Pella formation is exposed at few localities in this county, although the underlying St. Louis limestone outcrops over large areas.

The section in the banks of a small creek emptying into Des Moines river in the lower part of the town of Croton is typical.

*Section along creek near Croton.*

<table>
<thead>
<tr>
<th>PENNSYLVANIAN</th>
<th>FEET</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>PELLA</th>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Limestone, compact, light gray above but dark gray below; near the middle is a bed of calcareous shale 2½ feet thick....</td>
<td>9</td>
</tr>
<tr>
<td>1. Sandstone, yellowish, fine-grained; in some places soft and shaly in lower part; contact with bed below uneven; bearing large fucoid-like markings on surface of layers</td>
<td>4½</td>
</tr>
</tbody>
</table>

**UPPER ST. LOUIS**

The limestone member yields the following species:
Van Buren County.—The most important exposures of the Pella beds in Van Buren county appear along Des Moines river and its tributaries, especially on Indian and Reed creeks.

The following section was measured in an abandoned quarry on the south bank of Indian creek (NE.1/4 of NW.1/4, sec. 5, T. 67 N., R. 8 W.).

**Section of Pella beds on Indian creek.**

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.</td>
<td>Drift, yellowish, sandy</td>
</tr>
<tr>
<td>4.</td>
<td>Limestone, light gray, dense, breaking with conchoidal fracture; coarser-grained and slightly crinoidal in the upper part; in rather heavy layers separated by thin parts of shaly limestone; locally seamed with calcite veins following fractures; some layers exhibiting stylolytic structure</td>
</tr>
<tr>
<td>3.</td>
<td>Shale, bluish, argillaceous, bearing many pelecypods in calcareous seams near top</td>
</tr>
<tr>
<td>2.</td>
<td>Limestone, gray, subcrystalline, with discontinuous seams of fine-grained sandstone in thin undulating layers; bearing a few small pelecypods</td>
</tr>
<tr>
<td>1.</td>
<td>Sandstone, fine-grained, rather soft; light gray when fresh but weathering yellowish; in some places with angular chert fragments in basal part</td>
</tr>
</tbody>
</table>

**Upper St. Louis**

The shale bed (bed 3) and the overlying limestone (bed 4) contain numerous fossils, as is shown by the following lists:

**List of fossils from bed 3 of above section.**

**BRACHIOPODA—**
Productus ovatus Hall
Pugnoides ottumwa (White)
Girtyella indianaensis (Girty)
Spirifer pellicensis Weller
Composita triunuclea (Hall) !

**PELECYPODA—**
Edmondia sp.
Schizodus sp.
Schizodus sp.
Allorisma sp.

**List of fossils from bed 4 of above section.**

**BRACHIOPODA—**
Productus ovatus Hall
Pugnoides ottumwa (White)
Girtyella indianaensis (Girty)
Spirifer pellicensis Weller

**PELECYPODA—**
Edmondia sp.
Schizodus sp.
Schizodus sp.
Allorisma sp.

**BRYOZOA—**
Rhombopora sp.

**CRUSTACEA—**
Leperditia sp.

**GASTROPODA—**
Solenospira sp.

**List of fossils from bed 4 of above section.**

**Allorisma sp.**
Bellerophon sp.
Trilobita—
Phillipsia ! sp.
A remarkable section exhibiting both the Pella and the whole of the St. Louis appears in the south bluff of Reed creek about three-fourths of a mile above its mouth (near middle of north line, sec. 14, T. 68 N., R. 8 W.). The succession, as measured near the middle of the bluff, is as follows:

**Section of Pella beds on Reed creek.**

<table>
<thead>
<tr>
<th>Section of Pella beds on Reed creek.</th>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. Drift.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PELLA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Limestone, light gray, compact to subcrystalline; some layers lithographic-like and breaking with conchoidal fracture; layers 1 inch to 1½ feet thick, separated by shaly partings some of which are highly fossiliferous; exhibiting much stylolytic structure; increasingly shaly in lower part and grading downwards into the bed below; locally brecciated in part ..........</td>
<td>21</td>
<td>6</td>
</tr>
<tr>
<td>9. Shale, bluish, argillaceous to calcareous, of variable thickness owing to mashing ..........................................................</td>
<td>3 to 6</td>
<td></td>
</tr>
<tr>
<td>8. Limestone, light gray, compact, in thin irregular layers with shaly partings ..........................................................</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>7. Sandstone, bluish, fine-grained, rather soft, bearing rounded and subangular pebbles of compact gray limestone ................................</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>6. Limestone, gray, compact in middle but subcrystalline above and below ..........................................................</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5. Sandstone, bluish, fine-grained, calcareous, massive, bearing rolled chert fragments ..........................................................</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UPPER ST. LOUIS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Limestone, buff, magnesian, arenaceous ........................................</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>3. Limestone, buff, dolomitic, massive ........................................</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>2. Limestone, buff, dolomitic with small irregular remnants and blocks of compact gray limestone; slightly brecciated ..........</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>LOWER ST. LOUIS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Limestone, buff, dolomitic, mashed and brecciated, shaly in lower part ..........................................................</td>
<td>28</td>
<td></td>
</tr>
</tbody>
</table>

Beds 9 and 10 of this section, which are to be correlated with beds 3 and 4 of the preceding Indian creek section, are fossiliferous.

**List of fossils from bed 9 of above section.**

<table>
<thead>
<tr>
<th>BRACHIOPODA—</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pugnoides ottumwa (White)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PELECYPODA—</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solenomya † iowensis Worthen †</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sphenotus (several undescribed species)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glossites (species undescribed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edmondia (species undescribed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nucula † sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leda curta M. and W. †</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pinna (species undetermined)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myalina † sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myalina (species undetermined)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schizodus (several undescribed species)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aviculopecten (species undetermined)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allorisma (species undescribed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRUSTACEA—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leperditia (species undetermined)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**List of fossils from bed 10 of above section.**

<table>
<thead>
<tr>
<th>BRACHIOPODA—</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Productus ovatus Hall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Girtyella indianaensis (Girty)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pugnoides ottumwa (White)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spirifer pellaensis Weller</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Composita trinuclea (Hall) †</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schizodus sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PELECYPODA—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schizodus sp.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Other sections measured nearby in the same bluff showed considerable variation from that given, owing to differential erosion of the St. Louis prior to the deposition of the Pella and to the variable character of the basal beds of the Pella itself. The section presented, however, may be regarded as typical.

In another bluff on the opposite side of Reed creek about two hundred yards above the location of the preceding section the Pella beds are seen to rest upon somewhat lower beds of the Upper St. Louis. At this point, bed 10 of the foregoing section is represented by eighteen feet of limestone; bed 9 by three and one-half feet of shale; and beds 5, 6, 7 and 8 collectively by a continuous bed of sandstone ranging from twenty-four to thirty-four feet in thickness. The underlying St. Louis limestone is mashed here for the most part, and towards the top the matrix of the brecciated limestone is filled with sand grains probably derived from the overlying formation. The basal sandstone of the Pella attains a similar development in the vicinity of Keosauqua, whence the name Keosauqua sandstone as applied by Gordon.47

A very interesting and instructive exposure appears along a small branch of Des Moines river one and one-half miles north of Farmington, near the middle of the north line of the northeast quarter of section 26, T. 68 N., R. 8 W. Near the Yargus coal bank about fifteen feet of Pella beds is overlain by Des Moines sandstone. At the base of the exposure there is shown three to four feet of fine-grained Pella limestone. Overlying this member is eleven feet of fine-grained thin-bedded shaly sandstone also of Pella age. Des Moines sandstone caps the section. At one point in the bluff a shear zone appears in the Pella beds but does not traverse the Des Moines formation, which shows no disturbance whatever. Where this shear zone crosses the Pella sandstone there are numerous angular blocks of limestone resembling in every way the limestone which normally comes at the top of the Pella formation in this region. It is believed that the shearing took place directly after the deposition of the Pella and before erosion stripped off the limestone member which normally comes above the sandstone. After the shearing of fragments of this bed down into the sandstone a period of

47 Jour. Geol., vol. III, p. 304; 1895.
erosion, representing the disconformity between the Mississippian and Pennsylvanian systems, followed. It is believed that the shearing was contemporaneous, in part at least, with the local brecciation of the St. Louis limestone and that it was related to the regional uplift which caused a retreat of the Mississippian sea to the southward at the close of Pella time.

An exposure of the Pella beds appears approximately midway between the towns of Farmington and Bonaparte, on Slaughters branch (NW.1/4 sec. 23, T. 68N., R. 8 W.).

Section of Pella beds on Slaughters branch.

<table>
<thead>
<tr>
<th>Description</th>
<th>Feet</th>
<th>Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sandstone, fine-grained, light gray, soft and shaly in upper part. Exposed</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>2. Limestone, compact, gray, dense</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>3. Shale</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>4. Limestone, formerly quarried on a small scale</td>
<td>13</td>
<td>6</td>
</tr>
</tbody>
</table>

The capping limestone contains several typical Pella brachiopods, viz.:

- Productus ovatus Hall
- Girtyella indianaensis (Girty)
- Pugnoides ottumwa (White)
- Spirifer pellacensis Weller

At the southeast end of the bridge over Des Moines river at Keosauqua an exposure shows three to four feet of Pella limestone underlain by thirteen feet of sandstone. Blocks of the Pella limestone are mashed down several feet into the sandstone at one point.

Davis County. — In the report on the geology of Davis county, M. F. Arey describes exposures of limestone along Des Moines river and its tributaries in the extreme northeastern part of the county. He refers these to the Pella but in the absence of lists of diagnostic fossils it is possible that they represent the St. Louis.

Henry County. — The most representative sections of the Pella formation in Henry county occur along Brush creek in the eastern part of section 6 of Baltimore township. The following beds appear in the east bank of the stream just north of the wagon road at the point where it crosses the creek.

MISSISSIPPIAN STRATA OF IOWA

Section of Pella beds along Brush creek.

PELLA

3. Limestone, gray, fine-grained, thin-bedded; shaly partings between the layers filled with fossils ................................................................. 8½

2. Sandstone, fine-grained, gray, massive, weathering yellowish.... 21

LOWER ST. LOUIS

1. Limestone, buff, dolomitic, massive; Lithostrotion zone at the top .................................................................................................................. 2

A well defined synclinal flexure is developed in the beds of this locality. In a quarry in the opposite bank of the creek, directly west of this exposure, bed 3 has an exposed thickness of six and one-half feet and is followed by the same thickness of highly fossiliferous calcareous shale with intercalated limestone layers. The shale is gray when fresh but weathers yellowish. About six feet of drift comes above.

The following species characterize the limestone (bed 3):

**BRYOZOA**
- Fenestella sp.
- Productus ovatus Hall
- Pugnoides ottumwa (White)

**BRACHIOPODA**
- Girtyella indianaensis (Girty)
- Spirifer pellacensis Weller
- Composita trinuclea (Hall)

**PELECYPODA**
- Allorisma marionensis White

The overlying shale contains a somewhat more diversified faunule, as the following list shows:

**ANTHOZOA**
- Zaphrentis pellaensis Worthen
- Productus ovatus Hall
- Productus parvus M. and W.
- Spirifer pellacensis Weller
- Composita trinuclea (Hall)
- Chiothyridina sp.

**CRINOIDEA**
- Stems and fragments
- Anisotrypa fistulosa Ulrich
- Spirifer pellaensis Weller
- Composita trinuclea (Hall)
- Chiothyridina sp.

**BRYOZOA**
- Anisotrypa ramulosa Ulrich
- Orthotetes kaskaskiensis (McChesney)
- Allorisma sp.
- Vertebrata
- Fish teeth

Jefferson County.—A number of exposures of the Pella beds in Jefferson county have been carefully described by J. A. Udden⁴⁹. These occur on the north and middle branches of Walnut creek in sections 21 and 23 of Penn township; in the south bank of Brush creek, near the northeast corner of section 36, Lockridge township; in the bed of Wolf creek, south of the center of section 5, Round Prairie township; in the banks of Cedar creek in the southwest one-fourth of the southeast quarter of section 34, Round Prairie township; in the south bank of Rock creek in the northeast one-fourth of the northeast quarter of section 32, Round Prairie township; in a ravine about one-

sixth mile southwest of the center of section 23, Round Prairie township; in the south bank of Cedar creek in the northeast quarter of section 34, Cedar township; in an old quarry in the east bank of Cedar creek, northeast of the center of section 10, Liberty township; near the Chicago, Rock Island and Pacific railway in the northwest one-fourth of the southeast quarter of section 9, Liberty township; and in the bed of Lick creek near the center of section 25, Des Moines township.

The section in the south bank of Rock creek, which was visited by the writer, is typical for the entire area. Udden's description is copied without change.

**Section in the south bank of Rock creek (After Udden).**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Gray marl</td>
<td>1/3</td>
</tr>
<tr>
<td>9</td>
<td>Limestone</td>
<td>1/2</td>
</tr>
<tr>
<td>8</td>
<td>Gray marl</td>
<td>1/2</td>
</tr>
<tr>
<td>7</td>
<td>Limestone</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Marl</td>
<td>1/8</td>
</tr>
<tr>
<td>5</td>
<td>Limestone</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Yellow marl containing Productus ovatus, Productus marginicinctus, Pugnoides ottumwa, Spirifer keokuk, Seminula trinuclea, (1) Fenestella serratula, Anisotrypa fistulosa, cystophyllids and stems of crinoids</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Limestone</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Marl with some of the same fossils as those above</td>
<td>1/8</td>
</tr>
<tr>
<td>1</td>
<td>Quite evenly bedded ledges of bluish gray limestone</td>
<td>7 1/2</td>
</tr>
</tbody>
</table>

The thickness of the formation in this county is given by him as seventeen feet. The above section therefore contains all the members of the Pella represented in this part of the state.

The fauna of the formation in this county as listed by Udden, but now subject to some revision in the light of more recent paleontological studies, is as follows:

**List of fossils from the Pella beds in Jefferson county (after Udden).**

**PROTOZOA—**
- Endothyra baileyi (Hall)
- Other rhizopods not identified

**ANTHOZOA—**
- Zaphrentis pellaensis Worthen

**ECHINODERMATA—**
- Pentremites koninckiana Hall
- Archaeocidaris (spines and separate plates, small).
- Crinoids (stems)

**VERMES—**
- Spirorbis †

**BRYOZOA—**
- Anisotrypa fistulosa Ulrich
- Fenestella serratula Ulrich

**BRACHIOPODA—**
- Cleiothyris roissyi (Leveille)
- Dorbya keokuk (Hall)
- Dielasma formosa (Hall)
- Dielasma turgida Hall
- Eumetra marcyi (Shumard)
- Productus marginicinctus Prout
- Productus ovatus Hall
- Camaroteochia grosvenori (Hall)
- Pugnoides ottumwa (White)
- Seminula trinuclea (Hall)
- Seminula sp. undt.
- Spirifer keokuk Hall

**PELECYPODA—**
- Allorisma marionensis White
MISSISSIPPIAN STRATA OF IOWA

Antartella sp.  Leperditia carbonaria Hall
Lithophaga pertenuis M. and W. (†)  Phillipsia † (pygidium)
Pinna † (fragment)  Vertebrata—
Arthropleura—
Cytherelina glandella Whitfield

Wapello County.—Exposures of the Pella formation in Wapello county are confined to the valleys of Des Moines river and its larger tributaries in the central and northwestern parts. But rocks of this age are believed to underlie the mantle rock over small areas in the northeastern and southeastern corners of the county also.

It is probable that all the rocks in this county mapped and described by Leonard50 as St. Louis are of Pella age. The sandstone below the Pella limestone which he referred to the Verdi is believed to be a basal sandstone of Pella age.

One of the most instructive and complete exposures of the formation in this county is in an abandoned quarry on Harrows branch, one-fourth mile above Second street, in the northwest part of the city of Ottumwa. The succession is as follows:

Section on Harrows branch.

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.</td>
<td>Drift, yellowish ........................................</td>
</tr>
</tbody>
</table>

Des Moines

7. Shale, dark, carbonaceous, contact with shale below obscure.... 4

Pella

6. Shale, drab, marly, with harder calcareous seams in lower part; blotched and streaked with reddish patches ................. 9

5. Limestone, drab, fine-grained; massive when fresh but weathering shaly; grading into shale above and below .......... 2

4. Shale, like bed 6 but free from reddish patches; locally grading laterally into limestone ........................................ 1 9

3. Limestone, like bed 5 .................................................................. 6

2. Shale, like bed 4 ........................................................................ 3 2

1. Limestone, drab, fine-grained. Exposed ..................................... 2 6

The following fossils were collected from the Pella beds at this locality:

**Anthozoa—**

Zaphrentis pellaensis Worthen

**Crinoidea—**

Crinoid stems

**Bryozoa—**

Anisotrypa ramulosa Ulrich

Anisotrypa fistulosa Ulrich

Fenestrella sp.

**Brachiopoda—**

Orthotetes kaskaskiensis (McChesney)

**Productus parvus M. and W.**

**Productus ovatus Hall**

Pugnoideas ottumwa (White)

Girtyella indianaensis (Girty)

Spirifer pellaensis Weller

Composita trinuclea (Hall)

Cliothyridina hirsuta (Hall)

**Pelecyphoda—**

**Allorisma marionensis White**

PELLA BEDS AT DUDLEY

Other important exposures appear in the vicinity of the town of Dudley. The accompanying section is shown in a quarry opening on South Avery creek (SW. 1/4 of SE. 1/4, sec. 35, T. 73 N., R. 15 W.).

Section of Pella beds on South Avery creek.

4. Drift ................................................................. 1 to 2
3. Limestone, shaly. Exposed ..................................... 1
2. Shale, marly, with a six inch layer of shaly limestone in middle .................................................. 6½
1. Limestone, gray, massive when fresh but weathering to thin layers, fine-grained. Exposed ........................................... 6½

Bed 1 yields only a few species, namely: Productus ovatus Hall, Pugnoides ottumwa (White), Spirifer pellaensis Weller, Composita trinuclea (Hall) and Allorisma sp. The fossils of bed 2 are much more varied.

List of fossils from bed 2 of Pella formation on South Avery creek.

| ANTHOZOA— | Productus ovatus Hall |
| Zaphrentis pellaensis Worthen |
| CRINOIDEA— | Productus parvus M. and W. |
| Crinoid stems |
| BRYOZOA— | Girtyella indianaensis (Girty) |
| Anisotrypa ramulosa Ulrich |
| Anisotrypa fistulosa Ulrich |
| Composita trinuclea (Hall) |
| PELECYPODA— | Spirifer pellaensis Weller |
| Fenestella sp. |
| PELECYPODA— | Allorisma marionensis White |
| BRACHIOPODA— | Gastropod sp. |
| Orthotetes kaskaskiensis (McChesney) |

Two hundred yards south of the above exposure the following layers are exposed in the opposite bank of the creek.

Section of Pella beds two hundred yards south of the preceding one.

4. Drift ................................................................. 10
3. Limestone, gray, fine-grained, thin-bedded ........................................ 5½
2. Concealed ........................................................................ 2½
1. Sandstone, fine-grained, gray to buff, massive below but in thin cross-bedded layers above. Exposed ........................................ 10

Several feet of the Pella are exposed in an abandoned quarry just west of the Chicago, Burlington and Quincy railway station at Dudley.

Section of Pella beds in quarry at Dudley.

6. Drift ................................................................. 10
5. Limestone, gray, fine-grained, shaly ........................................ 1½
4. Shale, gray, marly ....................................................... 2
3. Limestone like bed 5 ................................................... 7½
2. Shale, like bed 4 ......................................................... 3
1. Limestone, dove-colored, very compact, thin-bedded; coarser-grained and crinoidal in lower part. Exposed ........................................ 6
The fauna of the formation at this place is very similar to that of the foregoing exposures.

*Fauna of the Pella beds in quarry at Dudley.*

**ANTHOZOA**
- Spirifer pellaensis Weller
- Composita trinuclea (Hall)

**CENOZOICA**
- Zaphrentis pellaensis Worthen
- Crenoid stems

**BRYOZA**
- A. spiriferida Ulrich
- A. pellaensis Ulrich
- A. ramulosa Ulrich
- Anisotrypa fistulosa Ulrich
- Allorisma marionensis White
- Anisotrypa fistulosa Ulrich
- Allorisma sp.
- Bellerophon sp.

**PELECYPODA**
- Orthotetes kaskaskiensis (McChesney)
- Productus ovatus Hall
- Productus parvus M. and W.
- Pseudoides ottumwa (White)
- Girtyella indianaensis (Girty)

**GASTROPODA**
- Phillipsia sp.
- Ostracoda—
- Leperditia sp.

**BRACHIOPODA**
- Bellerophon sp.

An excellent exposure of the Pella beds in disconformable contact with the Des Moines formation may be seen half a mile east of Dudley where an artificial channel for North Avery creek has been cut in order to shorten its course. The following section was measured near the west end of the cut:

*Section east of Dudley.*

7. Drift.

6. Limestone, light gray, compact, fine-grained, thin-bedded above but in heavier layers below; with a coarser-grained crinoidal layer 20 inches thick in lower part ........................................ 7

5. Sandstone, fine-grained, soft, bluish, resting on the irregular surface of the bed beneath .................................................. 1/6—1/2

4. Limestone, dark gray, fine-grained, compact, locally coarser-grained and crinoidal in part, very irregular owing to extreme brecciation and mashing; lower boundary irregular owing to mashing down into soft sandstone below .................... 3

3. Sandstone, fine-grained, bluish, soft .......................................................... 1 to 1 1/2

2. Limestone, compact, dark gray, brecciated, with a sandy matrix .......................................................... 1 to 2

1. Sandstone, gray, fine-grained, soft, irregularly and imperfectly stratified. Exposed .......................................................... 4 1/2

A short distance east of this point a black carbonaceous laminated shale of Des Moines age occupies a broad shallow valley cut into the Pella formation.

On North Avery creek, nearby, a bed of sandstone with an exposed thickness of ten feet is followed above by Pella limestone like bed 6 of the above section, a concealed interval of two and one-half feet intervening.

*Washington County.*—The Pella beds extend northward from Jefferson county a short distance into southern Washington county. Bain51 says:

"They have only been preserved from erosion in the immediate neighborhood of Brighton, in the bottom of what is probably a broad, shallow syncline."

The most representative exposures are in the western part of section 29 of Brighton township. The following succession is shown in the bank of a small ravine half a mile south of the Brighton mill.

**Section of Pella beds near Brighton mill.**

<table>
<thead>
<tr>
<th>FEET</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Drift</td>
<td>3</td>
</tr>
<tr>
<td>3. Limestone, gray, fine-grained, in one heavy layer, containing <em>Spirifer pellaensis, Pugnoides ottumwa</em> and <em>Straparollus</em> sp.</td>
<td>1 6</td>
</tr>
<tr>
<td>2. Limestone, drab, fine-grained, in layers 2 to 3 inches thick, separated by shaly layers 1 to 3 inches thick. <em>Pugnoides ottumwa</em> abundant</td>
<td>4 2</td>
</tr>
<tr>
<td>1. Shale, bluish, arenaceous, with lenses and seams of compact gray brecciated limestone. Exposed</td>
<td>3 6</td>
</tr>
</tbody>
</table>

Bed 1 of the preceding section has a thickness of one foot in a quarry opening one hundred yards north of the ravine. It is underlain by five feet of gray fine-grained thin-bedded basal Pella sandstone which rests unevenly on the St. Louis limestone.

**Keokuk County.**—Exposures of the Pella beds in Keokuk county apparently are confined to its western half. Bain\(^{52}\) refers to several quarries east and south of What Cheer in Washington township which derive stone from this formation. The more important of these are in the southeast quarter of section 11 and the northwest quarter of section 24. At the last locality *Pugnoides ottumwa* and other characteristic fossils were collected by him. Bain states that the quarries north of Sigourney, the county seat, are in both the Verdi and Pella limestones.

**Mahaska County.**—The distribution of the Pella beds in Mahaska county is similar to that of the St. Louis limestone, although they are not so extensive. Bain\(^{53}\) describes scattered outcrops of the formation along the north and south forks of Skunk river and in the valley of Des Moines river.

On the north fork of Skunk river exposures appear (1) in the Meyer’s section (T. 77 N., R. 16 W., sec. 1, NW.1/4 SE.1/4) where six feet of limestone is overlain by Des Moines shales and sandstones; (2) in the Union mills sections in the east half of

\(^{52}\) Iowa Geol. Survey, vol. IV, p. 305; 1895.
\(^{53}\) Idem, p. 324 ff.
section 23 (T. 77 N., R. 15 W.) and (3) in the McBride mill section (T. 76 N., R. 14 W., sec. 15, SW. ¼). At the last named locality Bain measured the following section:

Section at the McBride mill.

<table>
<thead>
<tr>
<th>FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Limestone, gray, subcrystalline, with interbedded fossiliferous marl layers .................................................</td>
</tr>
<tr>
<td>5. Unexposed .................................................................</td>
</tr>
<tr>
<td>4. Limestone, ash-gray, compact ........................................................................</td>
</tr>
<tr>
<td>3. Sandstone, soft, yellow .............................................................................</td>
</tr>
<tr>
<td>2. Limestone, as above .....................................................................................</td>
</tr>
<tr>
<td>1. Sandstone, as above .....................................................................................</td>
</tr>
</tbody>
</table>

Beds 1 to 4, which he refers to the Verdi, outcrop under the east pier of the bridge. Bed 6, the Pella, appears in a small quarry opening about two hundred yards west of the mill.

Bain identified the Pella on South Skunk river in (1) the Ballinger branch section (T. 76 N., R. 17 W., sec. 11, NW. ¼), (2) in the waterworks section (T. 76 N., R. 16 W., sec. 25, SW. ¼ SE. ¼), and (3) in the Spring creek section (T. 75 N., R. 15 W., sec. 4, NW. ¼). He also reports the presence of the Pella along Des Moines river in the Given (T. 74 N., R. 16 W., sec. 10, SW. ¼) and Bluff creek (T. 74 N., R. 16 W., sec. 23, NW. ¼) sections.

Poweshiek County.—The only exposure of the Pella beds recorded by Stookey 54 in his report on the geology of Poweshiek county is located in the southeast one-fourth of the northwest quarter of section 35, Sugar Creek township, where seven feet of interbedded shale and limestone of this age is overlain by Des Moines sandstone. The fauna listed by Stookey is very similar to that of the Pella in adjoining counties.

Marion County.—The type section of the Pella formation is near the town of Pella in Marion county. The nearest exposure of the beds to the town is in an abandoned quarry one-half mile southwest of the city limits (T. 76 N., R. 18 W., sec. 9, SE. ¼). Other quarry openings are located a short distance south in the northeast quarter of section 16. The limestone which was formerly quarried no longer outcrops, but the overlying fossiliferous shales have an exposed thickness of eight feet. The following species were collected from these shales:

---

PELLA BEDS IN WEBSTER COUNTY

List of fossils from Pella shales near Pella.

ANTHOZOA—
Zaphrentis pellaensis Worthen

CRINOIDEA—
Pentremites conoides Shumard

CRINOIDEA—
Crinoid stems

BRYOZOA—
Anisotrypa fistulosa Ulrich
Anisotrypa ramulosa Ulrich
Fenestella sp.
Polypora sp.

BRACHIOPODA—
Orthotetes kaskaskiensis (McChesney)
Productus ovatus Hall
Productus parvus M. and W.
Pugnoides ottumwa (White)
Pugnoides pellaensis (Weller)
Girtyella indianaensis (Girty)
Spirifer pellaensis Weller
Composita trinuclea (Hall)
Chiorthiurina hirsuta (Hall)

The limestone member of the Pella is exposed below the fossiliferous marls in the quarries southwest of the town of Tracy (T. 75 N., R. 18 W., sec. 35, NE. 1/4 of SE. 1/4). Near the middle of the quarry face the succession is as follows:

Section southwest of Tracy.

DES MOINES............................ 5. Shale, dark, impregnated with carbonaceous material, arenaceous above ........................................ 8

PELLA
4. Shale, fossiliferous ................................................................. 4 ½
3. Limestone, gray, fine-grained, in a single layer ...................... 1
2. Limestone, gray, fine-grained, thin-bedded, rather soft and shaly .............................................................................. 5
1. Limestone, similar to bed 3 ............................................................. 2

The characteristic fossils of the limestone members are:
Pugnoides ottumwa, Spirifer pellaensis, Composita trinuclea and Allorisma sp.

The assemblage in the shale is considerably more diversified, viz.:

List of fossils from shale bed at top of Pella in above section.

ANTHOZOA—
Zaphrentis pellaensis Worthen

CRINOIDEA—
Crinoid stems

BRYOZOA—
Anisotrypa fistulosa Ulrich
Anisotrypa ramulosa Ulrich
Fenestella cf. F. multispinosa Ulrich

BRACHIOPODA—
Orthotetes kaskaskiensis (McChesney)
Productus ovatus Hall

PELCEYPODA—
Allorisma marinensis White
Schizodus sp.

GASTROPODA—
Bellcrphon sp.

VERTEBRATA—
Fish teeth

Webster County.—No exposures of the Pella formation are known northwestward from southwestern Poweshiek county until Webster county is reached. Except for a small inlier of
St. Louis limestone in Story county the intervening area is covered everywhere by the Des Moines formation.

Fossils now known as characteristic Pella species were reported from the St. Louis limestone of this area by White\textsuperscript{55} as early as 1870. Many years later Wilder\textsuperscript{56} described fossiliferous marls on Lizard creek, one mile west of Fort Dodge, which he also referred to the St. Louis. Upon the basis of the fossils listed by Wilder, the beds were assigned to the Pella by Weller and Van Tuyl in 1915.\textsuperscript{57} More recent studies by Lees and Thomas\textsuperscript{58} have demonstrated the presence of a typical Pella fauna in the marls.

Lees and Thomas state that all the known exposures of the formation in Webster county are, with two exceptions, located in the valley of Lizard creek west of Fort Dodge. One of these exceptional localities is "in a ravine which opens into Des Moines valley from the northwest opposite the dam and about one-third mile above the railroad and wagon bridges over the river at the mouth of Lizard creek." Twenty to twenty-five feet of fossiliferous Pella shales is overlain here by the Coal Measures. The other locality is in the northwest quarter of section 6, Cooper township, in a small ravine on the east side of Des Moines river, about five miles above Fort Dodge. Two small outcrops here show a few inches of sandy shale at water level, above which is two feet of marl. Over this is a foot of clay shale in which were found a few specimens of \textit{Spirifer pellaensis} and \textit{Pugnoides ottumwa}. A bluff section on Lizard creek near the center of section 24, Douglas township, shows forty feet of Pella shales underlain by thirteen feet of interbedded sandstone and limestone of St. Louis age. The lower thirty-four feet of the Pella shale is mottled with red areas and contains \textit{Spirifer pellaensis, Pugnoides ottumwa, Composita trinuclea} and other fossils. (See also page 284.)

Several other exposures of Pella shales on Lizard creek are described by Lees and Thomas.\textsuperscript{59} In an exposure about one-fourth mile up the valley from the above mentioned section they found three feet of nodular gray limestone overlain by

\textsuperscript{56} Iowa Geol. Survey, vol. XII, p. 78; 1901. See also Wilder's statements in vol. XXVIII, pp. 146, 154, 164; 1915.
\textsuperscript{59} Idem, p. 600 ff.
thirty or more feet of fossiliferous gray-green shale which is followed in turn by five feet of red clay shale barren of life forms. Regarding other outcrops they say:

"About four hundred yards above the junction of North and South Lizard creeks, on the east bank of North Lizard there is an exposure of the gray-green shale which rises twenty-five or thirty feet above the stream. Over this shale lies fifteen to twenty feet of red shale. At several horizons in the gray-green shale there are harder limy bands which contain large numbers of fossil brachiopods. The contact of the red shale with the gray is quite sharp and lies just above a layer of fossiliferous yellow limestone.

The next exposures on this fork, and so far as known to the writers the last ones, are a group five miles up the valley and in the southeast quarter of section 8, Douglas township, about one-fourth mile below the Minneapolis and Saint Louis railroad bridge on the north bank of the stream. Here a small tributary ravine has been cut through six feet of yellow and green shale, below this through five feet of red and green shale, beneath which is exposed two feet of gray sandstone or sandy limestone, then five feet of shaly material beneath which in turn two feet of green shale is seen above the stream level."

None of the beds at this locality yielded any fossils.

Regarding the exposures on South Lizard creek Lees and Thomas have the following to say:

"In the lower one-half mile of South Lizard valley there are several exposures of the red and green shales. Only one of these, the southernmost, need be described here. This one shows beneath twenty or thirty feet of till a body of red clay shale twelve feet thick. Under it is eight feet of gray sandstone and below this bed a green and red shale extends fifteen feet to water level. Some of the shale near the base of this exposure is finely sandy. All the other outcrops are similar in the character of the beds exposed and it is noteworthy that none of the beds carry any fossils."

The fauna of the Pella beds of Webster county as reported by Lees and Thomas\textsuperscript{66} is as follows:

\begin{itemize}
  \item \textbf{Spongiae} –
    \begin{itemize}
      \item Clinitolithes lizardensis Lees and Thomas
    \end{itemize}
  \item \textbf{Vermes} –
    \begin{itemize}
      \item Spirorchis fortDodgensis Lees and Thomas
    \end{itemize}
  \item \textbf{Crinoidea} –
    \begin{itemize}
      \item Crinoid stems
    \end{itemize}
  \item \textbf{Bryozoa} –
    \begin{itemize}
      \item Batostomella interstincta Ulrich
    \end{itemize}
\end{itemize}


\begin{itemize}
  \item \textbf{Brachiopoda} –
    \begin{itemize}
      \item Orthotetes kaskaskiensis (McChesney)
      \item Pugnoides ottumwa (White)
      \item Girtyella indianensis (Girty)
      \item Spirifer pellaeensis Weller
      \item Composita trinuclea (Hall)
      \item Phillipsia sp.
    \end{itemize}
  \item \textbf{Trilobita} –
    \begin{itemize}
      \item Phillipsia sp.
    \end{itemize}
\end{itemize}

Batostomella (species undescribed)
Anisotrypa fistulosa Ulrich

CHAPTER V

THE GEODES OF THE KEOKUK AND LOWER WARSAW BEDS

Introduction

In no other area in North America do geodes attain such an exceptional development as in the Keokuk and Lower Warsaw beds of the central Mississippi Valley. Representative specimens of geodes from this region are now found in the mineral cabinets of many of the museums of the world. Apart from Professor Brush's preliminary examination and description of a few select specimens submitted to him in 1865 by A. H. Worthen, then director of the Geological Survey of Illinois, no study of these remarkable geodes has ever been made, in spite of the fact that they bear a variety of metallic sulphides and promise to throw some light upon the origin of more important deposits of these materials in sedimentary rocks which show no signs of igneous influence. The following report on their characteristics is therefore considered justified.

Definition of Geode

The term geode is derived from the Greek word meaning earthlike. The following definition of geode is given in Webster's International Dictionary:

a "A nodule of stone containing a cavity lined with crystals or mineral matter."

b "The cavity in such a nodule."

Geodes are described in Dana's Manual of Geology as "Spheres or irregular spheroids, or balls in rock, hollow within and lined with crystals."

Chamberlin and Salisbury in their text books on Geology state that geodes are formed by the partial filling of cavities by the inward growth of crystals.

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DEFINITION OF GEODE

Bassler, who has recently made a study of geodes, defines them thus:

"Spheroidal or irregular spheroidal, concretion-like masses, hollow and lined with crystals pointing inwardly are known to geologists as geodes."

The following definition is given by O'Hara in Bulletin 9 of the South Dakota School of Mines:

"Geodes are spheroidal masses of mineral matter formed by deposition of crystals from mineral solution on the walls of a rock cavity. The growth is constantly inward toward the center. If the process of deposition has continued sufficiently long, the crystals reach across the depositional space, interlock with each other and the geodes become solid. Often the crystals project only part way, leaving a considerable cavity and then the geodes when broken present a crystal lining of much beauty and interest."

In all but the last of these definitions the impression is given that geodes are always hollow and that they are formed by the partial filling of pre-existing cavities by the inward growth of crystals. Such a view, however, is incorrect, for the growth of crystals toward the interior has in many cases proceeded sufficiently for them to meet and coalesce, thus giving rise to solid geodes.

Furthermore geodes are not always spheroidal. Some of them do not even distantly approach the spheroidal form. Many are very irregular and nodular in shape. A more comprehensive definition is as follows: Geodes are rounded or nodular masses formed by the inward growth of mineral matter upon the walls of pre-existing cavities. They may be either solid or hollow, depending upon whether or not the process of filling has been carried to completion.

The origin of the cavities need not enter into the definition. They may be either original, as in amygdaloidal lava, or they may be due to solution. Solution cavities are characteristic of sedimentary rocks. In their most typical development, geodes possess siliceous or calcareous shells and in this respect they should be distinguished from geodic cavities which are inseparable from the enclosing rock.


Agates have a method of development analogous to that of geodes but they always consist of banded chalcedonic quartz. Also they are normally limited to igneous rocks while geodes are typically confined to shales and limestones.

Nodules and concretions differ in their origin from geodes and agates in that they grow from a nucleus outward by the segregation of like material originally disseminated through the surrounding rocks.

**Other Occurrences of Geodes**

Some of the more important occurrences of geodes in this country are as follows: (1) In the Keokuk limestone and the Lower Warsaw beds of the Central Mississippi Valley; (2) in the Little Falls dolomite of New York; (3) in the Lockport limestone at Lockport and Rochester, New York; (4) in the Knobstone shales of Indiana and Kentucky; (5) in the Tertiary beds of the Big Bad Lands of South Dakota; and (6) in Tertiary shales at Yaquima Bay on the coast of Oregon.

In England geodes occur in the marls and dolomitic conglomerate of the Keuper formation and in a basalt at Tortworth.

**Geodes of the Keokuk Beds**

Geodes attain their most typical development in the Lower Warsaw beds. But geodes and calcareo-siliceous masses are locally found in the Keokuk. These will be considered briefly before passing to a more detailed discussion of the geodes of the Lower Warsaw.

In this subdivision the masses are confined invariably to unfossiliferous calcareous shale beds and impure magnesian limestone layers which are interstratified with the bluish fossiliferous crystalline limestone. They are present at only a few localities in the area. The best known of these are (1) along the bed of a small intermittent stream two miles northwest of Denmark in Lee county; (2) in a quarry along Long creek in the northern part of section 18 of Union township, Des Moines county; and (3) at the mouth of Soap creek in the city of Keokuk.

The occurrence near Denmark is typical. Imperfect calcareous geodes and calcareo-siliceous masses appear in several
layers separated from each other by bluish fossiliferous limestone. The most productive layer, however, is an impure buff magnesian limestone about two and one-half feet in thickness. Rounded and lenticular masses, some of which exceed two feet in greatest diameter, are common at this level. The relation of such masses to the surrounding rock is not such as to indicate appreciable expansion during their growth. The maximum arching of the overlying layers noted was less than two inches for a mass two feet in diameter. The majority of these masses are solid, and although they possess chalcedonic shells, in part at least, as do the typical geodes of the area, and may have a similar method of origin, many of them cannot be regarded strictly as geodes. Rather they should be described as segregations. The interiors of such masses are characterized by no definite structural arrangement and many of them contain layers or smaller inclusions of material resembling the surrounding rock. They are usually occupied in large part, however, by crystalline calcite and fine-grained quartzose material. The calcite and massive quartz may be indiscriminately mixed but usually the calcite either occupies the entire interior or is limited to isolated pockets in the included limestone. In the latter case the calcite of some masses contains small inclusions of buff calcareous material and in some others is associated with masses of sphalerite, some of which are as large as a man’s fist. In still other cases it bears many fibrous inclusions of pyrite or small sphenoids of chalcopyrite. All three sulphides may occur in the same mass but not more than two have been found in any one calcite pocket. The chalcopyrite found in some masses has a zonal arrangement, the small sphenoids generally being most abundant about the periphery of the calcite clusters.

Such segregations are usually surrounded, either wholly or in large part, by a shell of chaledony which may differ in thickness from a thin film to several centimeters. The outer surfaces of most shells are marked by numerous ridges, protuberances and rounded depressions, and in some cases they show a blistered appearance.

An impure soft magnesian limestone layer which is exposed in the quarry in section 18, Union township, Des Moines county, and which belongs in the upper part of the Keokuk limestone, is
geode-bearing. Well formed hollow calcareous geodes are common at this place. Their shells consist commonly of buff calcareous material which is more indurated than the surrounding rock. But in some cases incomplete siliceous shells envelop a portion of the masses. Besides the rhombohedrons of calcite which line the interiors of these masses, crystals of sphalerite are abundant. In several instances this mineral was found to be associated with smithsonite, one of its decomposition products.

Well formed calcareous geodes occur in an impure limestone bed near the middle of the Keokuk at the mouth of Soap creek in the city of Keokuk. This geodiferous layer is six feet in thickness. It bears hollow calcareous geodes ranging up to ten or twelve inches in diameter. The interiors of these are lined with transparent rhombohedrons of calcite to which are attached numerous hairlike tufts and fibers of millerite, the sulphide of nickel. These tufts and fibers are intergrown with the calcite and in some cases they are entirely included by it.

Small geodic cavities have likewise been noted in the cherty limestone layers of the Montrose chert which was exposed in the excavation for the Mississippi river dam at Keokuk. These have no true shells and usually occur in compact chert bands. They are almost all lined with quartz crystals, but upon these are frequently superimposed rhombohedrons of calcite. Some of these rhombohedrons carry fibrous inclusions or needle-like projections of millerite. The nickel mineral, however, is not always confined to calcite, for in one instance its filaments were found implanted upon the crystals of a pure quartz geode.

**Geodes of the Lower Warsaw Beds**

**Occurrence and Size**

The geodes of the Lower Warsaw are remarkable for their abundance as well as for their beauty. Geodes occur in great profusion in the geodiferous phases of this horizon and many of the outcrops are thickly set with these rounded masses. The weathering of such outcrops releases large numbers of specimens and the stream beds at some localities are strewn with many geodes. (See Plate II.)
Group of geodes from the Lower Warsaw beds.
The geodes from this horizon range in size from about 0.2 centimeter up to 75 centimeters in diameter. Well developed geodes, however, of either extreme are very rarely found. Many of the smallest specimens consists of solid chalcedony, but well formed geodes no larger than a pea occur. The greater number of the largest examples, on the other hand, are either lenticular and poorly developed, or compound, in which case they consist of several individuals intergrown. Well formed geodes, however, ranging up to 60 centimeters in diameter are found, but most of these are chambered in their interiors.

Large and small geodes are not found intimately associated in any given layer, but there may be considerable range in size at different levels in the same exposure. Moreover, there may be marked differences in their dimensions at the same level at different localities.

In abundance the geodes of the geodiferous phase of the Lower Warsaw have a wide range both laterally and vertically. In places they are so numerous in a given layer that their freedom of growth has been interfered with and they are thus of very irregular shape. In other places, geodes are very sparingly distributed throughout the rock and none are present in an outcrop embracing an area of several square feet. In the non-geodiferous phase no trace of geodes may be found.

The proportion of well-developed geodes in the beds differs greatly at different localities. At some places well formed geodes do not constitute more than ten per cent of the total, but at others the great majority of those broken may be of typical character. The same relationship holds for different levels in the Lower Warsaw at the same locality.

**MINERALOGICAL CHARACTER**

Mineralogically the geodes are almost all siliceous but a few calcareous geodes and geodic calcareous nodules have been found. The siliceous types are without exception characterized by an outer shell of chalcedony. In most geodes this is followed by crystalline quartz, but calcite occasionally succeeds the chalcedony. In some instances, however, the interior is lined with botryoidal chalcedony and no crystalline quartz nor calcite appears. Many of these chalcedonic types bear cubes of pyrite,
and one specimen was found which contained sphalerite, partly decomposed to smithsonite. This geode bore also a slight incrustation and a few minute crystals of gypsum, but the same mineral has been found in normal quartz geodes. Some of the quartz geodes are solid. In many of those which are hollow the quartz crystals of the interior are studded with crystals of calcite, dolomite, ankerite, sphalerite, or pyrite. More rarely elongated crystals of magnetite or the red powder of hematite are found. Some of these quartz types, on account of their imperviousness, contain water, although the surrounding rocks may be dry.

Many hollow siliceous geodes in the vicinity of Niota, Illinois, are filled with a black viscous bitumen, and those from the upper argillaceous half of the Lower Warsaw, particularly at Keokuk and Warsaw, commonly contain kaolin in the form of a flocculent white powder.

Calcite geodes and geodic calcareous nodules with or without siliceous shells are much less common than the quartz variety. A few calcite geodes from the Denmark locality bear small sphenoids of chalcopyrite. The geodic calcareous nodules, however, are characterized in general by calcite of two periods of growth and many of them contain elongated crystals of pyrite. Calcareous nodules without geodic cavities and inclosed by siliceous shells identical with those of perfect geodes have been found at several localities.

**RELATION TO THE CONTAINING ROCK**

It has been stated previously that the Lower Warsaw is represented by geodiferous and nongeodiferous phases which may grade into each other laterally within short distances. The only apparent physical difference between the two phases is that the member where it bears no geodes is in most cases, although not in all, fossiliferous, while the geodiferous phase is, except for occasional limited seams of limestone, nearly destitute of fossil remains.

The Lower Warsaw, in its typical development, is roughly divisible into two halves. The lower of these is massive and has the composition of an impure magnesian limestone. Bands or seams of fossiliferous nonmagnesian limestone are sometimes
found interbedded with this type. Where it is geodiferous this limestone tends to bear large and well developed geodes which are distributed irregularly throughout the rock mass. The upper part, however, is much more argillaceous and in some exposures is laminated. The geodes in this part are much more numerous than in the lower part but they are much smaller and more imperfectly developed. In general, it may be said that the degree of development of the geodes varies directly with the amount of calcareous matter in the rocks. In this part of the Lower Warsaw most of the geodes are found in productive layers or bands parallel to the stratification and ranging from a few inches to several feet in thickness. These bands are as a rule separated from each other by layers of barren shales of differing thickness. Such bands, interbedded with unproductive shale, and in some localities thickly set with geodes, are in many cases traceable along the entire width of an outcrop.

The relationship of the geodes of the Lower Warsaw to the containing rock, as in the case of the masses in the Keokuk limestone, does not suggest appreciable expansion during their formation. At no place was the inclosing rock found to be under any strain at the contact, nor was there any evidence of flexing consequent upon lateral pressure. Some thin seams of limestone, however, which overlie the geodes are slightly arched upward. But such archings are no greater than would result if masses analogous in size to the geodes were imbedded in the sediment at the time of its accumulation, and this seems to be the true condition. This idea is further strengthened by the occurrence of a few limestone layers which exhibit a thinning where they pass over the upper surface of the geodes. This is the usual relationship. An excellent example of such thinning is found in the lower part of the Lower Warsaw at the outcrop along Fox river, near Fox City, Missouri.

A close study of geodes in place in the rocks reveals the fact that their greatest diameter invariably lies in a horizontal plane, provided their development has not been interfered with. Calcareous nodules when found exhibit a similar relationship.

Many of the geodes have been deformed and crushed in place by the pressure of the superincumbent strata. The imperfect development of such geodes indicates that the crushing must
have taken place while the process of geodization was yet in progress. Additional evidence of the settling of the rocks is found in the slickensided structure which characterizes much of the shaly material adhering to the siliceous shells of the geodes, and which, in some instances is even impressed upon the surface of the chalcedonic shells.

The extent of the geodes in the rock back from the outcrops is worthy of some consideration. Bassler⁴ in his discussion of the geodes of the Knobstone shales of Kentucky and Indiana calls attention to the impervious nature of shale and inclines to the view that the geodes of that formation, which are of fossil origin, are confined to the immediate neighborhood of joint planes or rifts in the strata through which water had easy access. In speaking of their occurrence he says:

"Usually the geodes were lying on the surface itself, free or partially covered with soil, and digging in the compact shale immediately beneath would reveal no trace of other specimens. In other cases they were apparently buried in the shale, but, in every instance of this kind, closer examination showed these examples to lie on the edge or very near to joint planes or rifts in the strata through which the water had easy access."

Such a relationship does not appear to hold for the geodes of the Lower Warsaw beds. They do accumulate along ravines as residual material, but they are found also in appreciable numbers in the unweathered shale. Blasting many feet into the bluff of the Lower Warsaw at Keokuk, Iowa, did not reveal any discontinuity of its geodiferous character. Geodes occur in a clay pit in the beds at Hamilton, and the sinking of a well into this division near Bentonsport revealed the presence of perfect geodes well down within the formation.

The mineralogical relationships of the geodes to the containing rock received some attention in this study. The general conclusion drawn from this investigation is that at any given locality each geodiferous layer or band, as a rule, bears geodes which are closely related among themselves but which may be mineralogically unlike those from other bands. Such differences, however, may be trivial, and one series may possess only a greater and more constant amount of one mineral than the other. Also the geodes from the same level may differ in general character.

at different localities. In this respect it has been found that there are characteristic geode provinces.

To illustrate the diversity of character of the geodes from different bands, specimens from several levels in the Lower Warsaw, at Warsaw, Illinois, were studied and classified upon the basis of their development and mineral content. The following tables represent the types found in three productive bands in the lower ten feet of the upper argillaceous half of the formation at that place. The bands are designated as band A, band B, and band C, respectively, A being the highest band.

### BAND A.

**Geodes dominantly of the quartz type.**

I. Geodes having well developed chalcedonic shells.

A. Hollow geodes.

1. Interior lined in part with drusy quartz and in part with granular quartz coated with chalcedony. 
2. Geodes similar to those of I A 1, but containing kaolin.
3. Geodes like I A 1, but with fine crystals of quartz occurring upon the chaledonized grains.
   (a) Without flakes of pyrite
   (b) With flakes of pyrite

B. Geodes solid or nearly so.

(a) Like I A 3a but from stained

II. Geodes with imperfect shells.

A. Otherwise like I A 2

B. Otherwise like I A 3

### BAND B.

**Geodes dominantly of calcite type.**

I. Geodes with well developed shells.

A. Hollow geodes.

1. Interior of chalcedonic shells lined with rhombs of calcite.
   (a) Without kaolin
   (b) Bearing kaolin

B. Solid geodes (quartzose)

II. Geodes with imperfect shells.

A. Hollow specimens.

1. Bearing calcite, kaolin, clay and sphalerite

B. Geodes solid or nearly so.

1. Otherwise like II A 1

2. Otherwise like II B 1 but containing no sphalerite

### BAND C.

**Geodes dominantly of calcite type.**

I. Geodes with well developed shells.

A. Hollow geodes.

1. Interior of shell studded with transparent crystals of calcite
2. Like I A 1 but bearing kaolin
3. Like I A 1 but bearing a few flakes of pyrite

B. Solid geodes.

1. Interior filled with impure calcite
2. Like I B 1 but containing kaolin
3. Like I B 1 but containing blende and kaolin
4. Like I B 1 but containing only blende
Another band a few feet above A yielded very imperfectly developed and nodular geodes. Many specimens from this level have only incomplete chalcedonic shells while their interiors are occupied by clay intermixed with kaolin. The greatest diameter of these nodular geodes is about three inches.

The lower part of the Lower Warsaw at this place bears much larger but less numerous geodes than does the upper division. The lower four and one-half feet is by far the most productive part of the seven and one-half feet of this division which is exposed. The geodes taken at this level from an area four and one-half feet high and ten feet wide were studied. The results of this study are given in the following table:

<table>
<thead>
<tr>
<th>I.</th>
<th>Well formed geodes with chalcedonic shells.</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>Solid quartz geodes</td>
<td>9</td>
</tr>
<tr>
<td>B.</td>
<td>Hollow quartz geodes.</td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Interior lined with pure quartz crystals.</td>
<td></td>
</tr>
<tr>
<td>(a)</td>
<td>Crystals not bearing flakes of pyrite</td>
<td>3</td>
</tr>
<tr>
<td>(b)</td>
<td>Crystals bearing flakes of pyrite</td>
<td>6</td>
</tr>
<tr>
<td>2.</td>
<td>Interior lined with quartz crystals which are coated with chalcedony.</td>
<td></td>
</tr>
<tr>
<td>(a)</td>
<td>Without flakes of pyrite</td>
<td>2</td>
</tr>
<tr>
<td>(b)</td>
<td>With flakes of pyrite</td>
<td>5</td>
</tr>
</tbody>
</table>

II. Imperfect geodes; either broken or possessing brittle defective shells; interiors hollow but occupied by granular and finely crystalline quartz.

| A. | Already broken | 29 |
| B. | Broken with hammer | 9 |

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At this locality the geodes from any one layer were not found to differ greatly in their mineralogical character, and this is the general rule. Instances have been found, however, in which there is considerable range in the mineral content of the geodes from the same level. This feature is illustrated by the following table prepared from the study of geodes taken from a band in the upper part of the Lower Warsaw, which is exposed along a small stream on the east side of Mud creek, about one mile above its mouth, in Henry county, Iowa.

<table>
<thead>
<tr>
<th>I.</th>
<th>Well formed geodes with chalcedonic shells.</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>Hollow geodes.</td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Interior lined with crystalline quartz</td>
<td>2</td>
</tr>
<tr>
<td>2.</td>
<td>Like I A 1 but quartz crystals bearing elongated crystals of magnetite upon their surfaces</td>
<td>1</td>
</tr>
<tr>
<td>3.</td>
<td>Like I A 2 but containing calcite also</td>
<td>1</td>
</tr>
<tr>
<td>4.</td>
<td>Like I A 1 but containing calcite also</td>
<td>3</td>
</tr>
<tr>
<td>5.</td>
<td>Like I A 4 but containing calcite</td>
<td>7</td>
</tr>
</tbody>
</table>

II. Solid and imperfectly developed geodes:

| A. | Interior partly filled with shaly material | 8 |
The same feature is illustrated even more forcibly by the mineralogical nature of the geodes which occur in a band along a ravine which cuts into the Lower Warsaw in the vicinity of the Fort Madison and Appanoose Stone Company’s quarry near Niota, Illinois. The geodes obtained from this band were as follows:

I. Well formed geodes with siliceous shells.
   A. Hollow geodes.
      1. Interior lined with mammillated chaledony.
         (a) Metallic sulphides wanting .............................................. 6
         (b) Chaledony bearing pyrite.
            1. Without calcite .......................................................... 3
            2. With calcite .................................................................. 1
         (c) Chaledony bearing sphalerite ........................................... 1
      2. Interior lined with quartz crystals.
         (a) With pyrite .................................................................. 1
         (b) Without pyrite .............................................................. 1
      3. Interior lined with crystals of calcite.
         (a) With pyrite .................................................................. 2
         (b) Without pyrite .............................................................. 2
   B. Solid geodes.
      1. Solid chaledony .................................................................. 1
      2. Solid calcite .................................................................... 3

II. Imperfectly developed geodes; containing shaly matter.
   A. Without kaolin ................................................................... 3
   B. With kaolin ........................................................................ 1

The formations overlying the Lower Warsaw do not appear to have influenced geode development, for geodes occur at localities where the overlying strata are still preserved, as well as at localities where they have been completely eroded. Thus, at Warsaw the geodiferous beds are succeeded above by the Upper Warsaw formation; but at Lowell the beds are overlain at the most productive point only by drift.

The presence or absence of unconformities between the Lower Warsaw and the overlying formations, however, may have had some influence, but it is believed that the effect, if there was any, had to do with the time of origin rather than with the mode of development.

IMPORTANT LOCALITIES

Some of the most typical localities for studying the Lower Warsaw and its geodes have already been mentioned in connection with the discussion of the stratigraphy of the beds. But reference is again made to these localities with greater emphasis.

The best known localities, without a doubt, are Keokuk, Iowa, placed on the geodes.
and Warsaw, Illinois. It was from these places that A. H. Worthen collected many specimens to distribute among the museums of the world. The same localities have, in more recent years, afforded most of the geodes taken from the region for museum and ornamental purposes.

The Lower Warsaw is most typically developed at Keokuk along Soap creek near the end of Fourteenth Street, but it is exposed also along the west bluff of Mississippi river from the Union station southward for a distance of at least two miles. The Soap creek exposure is most satisfactory for the study of geodes. A section of the beds at this locality has been recorded earlier in this report. (See page 193.)

The most characteristic geodes at this locality are the thin-shelled siliceous types which bear crystals of dolomite and ankerite. These are best developed in the lower part of the formation but on account of the fragile nature of their siliceous shells they have been broken in most instances by the scaling off of large flakes of the containing rock which adheres tightly to the geodes.

The geodes of the upper part of the beds are much smaller than those from the lower part, and like those from Warsaw at this horizon, many of them contain the white powder of kaolin. The subjoined table will indicate the general character of the geodes occurring in a persistent band near the middle of the upper part of the beds.

1. Geodes well developed and hollow.  
   A. Interior lined with drusy quartz .............................................................. 1  
   B. Interior lined with drusy quartz which bears small crystals of pyrite .............................. 2  
   C. Interior occupied by drusy quartz, pyrite, dolomite and calcite .... 1  
   D. Interior lined with drusy quartz studded with dolomite ....... 3  
   E. Interior lined with drusy quartz, dolomite and pyrite ... ... ... ... ... ... ... ... ... ... ... ... 1  
   F. Interior occupied by drusy quartz, dolomite and kaolin ............ .... 1  
   G. Interior lined with coarse crystals of quartz ............................................... 2  
   H. Coarse crystals of quartz and pyrite ..................................................... 1

2. Geodes well developed but solid ................................................................. 2  

3. Geodes imperfectly developed; interior nearly filled.  
   A. Lined with drusy quartz and dolomite and bearing kaolin ....... 7  
   B. Interior consisting of drusy quartz, dolomite, kaolin and blende.... 1

Another excellent place for studying geodes is along the east bluff of a creek just northeast of the town of Warsaw (fig. 16), where the Lower Warsaw is well exposed. A detailed section of the rocks at this point has been given on page 190. The nature of the geodes at this place is indicated by the tables pre-
sent under the discussion of the mineralogical relationship of
the geodes to the containing rock. (See pages 315 to 317.) One
of the most striking features in connection with the geodes at
this locality is that although they are otherwise quite similar to
the Keokuk specimens, they were not found to bear dolomite,
which is a very characteristic mineral in the geodes at Keokuk.

![Fig. 16.—Geodes in place in Geode bed along creek just northeast of Warsaw, Illinois.](image)

Geodes occur also at Soap Factory Hollow, a creek two
miles south of Warsaw, and along the beds of creeks tributary
to the Mississippi between Warsaw and Hamilton. Of these
creeks Crystal Glen, whose mouth is about two miles above War-
saw, is the most important. Many geodes are strewn along the
bed of this stream and about a mile up the valley an outcrop of
the lower part of the geodiferous phase of the Lower Warsaw
may be seen. The exposure at this point is about eight feet
high and is made up of highly calcareous shale interstratified
with layers of limestone. The geodes occur both in the lime-

stone and in the shale. They are dominantly of the quartz, calcite and quartz-calcite varieties. Metallic sulphides are rare.

At Hamilton geodes are common along Railroad creek but conditions are the most favorable for studying them at the clay pits of the Hamilton Clay Company, situated about one-half mile southeast of town. The bluish nonfossiliferous shales of the upper part of the Lower Warsaw are here used for the manufacture of brick and tile and have been exposed to a maximum thickness of about eight feet. Many geodes which have been picked from the shale in the process of excavation are now scattered over the floors of the pits. More than one hundred of these were broken. Of this number about one-fourth were of the solid quartz variety and the remainder consisted chiefly of hollow quartz geodes whose interiors were in most cases studied with rhombs of calcite or crystals of dolomite or ankerite. A few, however, were found to contain pyrite and an occasional one contained sphalerite. The ankerite is in many cases partly decomposed to limonite. The interior linings of nearly all of the geodes at this place are incrusted, in part at least, with lime carbonate.

Many of the hollow geodes have been fractured transversely and recemented by calcareous material. These are for the most part much discolored in their interiors. The rupture of these is believed to have been caused by the freezing of included water when they were not far below the surface. A few deformed geodes also were observed. Most of these contained kaolin and included clay but a few were found to contain dolomite or ankerite.

The exposure of the Lower Warsaw at Fox City, Missouri, is very interesting from many standpoints. Reference has already been made to the excellent opportunities at this place for studying the relation of the geodes to the containing rock. Many geodes have been collected at this locality and considerable blasting has been done along the face of the bluff to facilitate their removal from the rock. The upper part of the formation at this place furnishes the greatest number of specimens, but they are small and most of them are poorly developed. In size they range from about 0.2 centimeter to 20 centimeters in diameter. Many of the smallest geodes consists of solid chalcedony.
But the larger geodes are usually of the quartz type and many are nearly or quite solid. Other varieties of subordinate importance are the quartz-pyrite, quartz-calcite, quartz-calcite-pyrite and the kaolinitic types.

The geodes from the lower part of the shale are of far greater importance than those from the upper part. At no other known locality in the area can such large and well developed geodes be so satisfactorily studied in place in the rocks. Numerous well formed quartz geodes ranging up to 45 centimeters in greatest diameter may be seen dotting the face of the bluff. They reach their maximum development, however, in a layer six feet in thickness near the base of the exposure. The geodes from this layer may be classified as follows:

A. Geodes exceeding six inches in diameter.
1. Interior hollow.
   (a) Interior lined with quartz crystals which bear small flakes of pyrite upon their surfaces ........................................... 2
2. Solid geodes.
   (a) Interior filled with crystalline quartz ................................ 1

B. Geodes less than six inches in diameter.
1. Interior hollow.
   (a) Pure quartz type .................................................................. 4
   (b) Interior lined with quartz crystals bearing flakes of pyrite ................................................................. 26
2. Solid or almost solid geodes.
   (a) Pure quartz filling the interior ................................................. 2
   (b) Interior filled with quartz which bears pyrite ................. 2

The widespread occurrence of pyrite and the paucity of calcite are the most characteristic features of the geodes at this place.

Another Missouri locality for collecting geodes is near Wayland. A few feet of the Lower Warsaw are exposed about one-half mile southwest of this place, in the east bank of Fox river. Here many of the geodes contain calcite. St. Francisville, Missouri, also is said to be a good locality for quartz geodes.

The geodes from the lower part of the Lower Warsaw at several localities near Niota, Illinois, are strikingly contrasted to those in other occurrences in that many of them are partly or completely filled with a black viscous bitumen. The fact that such bituminous geodes occur in a non-bituminous shale and may be found in close proximity to ordinary geodes which show no trace of bitumen, lends to this feature still greater interest. As a general rule, however, the regular hollow geodes which
occur in the same layers with bituminous types show at least a black stain in their chaledonic shells.

Such bituminous geodes occur along a small creek in the southern limits of Niota. But the most satisfactory place to study them is two miles south of Niota along the north and south forks of a small creek a short distance back from their confluence. At the more northerly of these places bituminous geodes occur only in a layer a few feet in thickness near the base of the Lower Warsaw. Above this layer occur thin-shelled geodes lined with drusy quartz studded with ankerite. These show no traces of petroleum.

The geodes which bear oil are, so far as could be ascertained, no different from the geodes which normally occur at this horizon. Most of them are of either the calcite or the quartz types but some geodes lined with botryoidal chalcedony also contain bitumen. Furthermore, the thickness of the wall seems to have had no great influence, for almost solid quartz geodes have been found to contain a small amount of the crude oil in their centers. No bitumen or carbonaceous material has ever been found included in the quartz. The bitumen, then, must have been introduced at some time subsequent to the development of the geodes. It certainly has not interfered with their development. The source of the oil is not positively known. It may have migrated into the basal part of the Lower Warsaw from the underlying formations. When it penetrated the geodes it must have been in a much more fluid condition than it now is.

Other outcrops of the Lower Warsaw occur along a small creek which empties into the Mississippi about three miles below Niota. Near the sources of this creek many rounded calcareous nodules occur in a layer of shale exposed along the bed of the stream. One of these masses was found when broken to bear a geodic cavity lined with calcite.

Toward the mouth of the same stream, however, the geodiferous shales are exposed in their usual facies. They are capped with drift at this point and are underlain by the upper ledges of the Keokuk limestone. The maximum exposure of the Lower Warsaw is about thirty feet. The geodes at this place have nearly all been deformed by the weight of the overlying sediments and in consequence of such deformation the upper or
lower sides of many of the geodes were crushed inward before geodization was complete. Their interiors are now occupied by impure clay and kaolin. No bitumen was found in any of the geodes at this locality, although conditions were favorable for its retention. A similar condition prevails at the outcrops above Niota. Thus in the ravine near the Fort Madison and Appanoose Stone Company’s quarry, no trace of oil was found, although well developed geodes occur at that place.

The most famous, and in fact the only known, locality for collecting geodes in Henry county, Iowa, is east of Lowell, in Baltimore township, along Mud creek, a tributary of Skunk river. Many geodes occur along the bed of this stream and several outcrops of the Lower Warsaw appear. The first outcrop of the Lower Warsaw to be seen in following up this creek from its mouth is one in the southern part of section 27 at the west end of the iron bridge on the Lowell road. The beds are succeeded above by St. Louis limestone. The exposure of the Lower Warsaw at this place, however, is largely concealed and cannot be satisfactorily studied. But a few rods farther upstream a low bluff capped with drift on the east side of the stream furnishes a section sixteen feet in thickness. The upper ten feet of the beds at this place is very argillaceous, but the lower six feet is calcareous and some of the layers approach in composition an impure magnesian limestone.

The geodes of the more shaly part are small, imperfectly developed and nodular. The siliceous shells of these are of a reddish color and in some specimens the red tint shows through the transparent druses of quartz which line the interior. The lower part, on the other hand, bears more perfectly developed geodes which are dominantly of the quartz type. These have a maximum diameter of more than ten inches. Flakes of pyrite or single crystals of sphalerite occur in the interiors of some of these geodes while a few were found which were filled with water. A short distance above this point and just west of the second wagon bridge which spans Mud creek appears a third outcrop of the beds. At the base of this section appears a layer which was not exposed at the above described section. At the top of the basal layer there occurs a band which is thickly
set with rounded nodules which appear to be more calcareous than the containing rock.

Still farther up the creek the uppermost ledges of the Keokuk beds appear in the bed of the stream, a fact which suggests that an anticlinal arch exists at this place. No other exposures of the Lower Warsaw appear until the northern limit of section 27 is reached. Here on the east bank of the stream is a bluff of shale thirty feet in height, without any indurated rocks above the shale beds. Parts of the formation are exposed also a few rods north of this point in the southern part of section 22 in an extension of the same bluff and along the ravines emptying into Mud creek above this place on the same side of the stream. These are the most northerly outcrops of the Lower Warsaw. Beyond this point only the limestones of the Keokuk appear.

The upper part of the Lower Warsaw which is exposed at the bluff in the northern part of section 27 consists of argillaceous shale. The lower part is made up of calcareous shale inter-stratified with bands of impure magnesian limestone. The upper argillaceous portion is twelve feet in thickness and bears many geodes, but most of them are very small. In character they are dominantly of the quartz type. The surfaces of many of the specimens from this level are partly coated with mamillary pyrites and many of their shells are of the red variety of chalcedony. These geodes differ from those from other localities at the same level in that they do not bear kaolin. Many of the imperfect specimens, however, contain impure clay.

Just below the argillaceous member there occurs a band of soft impure buff magnesian limestone which bears large quartz geodes. A few of these have a maximum diameter of two feet. They are usually somewhat lenticular in shape and are chambered within. The walls of some of the geodes from this level are quite thin but others possess very strong shells and can be broken only with great difficulty. In some of the geodes from this layer characteristic twinned crystals of calcite are found.

The formation is poorly exposed at the bluff in the southern part of section 22 but many geodes similar in character to those in the magnesian layer of the above exposure are strewn over the surface of the slope. In addition to the types described
from the foregoing locality there are found at this place a few geodes whose interiors are partly or completely occupied by a soft white gritty variety of silica which in some cases is intersected by a network of veins of transparent quartz. In some chambered specimens this material is limited to one of several chambers but in simple geodes it may occupy the entire interior. In some instances cavities lined with small transparent crystals of quartz appear in the interior of masses of this material.

One small quartz geode from this exposure was found to bear small slender crystals of magnetite and the red powder of hematite. Along the bed of one of the ravines a few rods north of this point there appear many large quartz geodes whose interiors are stained with limonite as the result of the decomposition of small flakes of pyrite which they formerly contained. Several of these geodes have a maximum diameter of two feet, but specimens of such size were invariably found to be of the compound type. None of these large geodes was found in place but judging from the material adhering to their shells they were derived from a layer of impure magnesian limestone.

A short distance farther up the creek many geodes are to be found in the drift on the west side of the creek. Beyond this point a few appear along the bed of the creek as far north as the bridge crossing the stream in the northern part of section 22.

Satisfactory outcrops of the Lower Warsaw in Des Moines county are rare and apparently the typical geodiferous phase of the subdivision is lacking, for well developed geodes were not found.

Near Denmark in Lee county an interesting exposure of the Lower Warsaw is to be found along a small stream flowing through the old Leverett estate, two miles northwest of the town. In the bed of this creek there appears at one point a layer of calcareous shale which bears many siliceous and calcareous nodules some of which are geodic. Some of the calcareous nodules are inclosed by chalcedonic shells and the resemblance of these to the siliceous masses strongly suggests that the latter have been formed by the replacement of their calcareous content by silica. Furthermore the similarity of the geodes to such calcareous and siliceous nodules is striking. The
surfaces of many of the nodules and geodes at this place are partly encrusted with pyrite. Well developed geodes are not common and the majority of those found are of the calcite or chalcedony types. Of the calcite geodes some are lined with rhombohedral calcite but others bear dog tooth spar. Some of the latter variety bear sphenoids of chalcopyrite. Many of the chalcedony geodes, on the other hand, lack characteristic mamillary structure. Some of the hollow specimens bear perfect cubes of unaltered pyrite in their interiors.

Other interesting localities for studying geodes occur in Van Buren county. The most important of these are: along Indian creek across the river from the town of Farmington; along Bear creek one-half mile south of Vernon; and along Copperas creek about two miles northwest of Bentonport. At the Farmington and Vernon localities rounded calcareous nodules, some with and some without inclosing shells of chalcedony, are common in the shale. Some of these are hollow and lined with crystals. Exteriorly most of such masses are indistinguishable from the typical geodes with which they are occasionally associated, but when they are broken their true character is revealed. Many of those which are hollow bear a brownish variety of calcite upon which in some cases there are superimposed bright transparent rhombohedrons of the same mineral of a later period of growth. Elongated crystals of pyrite are frequently found in association with this last variety of calcite.

In many of the solid nodules there is considerable evidence of the partial replacement of original calcareous material by silica. This replacement product commonly assumes the form of irregular patches of reddish chalcedony but in some specimens rounded masses of bluish chalcedony occupy part of the interior. In addition some specimens bear many radiating groups of small quartz crystals imbedded in the mass.

The Copperas creek locality is noted mainly for the deformed condition and the irregular surfaces of the geodes. But the occurrence of bands and lenticular masses of reddish siliceous material intermixed with calcite also is of considerable interest. The upper and lower surfaces of such bands and masses are thickly set with small nodular elevations which generally are blended together and many of which are geodic.
DESCRIPTION OF GEODES

Over seventy-five per cent of the geodes at this place are either crushed or of a very irregular shape, and only a fraction of the well rounded specimens attain a normal state of development. Among the few well formed specimens one geode of the quartz type was found to bear slender elongated crystals of magnetite partly decomposed to limonite.

DESCRIPTION OF TYPICAL GEODES

The mineralogical variations of the geodes are such that it is impossible to give a general description of their characters which is satisfactory. In order that the many mineralogical relationships may be fully presented a number of typical geodes are described below.

Geode No. 1.—Shape roughly oblong. Surface bearing minute concretionary masses of chalcedony and in places exhibiting faint slickensided structure. Dimensions 23.1 by 18.2 by 15.6 cms. Interior hollow; wall 0.5 cm. to 5. cms. thick. Chalcedonic shell 0.1 to 0.7 cm. in thickness. Cavity lined with transparent terminations of quartz crystals. When it was broken this geode was partly filled with water.

Position and locality: In place in an exposure of the Lower Warsaw along the east bank of Mud creek, just above the iron bridge east of Lowell, Henry county.

Geode No. 2.—Shape lenticular; surface fairly smooth but showing minute concretionary protuberances. Dimensions 15.1 by 14.1 by 8.8 cms. Interior hollow; wall 0.85 cm. to 2.8 cms. in thickness; chaledonic shell not distinctly marked off; outer part consisting in large part of fine-grained calcareous material partly replaced by concretionary silica; inner part occupied by an irregular band of bluish chalcedony. Upon this band there occurs a perfect lining of small transparent quartz crystals to which the underlying chalcedony imparts a bluish tint.

Position and locality: Basal part of Lower Warsaw two miles northwest of Denmark, Lee county.

Geode No. 3.—Shape approximately spheroidal with slight compression at one point. Surface exhibiting many small

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3 The dimensions given are the greatest in each of the three directions. Statements made regarding the thickness of the wall or of the chalcedonic shell are based only upon the section obtained in breaking the geodes.
rounded elevations of chalcedony. Adhering shale showing slight slickensided structure in direction of greatest diameter. Dimensions 18.6 by 17.3 by 15.8 cms. Interior hollow; separated by a perforated partition into two almost equal chambers. Outer wall 2.2 to 3.75 cms. in thickness, outer shell of chalcedony averaging 0.35 cm. in thickness. Inner part of wall occupied by crystalline quartz. Chambers lined with pointed quartz crystals. In one chamber there is superimposed upon this quartz a thin layer of bluish chalcedony. No trace of this mineral is to be found in the other chamber. Both chambers slightly iron stained. Close study of this geode shows that it is compound in character, having resulted from the union of two individuals. The presence of the chalcedony in only one chamber, however, when the intervening wall offers no resistance to passage of solutions, is difficult to explain.

Position and locality: Along the bed of Mud creek in section 27 of Baltimore township, Henry county.

*Geode No. 4.*—Shape lenticular, with lower side compressed, upper surface corraded in places, bearing the usual concretionary elevations and marked with several gougelike depressions; lower surface smooth but irregular. Dimensions 29 by 28.2 by 17.25 cms. Interior nearly solid. Outer shell of chalcedony ranging from practically nothing to 0.8 cm. in thickness; bearing a single minute crystal of sphalerite. Succeeding this shell inwardly there is a band of unequal thickness of solid crystalline quartz analogous to that which lines ordinary quartz geodes. Resting upon this and coating the quartz crystals there appears a layer of banded chalcedony averaging 0.8 cm. in thickness. Following this there occurs a second layer of quartz more finely crystalline than the first. In a part of the cavity there is a thin coating of chalcedony on the terminations of the crystals of this layer. Implanted on this coating are a few cubes of pyrite, and in the lower part of the cavity there is a slight incrustation of calcium carbonate. A large part of the cavity is occupied by a mass of crystalline calcite, which bears included flakes of pyrite. About the periphery of this mass are crystals consisting of a combination of hexagonal prisms of the first order with the negative rhombohedon.

Position and locality: Along the bed of a ravine tributary
to Mud creek in the southern part of section 22, Baltimore township, Henry county.

*Geode No. 5*—Shape globular. Surface fairly smooth and regular. Dimensions 16.5 by 14.8 by 13.9 cms. Interior hollow, lined with botryoidal chalcedony. Width of lining 0.35 cm. to 2.7 cms. Outer chalcedonic shell 0.2 cm. to 1.3 cms. thick; bearing a trace of calcareous material. Line of contact with inner layer of chalcedony in general very irregular. Lining of botryoidal chalcedony showing faint evidence of banding and marked by numerous rounded pits which extend out to the crust. One such pit of irregular shape is filled with crystalline sphalerite which is decomposing to smithsonite. The latter mineral forms an incomplete crust over the unaltered sulphide. A slight deposit of the same mineral forms a coating in the bottom of the cavity of the geode. In addition there are a few flakes of gypsum.

Position and locality: In place in the Lower Warsaw along a ravine near the Fort Madison-Appanoose stone quarry, near Niota, Illinois.

*Geode No. 6*—Shape subglobose. Surface with many small rounded concretionary protuberances of chalcedony. Dimensions 8.3 by 8.1 by 7.1 cms. Interior hollow; wall siliceous; thickness 0.4 cm. to 2.1 cms. Outer shell of chalcedony 0.3 to 0.5 cm. thick. Cavity lined with terminations of small quartz crystals bearing slender prismatic crystals of magnetite, and stained with the reddish powder of hematite. The hematite is later than the magnetite for it forms a coating on some of the crystals of that mineral.

Position and locality: From an exposure in the east bank of Mud creek in the southern part of section 22, Baltimore township, Henry county.

*Geode No. 7*—Shape roughly spheroidal. Outer surface with irregular elevations. Dimensions 17 by 14 by 13.5 cms. Interior hollow; walls chalcedonic, 1.2 to 3 cms. thick, showing no trace of banding. Shell not distinct. Cavity lined with drusy quartz which possesses a sufficient coating of chalcedony to give it a milky white appearance. Thickly implanted upon this material are small, slightly tarnished cubes of pyrite. In one part of the
cavity there also are one large and several small crystals of calcite. The large crystal is of the same form as that found in geode No. 4. It envelops pyritiferous drusy quartz and is clearly younger than that mineral. In one part of the wall there occurs a pocket of calcite which bears inclusions of pyrite.

Position and locality: In place in lower part of Lower Warsaw two miles northwest of Denmark.

Geode No. 8.—Vertical section subcircular, horizontal section subquadrangular. Surface with minute elevations. Dimensions 9.15 by 8 by 6.6 cms. Interior hollow; wall siliceous, averaging about 1.6 cms. in thickness. Chalcedonic shell 0.25 to 0.5 cm. thick, bearing small pockets of kaolin. Succeeding the shell there is a band of crystalline quartz, which is again followed by a coating of chalcedony of differing thickness. Many small bright cubes of pyrite occur on this coating and a few minute crystals and a thin incrustation of gypsum occur in a part of the cavity. A few stains of limonite were observed on the chalcedonic lining.

Position and locality: In place in Lower Warsaw bed along Soap creek, Keokuk.

Geode No. 9.—Geode large, sub-ovate; longer and wider than high. Surface smooth but marked by irregular elevations and depressions. Dimensions 39 by 37 by 25.3 cms. Interior occupied for the most part by a large rounded mass of cryptocrystalline silica coated with crystalline quartz. Several quartz-lined cavities intervene between this mass and the wall of the geode.

Position and locality: In Lower Warsaw beds along Mud creek, south part of section 22, near Lowell.

Geode No. 10.—Shape spheroidal; surface with small irregular protuberances and minute rounded elevations. Dimensions 13.8 by 12.3 by 10.7 cms. Wall siliceous; interior hollow, lined with quartz crystals, and almost completely filled with black viscous bitumen.

Position and locality: Along bed of creek south of Niota, Illinois.

Geode No. 11.—Shape, nodular; flattened upon one side by contact with another specimen; surface smooth. Dimensions
9.8 by 7.8 by 6.6 cms. Interior hollow; wall about 1.1 cms. in thickness; outer part consisting of a thin shell of chalcedony; inner part made up of fine-grained impure calcareous material. Lining this wall are small scalenohedrons of calcite on which are numerous flakes and sphenoids of chalcopyrite.

Position and locality: In place in lower part of Lower Warsaw, two miles northwest of Denmark.

*Geode No. 12.*—Shape nodular; surface irregular. Dimensions 12.5 by 11.2 by 8 cms. Interior hollow; wall 0.55 cm. to 1.5 cms. thick, consisting of finely crystalline calcareous material; no trace of a chalcedonic shell. Brownish rhombs of calcite, some which are much elongated, line the wall, and implanted on them are small tarnished crystals of pyrite which exhibit the faces of the pyritohedron. Superimposed upon both minerals are many clear, transparent rhombs of Iceland spar with which are associated acicular crystals of unaltered pyrite either as inclusions or as freely projecting needles which upon superficial examination might be mistaken for millerite. Two periods of mineralization are indicated by this geode.

Position and locality: In place in the upper part of the Lower Warsaw beds along Indian creek near Farmington, Van Buren county.

*Geode No. 13.*—Shape lenticular. Surface rough and irregular, partly coated with mammillary pyrites. Dimensions 21 by 19.1 by 11.4 cms. Interior hollow; wall siliceous, 0.8 cm. to 3 cms. thick. Outer shell of chalcedony distinct; showing concretionary structure; partly replaced by pyrite 0.2 cm. to 1.1 cms. in thickness. Cavity lined with quartz and occupied in part by a large mass and smaller aggregates of calcite which are thickly set with included flakes of pyrite. Small crystals of pyrite are implanted upon the quartz also and the latter mineral is partly coated with an incrustation of calcium carbonate.

Position and locality: Along bed of ravine emptying into Mud creek near Lowell.

*Geode No. 14.*—Shape irregular and nodular, surface with concretionary elevations of chalcedony. Dimension 8.5 by 7 by 6.5 cms. Wall siliceous, averaging about 0.6 cm. in thickness. Outer shell of chalcedony 0.1 to 0.5 cm. thick; concretionary;
bearing a few small cavities filled with kaolin. Interior of wall thickly set with small pointed quartz crystals beyond which occur aggregates of dolomite crystals, which possess characteristic curved surfaces. Remainder of cavity almost filled with white fluffy powder of kaolin. Solution of several dolomite crystals from different places in the cavity showed that some contained inclusions of kaolin, for a cloudy liquid resulted in a few instances. Microscopic examination of the quartz, however, did not reveal any inclusions of the powder in it.

Position and locality: In place in bluff back of Harrison lumber mills two miles below the Union Station at Keokuk.

Geode No. 15.—Shape subglobose; surface rough and irregular. Dimensions 11.3 by 9.9 by 9.3 cms. Interior hollow; wall 1.8 to 5.1 cms. in thickness; outer part siliceous; inner part dolomite. Chalcedonic shell concretionary, 0.5 cm. to 2 cms. thick, containing small cavities and irregular pockets of limonite and kaolin. Inner lining of dolomite continuous. Shell succeeded by massive dolomite in lower part on which are superimposed crystals of the same mineral. But in the upper part crystals of dolomite succeed the siliceous shell directly. The crystals are rhombohedrons with characteristic curved surfaces.

Position and locality: In upper part of fossiliferous phase of the Lower Warsaw, two miles below the Union Station at Keokuk.

Geode No. 16.—Geode small, globular; surface bearing minute rounded elevations of chalcedony. Dimensions 7 by 7 by 6.3 cms. Interior hollow; wall thin, consisting of a shell of chalcedony, averaging 0.5 cm. in thickness, succeeded in all but what seems to be the lower part, by a thin layer of drusy quartz. In the part excepted, a layer of the massive quartz containing one large and several small pockets of limonite intervenes between the shell and the drusy coating. Superimposed upon the quartz lining are a few rhombs of calcite, the largest of which measures 1.3 cms. in diameter, and several aggregates of ankerite crystals. A whitish efflorescent-like coating of calcium carbonate is present as an incrustation on these minerals and on the drusy quartz.

*Geode No. 17.*—Geode small, nodular; surface rough. Dimensions 6.0 by 5.5 by 38.0 cms. Wall thin, averaging 0.5 cm., consisting of an outer shell of chalcedony lined with a thin layer of whitish granular calcite upon which appear numerous minute crystals of pyrite. Interior almost completely filled with flaky kaolin. The calcite crystals contain minute flakes of this mineral.

Position and locality: Lower Warsaw along bluff back of Harrison lumber mills two miles below Keokuk Union Station.

*Geode No. 18.*—Geode large; shape very irregular; surface rough and uneven. Dimensions 37.3 by 29.0 by 28.5 cms. Entirely siliceous. Wall averaging about two centimeters in thickness; lined with crystals; chalcedonic shell distinct. Interior occupied by a large mass of chalcedonic silica which is covered by a coating of crystalline quartz, some of the crystals of which are united with those of the wall. The whole interior is strongly stained with limonite, and locally it is incrusted with calcium carbonate.

Position and locality: Along bed of a ravine in southern part of section 22 of Baltimore township, Henry county.

*Geode No. 19.*—Geode of medium size, subglobose; surface rough, irregularly pitted. Dimensions 11.5 by 10.8 by 8.5 cms. Interior hollow; wall averaging about 2.5 cms. in thickness; chalcedonic shell distinct, bearing minute cavities, some of which are filled with kaolin. Following this is a layer of crystalline quartz, the interstices of which are filled with chalcedony. Superimposed upon the quartz layer and lining the interior of the geode is a band of chalcedony about three-tenths centimeter thick which bears botryoidal prominences. A few bright untarnished flakes of pyrite rest upon the surface of the chalcedony. In the lower part of the cavity there is a yellowish stain of limonite.

Position and locality: In place in Lower Warsaw, along Soap creek, Keokuk.

*Geode No. 20.*—Shape nodular and very irregular; surface bearing many rounded elevations, as if formed by the coal-
escence of many small nodules. Dimensions 14.8 by 13.1 by 9.1 cms. Interior hollow; wall siliceous, averaging about 2.4 cms. in thickness. Outer shell of chalcedony exhibiting faint traces of banding; about 0.4 cm. thick. Inner part of wall consisting of massive crystalline quartz. Cavity lined with closely intergrown crystals of quartz. In one part of the cavity there occurs a small mass of crystalline calcite about two centimeters long and one centimeter wide, and implanted upon both the quartz and calcite are slender prismatic crystals of magnetite. There is a slight incrustation of calcium carbonate in what seems to be the lower part of the cavity.

Position and locality: In Lower Warsaw, along Copperas creek two miles northwest of Bentonsport, Van Buren county.

**Geode No. 21.**—Size small; bun-shaped; surface fairly smooth. Dimensions 9.4 by 8.4 by 4.7 cms. Interior hollow; wall about 0.7 cm. thick; outer half consisting of reddish chalcedony which has a concretionary structure; inner part consisting of discolored crystalline calcite. Cavity lined with imperfect scalenohedrons of brownish discolored calcite.

Position and locality: In place in Lower Warsaw, along Bear creek near Vernon, Van Buren county.

**Geode No. 22.**—Shape approaching lenticular but laterally compressed. Surface with minute elevations of chalcedony. Dimensions 11.0 by 10.8 by 8.3 cms. Interior hollow; wall siliceous; outer shell distinct, showing a reddish tint. Interior of wall lined with drusy quartz which, for the most part, is iron stained. Implanted upon this quartz occur many small cubes of pyrite which are decomposing to limonite. Superimposed indiscriminately upon quartz and pyrite there are, in some parts of the cavity, small twinned rhombohedrons of calcite. Related to all three minerals and obviously subsequent to them are a few slender projecting crystals of gypsum of the usual form. One elongated crystal has a length of 1.5 cms., its greatest width being not more than 0.1 cm.

Position and locality: In place in Lower Warsaw beds along bluff of Mud creek in southern part of section 22 of Baltimore township, Henry county.
Minerals of the Geodes and the Inclosing Rocks

Quartz (Rock Crystal), SiO₂.—This is the most common mineral found in the geodes. The majority of specimens are either lined or completely filled with crystalline quartz. The crystals almost without exception consist of the first order hexagonal prism terminated with positive and negative rhombohedrons. Usually only the pyramidal terminations line the cavities of the quartz geodes, but doubly terminated crystals are found loose in the interiors of some specimens.

Chert, SiO₂.—Discontinuous bands and irregular nodules of chert occur in the Keokuk limestone and in the limestone layers of the Lower Warsaw. The relation of the material to the limestone suggests that it has resulted from the replacement of that rock.

Chalcedony, SiO₂.—The outer siliceous shell which covers almost all geodes is of the variety of quartz known as chalcedony. The same mineral also occurs as a bluish lining with botryoidal prominences in the interior of some geodes and it appears commonly as a coating on the surfaces of the quartz crystals which line the cavities. In the first mode of occurrence the chalcedony in most cases has a concretionary structure, but in the last two modes it may show only faint evidence of banding.

Calcite, CaCO₃.—This is a common constituent of the geodes and its relationships are such as to indicate at least two periods of formation. This mineral is most commonly found as isolated crystals or crystal aggregates on the quartz of quartz geodes. But calcite in some instances succeeds the siliceous shell directly. In all geodes not characterized by chalcedonic shells and in the geodic calcareous nodules this mineral lines the interior. The calcite of the Keokuk limestone in some cases includes crystals of metallic sulphides such as hairlike tufts of millerite, sphenoids of chalcopyrite and slender elongated crystals of pyrite. In the Lower Warsaw, on the other hand, some of the crystals include the white powder of kaolin and a few of them contain flakes of pyrite. But in many of the geodes from this horizon the calcite was deposited subsequently to the pyrite. The crystals of the earlier period of formation exhibit a variety
of forms and some of them show a brownish discoloration. The most common forms of the calcite of this age are the rhombohedron, the scalenohedron, and the scalenohedron modified by the rhombohedron.

Much of the calcite of later growth consists of bright, transparent rhombohedrons of Iceland spar, some of which rest on calcite of earlier growth. Other forms assumed by the calcite of this age are the rhombohedron, the hexagonal prism of the first order in combination with the rhombohedron, and a twinned rhombohedron.

**Dolomite, CaCO₃, MgCO₃**—Rhombohedrons of this mineral exhibiting characteristic curved surfaces are commonly found in the geodes at Keokuk, Iowa, and Niota, Illinois. The dolomite appears as aggregates of crystals resting on the quartz of the geodes, or it follows the siliceous shell directly.

**Ankerite, (Ca.Mg.Fe)CO₃**—Some of the crystals outwardly resembling dolomite possess a high iron content and undoubtedly they are to be classed as ankerite. The decomposition of these crystals generates a considerable amount of limonite. The limonite thus formed is in many instances a more or less perfect pseudomorph after the ankerite.

**Magnetite, Fe₃O₄**—Slender elongated crystals of magnetite appear in the interiors of some of the geodes from the Lower Warsaw. In most cases the crystals of this substance are implanted on quartz, but in one instance they occur on both quartz and calcite. Microscopic examination shows that some of the magnetite crystals have been partly altered to limonite. This mineral has not been reported previously from the geodes.

**Hematite, Fe₂O₃**—In a few of the geodes from the Mud creek locality the reddish powder of hematite is found staining the interior lining of quartz. Geode No. 6 exhibits such a relationship.

**Pyrite, FeS₂**—Pyrite is by far the most abundant metallic mineral associated with the geodes. It occurs both in the geodes from the Keokuk limestone and in those from the Lower Warsaw. It is found also as free crystal aggregates in the
shale and as a mammillaried coating on the surface of some geodes of the Lower Warsaw.

Within the geodes, pyrite of at least two periods of growth appears. Geode No. 12 illustrates this feature excellently. This mineral favors no particular associations for its crystals. They occur implanted indiscriminately upon quartz, chalcedony, or calcite. In some specimens it is also included in calcite. The pyrite of such inclusions is almost invariably in a fibrous or flaky condition. This is especially true of the geodes of the Keokuk limestone. Geode No. 13 from the Lower Warsaw exhibits such a relationship. The majority of the uninclosed crystals of pyrite assume more or less well developed forms, but in a few geodes, of which No. 12 is the type, there are slender elongated crystals which might easily be mistaken for millerite. The hexahedron is the most common of the crystal forms which are normally found. Others which have been noted are the pyritohedron and the cube with octahedral modifications. Decomposition of the pyrite has taken place in many of the geodes and bright unaltered crystals are not often found. The alteration has been accompanied by the formation of limonite in each case and the interiors of many of the geodes are, as a consequence, strongly iron stained.

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c
erite, NiS.—M
erite has been found in the geodes of the Keokuk limestone at Keokuk and in the geodic cavities of the Montrose chert exposed in the excavation for the dam at the same city. In both of these occurrences the millerite is closely associated with calcite. In but a single instance was it found on quartz. Many of the slender needles of this mineral are included in the calcite, but some freely projecting tufts are found. The inclusions resemble very much the flakes of pyrite found in the calcite of the geodes of the Lower Warsaw.

Chalcopyrite, CuFeS₂.—Small sphenoids of this mineral have been found in the geodes both from the Keokuk limestone and from the Lower Warsaw at the locality northwest of Denmark. At no other place in the area was this mineral found in these beds. The crystals of this substance are always associated with calcite. None has ever been found on quartz. In the Keokuk limestone the small sphenoids are entirely included by the cal-
cite, but in the geodes of the Lower Warsaw crystals of chalcopyrite are implanted on the surface of rhombohedrons and scalenohedrons of this mineral.

*Sphalerite, ZnS.—*Sphalerite is commonly found in the geodes both from the Keokuk limestone and from the Lower Warsaw. It occurs as irregular crystalline masses which range in size from very small particles to those having a diameter of four inches. It is usually associated with calcite and the two minerals are in many instances so intergrown as to indicate a contemporaneous deposition. In some geodes, however, sphalerite is found with quartz.

In the Lower Warsaw the crystals of sphalerite attain their greatest development in those geodes which have been crushed, or which are otherwise imperfectly developed. Crystals of blende are not common in well formed specimens. This mineral is very common in the large rounded masses which occur in the Keokuk limestone two miles northwest of Denmark. At no other place in the region is sphalerite known to be so abundant.

*Limonite, 2Fe₂O₃+3H₂O.—*Limonite is the most common alteration product of the geodes and the interiors of a large percentage of the specimens are discolored by this mineral. The hydrate of iron has two common modes of origin, namely, by the alteration of pyrite and by the decomposition of ankerite. It occurs either as a rusty stain or as small ochrous masses in the interiors or in the shells of the geodes.

*Smithsonite, ZnCO₃.—*The carbonate of zinc occurs in some geodes as an alteration product of sphalerite, with which it is closely related. It usually appears as an encrusting film over the unaltered sulphide.

*Malachite, CuCO₃+Cu(OH)₂.—*The green basic carbonate of copper is associated with the small sphenoids of chalcopyrite in some of the geodes which occur in the Keokuk and Lower Warsaw beds northwest of Denmark.

*Kaolin, Al₂O₃, 2SiO₂+2H₂O.—*In some of the geodes there occurs the flocculent white powder of kaolin. This mineral is commonly found in the specimens from the upper argillaceous part of the Lower Warsaw at Keokuk, Iowa, and Warsaw, Illi-
noises, but it also occurs in imperfectly developed geodes at other localities. Examination of the powder under the microscope shows it to be in the form of fine scales. The relation of this mineral to the argillaceous material in some of the specimens suggests that it may have been formed by a leaching process. Most of the geodes in which it occurs are poorly developed and the calcite found in some kaolinitic specimens includes the white powder of this mineral. In such cases the kaolin evidently was formed early in the history of the geodes.

_Gypsum_, CaSO₄·2H₂O.—Gypsum occurs in the shales of the Lower Warsaw as irregular flakes and in a few of the geodes from the same horizon as incrusting films and tabular monoclinic crystals.

_Water_, H₂O.—Some of the geodes, as has been stated, contain water. No analysis of this water was undertaken by the writer for it was thought that little emphasis could be placed upon the result, since circulation and diffusion must have continued long after the geodes were formed. Professor Brush, however, has made a chemical examination of the water contained in a geode from this region. His report follows:

"A portion of this water weighing 16.327 grammes, gave, on evaporation, a crystalline residue weighing .094 grammes, which on analysis, proves to consist of sulphate of lime and sulphate of magnesia, with minute traces of silica. Another sample was examined for carbonic acid with a negative result."

The character of this sample suggests that the water was introduced after the geode was formed.

_Bitumen._—A hydrocarbon. In the vicinity of Niota, Illinois, many of the geodes from the Lower Warsaw are partly or completely filled with a black, viscous asphaltic bitumen. In a few specimens from this place a black solid hydrocarbon was found. This has resulted undoubtedly from the natural distillation of lighter hydrocarbon from the liquid bitumen commonly observed.

In many cases the rocks containing bituminous geodes show no evidence of bitumen but the shells of some of the geodes are strongly discolored with this material.
PARAGENESIS OF THE MINERALS

In the discussion of the order of deposition of the minerals only the primary ones are considered. With reference to these minerals, no constant order of succession holds for all geodes, and the same order of formation may not obtain in two adjacent specimens.

For the purpose of illustrating the variations in the succession of the minerals in the geodes the order of their deposition in a number of typical specimens is given. The chalcedony of the shells of the geodes is listed first for it must be conceded that this was formed prior to the deposition of the minerals now found in the interior of the geodes.

1. Chalcedony, quartz.
2. Chalcedony, quartz, chalcedony.
3. Chalcedony, chalcedony, quartz.
4. Chalcedony, quartz, chalcedony, pyrite.
5. Chalcedony, chalcedony, sphalerite.
6. Chalcedony, quartz, chalcedony, quartz, chalcedony, pyrite, calcite with included pyrite.
7. Chalcedony, quartz, chalcedony, pyrite, calcite.
8. Chalcedony, quartz, calcite with included pyrite.
9. Chalcedony, quartz, pyrite, calcite.
10. Chalcedony, quartz, pyrite, calcite with included pyrite.
11. Chalcedony, quartz, chalcedony, pyrite, sphalerite.
12. Chalcedony, quartz, dolomite, calcite.
13. Chalcedony, quartz, calcite, calcite.
14. Chalcedony, quartz, magnetite, hematite.
15. Chalcedony, quartz, pyrite, magnetite.
16. Chalcedony, quartz, pyrite, dolomite.
17. Chalcedony, quartz, dolomite.
18. Chalcedony, quartz, bitumen.
19. Chalcedony, quartz, calcite, bitumen.
20. Chalcedony, quartz, ankerite, calcite.
22. Chalcedony, calcite, chalcopyrite.
23. Chalcedony, calcite, calcite and chalcopyrite.
27. Calcite and millerite.
28. Quartz, millerite.

First in the process of development of the siliceous geodes there was formed in nearly every case a thin chalcedonic shell. Upon this is superposed quartz, in either the crystalline or chalcedonic condition, or calcite. But where quartz is present in the specimens studied it always rests on the siliceous shell or on an inner layer of chalcedony.

The cause of the alternation of crystalline quartz and chalcedony in some of the geodes is not known. If the layers were all
formed during one period of growth, as seems probable, changes in the condition and amount of silicia supplied may have given rise to the phenomenon. Changes in temperature or pressure cannot be appealed to because in many cases adjacent quartz geodes in the strata show no such alternations.

The position of calcite in the geodes is subject to even more variations. In some instances it succeeds the chaledonic shell directly, but in more cases it rests upon a lining of quartz or chalcedony. Two distinct periods of growth of this mineral are indicated. In some of the geodes calcite of both generations appears. Geode number 12 illustrates this feature excellently. In some specimens the earlier calcite is discolored and in many cases it is contemporaneous with, or directly followed by sphalerite, millerite, chalcopyrite, or pyrite. Crystals of dolomite or ankerite are sometimes found intervening between the earlier calcite and that of later age. These crystals rest directly upon calcite or quartz or in some instances upon the pyrite which succeeds them. Much of the calcite of later formation is clear and transparent, and some of the crystals are characteristically twinned. Pyrite is commonly associated with this variety of calcite, either as included flakes or as implanted crystals. The occurrence of crystals of magnetite on calcite of this age in geode number 20 suggests that deposition of this mineral directly followed.

The kaolin which occurs in some of the geodes has no constant relationship. In some instances it occupies the interior of well-formed geodes (see geode number 14) but in most cases it appears in imperfect specimens. In the latter condition the kaolin evidently is residual for it has interfered with the normal geode development. In the more perfectly formed kaolinitic types, however, the material may possibly have been introduced after the geodes were formed. But the evidence is in favor of the view that it is an original constituent.

**Origin of the Geodes**

The following discussion of the origin of the geodes is taken from an earlier paper by the writer.⁶

The origin of the geodes of the Keokuk and Lower Warsaw

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beds has long been a disputed question, and, although there has been considerable speculation upon the subject, no one theory of their development has, as yet, been widely held. The existence of perfectly developed geodes in strata often very impervious to underground circulation furnishes a problem which is exceedingly difficult to solve. The containing rock is in many cases highly argillaceous and no structures which might serve as passage ways for mineralizing solutions are to be seen.

It was formerly believed that the geodes were formed by the deposition of mineral matter on the walls of cavities formed by the solution of sponges imbedded in the rocks. Thus, Dana states:7

"They have been supposed to occupy the centers of sponges that were at some time hollowed out by siliceous solutions, like the hollowed corals of Florida, and then lined with crystals by deposition from the same or some other mineral solution."

This theory has had many followers and S. J. Wallace has even gone so far as to coin a generic name for the sponge whose solution is supposed to have afforded the cavities in which the geodes were developed.8 To this genus, called *Biopalla*, eight species were referred upon the basis of difference in size, shape, and surface markings of the geodes. The sponge hypothesis, however, is not now widely held. No evidence of sponges capable of giving rise to geodes has ever been found in the Keokuk or Warsaw beds. Moreover, the geodes vary widely in size and shape, a fact which argues strongly against any theory which presupposes such an origin. Many specimens are nodular and irregularities of the greatest variety characterize their exterior form. It may safely be said that no two of them assume exactly the same proportions.

Professor Shaler, in a paper entitled "Formation of Dikes and Veins,"9 also devotes some space to the development of geodes and, although his studies were based upon geodes known to be of fossil origin which occur in the Knobstone shales of Kentucky, his conclusions may well be considered at this point:

Normal geodes are hollow spheroids and are generally found in shales. They clearly represent, in most cases, a segregation of silica, which has evidently taken place under conditions of no very great heat, brought about by deep burial beneath sediments or other sources of temperature. It is difficult in all cases to observe the circumstances of their origin, but in certain instructive instances this can be traced. It is there as follows: Where in a bed in which the conditions have permitted the formation of geodes the calyx of a crinoid occurs, the planes of junction of the several plates of which it is composed may become the seat of vein-building. As the process advances these plates are pushed apart and in course of time enwrapped by the silica until the original sphere may attain many times its original diameter and all trace of its origin lost to view, though it may be more or less clearly revealed by breaking the mass.

In the process of enlargement which the geodes undergo they evidently provide the space for their storage by compressing the rock in which they are formed. In the rare instances where I have been able to clearly observe them in their original position they were evidently cramped against the country rock, the layers of which they had condensed and more or less deformed. Although when found upon the talus slopes or the soil these spheres usually contain no water in their central cavities, these spaces are filled with the fluid while they are forming and so long as they are deeply buried. There can be no doubt that this water is under a considerable though variable pressure.

The conditions of formation of spheroidal veins or geodes clearly indicate that an apparently solid mass of crystalline structure may be in effect easily permeated by vein-building waters, and this when the temperature and pressure could not have been great. It is readily seen that the walls of these hollow spheres grow interstitially while at the same time the crystals projecting from the inner side of the shell grow toward the center. We, therefore, have to recognize the fact that the silex-bearing water penetrated through the dense wall. In many of these spherical veins we may note that the process of growth in the interior of the spheres has been from time to time interrupted and again resumed. These changes may be due to the variations in pressure to which the water in the cavities is necessarily subjected as the conditions of its passage through the geode-bearing zone are altered.

More recently Bassler has written on the formation of the Knobstone geodes. He says:

"The majority of geodes in the Knobstone group may be

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traced directly or indirectly to a crinoidal origin for the simple reason that these strata are often crowded with the fragments of this class of organisms. Probably next in order as a geode maker is the common brachiopod *Athyris lamellosa*, but no class of fossil is exempt from replacement by silica when the proper conditions obtain."

Bassler is of the opinion that the Keokuk and Lower Warsaw geodes may have the same mode of origin as those of the Knobstone. But he disagrees with Shaler as to the details of geode development. Thus:

"Returning to the suggestion in Dana's *Manual of Geology* that the Keokuk geodes are hollowed out sponges lined with crystals it seems more reasonable, in view of the absence of such sponges in that formation and the presence of numerous specimens indicating the origin described above, that the latter is nearer the truth. Prof. Shaler's idea that this class of geodes is formed when deeply buried is not in accord with the facts, nor does there appear to be any necessity for the water of formation to be under a considerable though variable pressure. Ordinary surface waters charged with silica seem to be sufficient."

This generalization in so far as it relates to the geodes of the region studied, would seem to be too broad. Out of several thousand geodes examined only one, which had plainly been formed by the enlargement of a specimen of the crinoid *Barycrinus*, showed evidence of this method of geodization.

The origin of the geodes in the region studied is believed by the writer to be related to the calcareous concretions which originally must have been very abundant in the beds and which are still preserved at some localities. These nodules, being more soluble than the inclosing rocks, have been in large part removed, thus affording cavities in which the geodes could be formed. Where they are still preserved, the concretions have exactly the same relationship to the containing rock as the geodes and possess analogous shapes. They were obviously formed on the sea-bottom while the strata were being deposited, since lines of stratification do not pass through them and no evidence of expansion is encountered about their borders. The process of solution seems to have started in the interior and proceeded outwards. That this was the method of removal is indicated by the occurrence in the beds of some geodetic nodules
whose interiors were only partly hollowed out when deposition began. Carbonic acid and sulphuric acid, the latter of which must have been generated by the decomposition of the pyrite so common in the beds, probably were the most active solvents.

The white powder of kaolin found in some of the geodes is thought to represent, at least in part, a residual product resulting from the leaching of the original argillaceous content of the nodules. That kaolin can be so formed is clearly indicated by the presence of this mineral so related to impurities in some of the nodules that its derivation cannot be questioned. The more common occurrence of kaolin in the geodes from the more argillaceous part of the beds is significant in this connection. Moreover, the great majority of the geodes which contain kaolin are imperfectly developed and the calcite of such specimens invariably includes the white powder of this mineral. These facts strongly support the idea that the kaolin must be a residual product.

Concerning the time of formation of the geodes, little is definitely known. The removal of the calcareous nodules which, it is assumed, preceded the geodes, implies an interval of solvent action during which the Keokuk and Lower Warsaw beds were above ground-water level. The growth of geodes, on the other hand, undoubtedly took place below ground-water level.

In the development of the geodes at least two periods of mineralization are involved. The first period of development was by far the most important. During this period of growth the quartz, chalcedony, dolomite, and a considerable amount of the calcite together with almost all of the metallic sulphides were deposited.

Of the minerals of the second period of growth, transparent crystals of calcite and slender un tarnished flakes of pyrite are by far the most important. The minerals of this class are doubtless much younger than those of the former as suggested by the fact that in many instances the pyrite associated with the newer calcite is perfectly fresh while in the same geode the earlier pyrite is badly decomposed.

The secondary minerals of the geodes such as limonite, gypsum, smithsonite, and malachite are for the most part of much more recent origin. They have resulted from the alteration of
the primary sulphides as is shown by their association with the partly decomposed members of this group.

The bitumen which occurs in some of the geodes must have been introduced sometime after their formation, since it has not interfered with the normal geode development.

The process of geodization evidently consisted of the inward growth of crystals upon the walls of cavities left by the solution of the imbedded concretions. The growth was necessarily accomplished by deposition from a solution which filled the interior completely. As this solution became depleted in its mineral content, more was introduced by some process of diffusion and a continuous deposition resulted. In some instances a very impervious wall was developed and growth must have been extremely slow. But in the majority of geodes numerous feeding channels in the walls afforded ready passage to the solutions after they penetrated the siliceous shells.

The mineralogical differences of geodes which occur in close proximity to each other are difficult to account for. It must be assumed either that the process of geodization was a very local one and that each individual geode possessed only a small sphere of attraction, or that a peculiar localization of conditions favored in some instances the deposition of mineral matter more widely diffused through the mineralizing solutions.
CHAPTER VI

GEOLOGIC HISTORY

Conditions at the Close of the Devonian

The character and distribution of the Upper Devonian deposits in Iowa are such as to suggest that they extended over a larger area in pre-Kinderhook time and it is believed that an erosion interval preceded the incursion of the first Mississippian sea. However, the data bearing on the stratigraphic relations of the Kinderhook and underlying Devonian deposits in Iowa are meagre, owing to the fact that no contact of these older strata with layers definitely known to represent the basal Kinderhook has been observed.

The Kinderhook Transgression

With the opening of Mississippian time an interior sea occupied a considerable area in the Mississippi Valley region. The greater proportion of limestone in the group in central and north-central Iowa suggests that clearer and deeper seas prevailed in those areas than to the southeast. The deposits formed at this time undoubtedly once extended a considerable distance northeast of their present belt of exposure.

Conditions During Osage Time

The extent of the changes at the close of Kinderhook time is not definitely known. The next succeeding Burlington limestones, exposures of which are now confined to the southeastern part of Iowa, appear to follow the Kinderhook group conformably. Inasmuch as they exhibit a marked thinning in passing from the city of Burlington to southern Louisa county, it is probable that they did not extend far to the northwest.

The Keokuk formation succeeds the Burlington without a stratigraphic break and has essentially the same geographic distribution in Iowa. It thins to the northwest and is shaly in its upper part, the argillaceous horizon gradually descending in
the formation towards the northwest. This suggests a gradual recession of the sea to the south during Keokuk time.

Oscillations During Meramec Time

The contraction of the seas during Keokuk time was apparently continued through the Warsaw. The deposits of this age consist predominantly of shales. Both divisions of this formation are confined to the southeastern part of the state, the Upper Warsaw being even more restricted than the Lower.

At the close of the Warsaw time the interior sea retreated more rapidly to the south, apparently as a result of an uplift of the Wisconsin positive element to the north, and the Warsaw and earlier Mississippian formations were subjected to erosion.

The returning sea of Spergen time probably was but little more extensive than that of the Warsaw, since the deposits of Spergen age in Iowa are of the near-shore type and are likewise confined to the southeastern part of the state.

The close of the Spergen was marked by a southward retreat similar to that at the close of the Warsaw. The readvancing Lower St. Louis sea extended far to the north, overlapping all the earlier divisions of the Mississippian except the Kinderhook, upon which it rests in Humboldt county. Early in St. Louis time, however, another elevation of the northern area took place and the strand line retreated rapidly to a point somewhere between Alton, Illinois, and Ste. Genevieve, Missouri. The disconformity resulting from this retreat has been found as far south as Alton, but no trace of it is shown in the section at Ste. Genevieve. Following a slight interval of erosion the St. Louis sea returned as rapidly as it had receded and the deposition of Upper St. Louis limestone in Iowa resulted.

The unstable conditions of the St. Louis were terminated by still another uplift. The duration of the erosion interval which followed could not have been great, for the deposits of the returning Ste. Genevieve sea, which must have rivaled that of the early St. Louis in size, have not been found to rest upon formations older than the Lower St. Louis.

Warping at Close of Meramec Time

At the close of Ste. Genevieve time the sea withdrew from the
upper Mississippi Valley again, and the entire region remained a land area until the close of the Mississippian period. A great warping took place during and following this emergence, which resulted in a tilting of the Mississippian and earlier formations to the southwest and is known to have been accompanied by the development of small northwest-southeast trending anticlines and synclines and by extensive brecciation of the hard, brittle St. Louis limestone. (See page 236.) Consequent upon this uplift erosion proceeded rapidly during the remainder of the Mississippian and the tilted beds were partly truncated, thus giving rise to a series of northwest-southeast belts of formational outcrops in Iowa, many of which were later buried by the Coal Measures.

This southwestward tilting of the beds in Iowa was related to a widespread late Mississippian deformation involving also eastern Nebraska, eastern Kansas and Missouri, which outlined a great southwestwardly pitching geosyncline later occupied by the early Pennsylvanian sea advancing along a narrow trough from the southwest and gradually spreading to the margins of the basin by overlap. A structure contour map of the geosyncline and a discussion of its influence on Pennsylvanian sedimentation have been published previously by the writer.1

The geosyncline was shallow in early Pennsylvanian time as is indicated by the fact that the maximum known thickness of the Cherokee stage, which doubtless represents the time of greatest sea extension in the province during the period, is only 712 feet. However, it must be remembered that the rim of the basin had been lowered considerably by pre-Pennsylvanian erosion. At the present time, the basin is considerably deeper as a result of subsidence during Pennsylvanian time.

1 Jour. Geol., vol. XXV, pp. 150-156; 1917.
PLATES ILLUSTRATING MISSISSIPPIAN FOSSILS

On the following plates the illustrations are all natural size. Some of the type fossils suggested by Doctor Van Tuyl had to be omitted due to lack of space. This is especially true of the large Keokuk brachiopods to include which another plate would have been necessary. Most of the brachiopod illustrations were furnished by Doctor Stuart Weller from the original plates of his Monograph 1, Illinois Geological Survey. Some of the crinoids are copied from Wachsmuth and Springer's Crinoidea Camerata. All others are illustrations of specimens in the paleontological collections at the State University of Iowa.

—A. O. Thomas.
PLATE III

TYPE KINDERHOOK FOSSILS

Fig. 1. *Leptopora typa* Winchell.
Calycinal view of an incomplete colony.
In railway cut three miles northeast of Morning Sun.

Fig. 2. *Leptopora concava* Weller.
Impression of the external surface of a brachial valve.
Bed No. 5, Burlington.
After Weller, Monog. 1, Ill. Geol. Surv.

Figs. 3, 4. *Schellwienella inflata* (White and Whitfield).
Brachial and lateral views of an internal cast.
Bed No. 7, Burlington. After Weller.

Fig. 5. *Chonetes ingani* Norwood and Pratten.
Pedicile view.
Bed No. 6, Burlington. After Weller.

Fig. 6. *Chonopectus fischeri* Norwood and Pratten.
View of a very perfect pedicle valve showing the spines along the cardinal margin.
Bed No. 3, Burlington. After Weller.

Figs. 7, 8. *Productus arnatus* Hall.
7. Pedicle view of a shell from Chouteau Springs, Missouri.
8. Lateral view of a pedicle valve from Bed No. 6, Burlington. After Weller.

Figs. 9, 10. *Porophorynchus transversus* Weller.
10. Anterior view of a cast from Chonopectus sandstone, Burlington. After Weller.

Figs. 11, 12. *Spiriferina solidirostris* White.
Pedicile and brachial views of the cotypes.
Bed No. 7, Burlington. After Weller.

Fig. 13. *Spirifer platynotus* Weller.
View of a brachial valve of one of the cotypes.
Bed No. 6, Burlington. After Weller.

Figs. 14, 15. *Spirifer biplicatus* Hall.
Pedicile and brachial views.
Chonopectus sandstone, Burlington. After Weller.

Figs. 16-18. *Spirifer subrotundus* Weller.
Pedicile, brachial and lateral views.
Chonopectus sandstone, Burlington. After Weller.

Figs. 19, 20. *Reticuloria cooperensis* (Swallow).
Pedicile and brachial views of a specimen from Pettis county, Missouri.
It is common at Burlington and elsewhere in Iowa. After Weller.

Fig. 21. *Edmondia jejuna* (Winchell).
View of right valve of an internal mold.
Wassonville.

Internal and external views of left and right valves, respectively.
Wassonville cherts, Wassonville.

Fig. 24. *Dentalium grandocum* Winchell.
A typical specimen from the Wassonville cherts.

Fig. 25. *Straparollus obtusus* (Hall).
Apical view.
Obitite beds, Humboldt.
PLATE IV

TYPE BURLINGTON FOSSILS

Figs. 1, 2. *Zygocoenia calecola* (White and Whitfield).
Two specimens showing size and curvature.
Bed No. 4, Burlington.

Figs. 3, 4. *Obritchnites norwoodii* (Owen and Shumard).
Basal and interradial views of a nearly perfect specimen showing the elevated ambulacra.
Upper Burlington limestone; Burlington.

Figs. 5, 6. *Cryptoblastus melo* (Owen and Shumard).
Interradial and apical views showing the sunken ambulacra. Burlington

Figs. 7, 8. *Macroceramus cronatiarum* (Shumard).
Right posterior views of two typical calyces of one of the commonest Burlington crinoids.
Burlington.

Fig. 9. *Dizygoecerus volutus* (Shumard).
Left posterior view of a typical calyx.
Burlington.

Fig. 10. *Pterygoecerus pyriformis* (Shumard).
Anterior view of a typical calyx.
Burlington.

Fig. 11. *Teleioceramus umbrosus* (Hall).
Posterior view of a typical but rather small calyx.
Burlington.

Pedicle and brachial views of typical shells from Burlington limestone at Springfield, Mo. 14 is a view of the interior of a brachial valve from the Kaskaskia limestone of the same locality. After Weller.

Figs. 15, 16. *Productus burlingtonensis* Hall.

Fig. 17. *Hyposome errantibus burlingtonensis* (Hall).
Pedicle view of a typical shell.
Burlington. After Weller.

Figs. 18, 19. *Spiroceras primitae* Hall.
View of an incomplete pedicle valve showing the markings and the interior of another pedicle valve showing the muscle scar.
Springfield, Mo. After Weller.

Fig. 20. *Spiriferella plana* (Hall).
Interior of apical part of a pedicle valve showing the dental lamellae.
Burlington. After Weller.

Fig. 21. *Asperites lenticulatus* (Levêillé).
Pedicle view of a nearly perfect specimen.
From the Kaskaskia limestone; Warsaw, Illinois. It is also common in the Burlington limestone.

Fig. 22. *Lepidopsis cupulans* (Hall).
Sole view of a shell.
Bed No. 6, Burlington.
PLATE V

TYPE KEOKUK AND WAESAW FOSSILS

Figs. 1, 2. *Pulmonaria obtusa* Meek and Worthen.
Calyceal and lateral views of two colonies. Keokuk.

Fig. 3. *Macrorhizus hageni* Hall.
Postero-lateral view of a typical calyx from Keokuk.
After Wachsmuth and Springer.

Fig. 4. *Doryteina wabashiensis* Roemer.
Anal view of a very fine calyx. Keokuk.

Fig. 5. *Archimedes owensii* Hall.
Part of spiral axis. Keokuk.

Fig. 6. *Orthotetes keokuk* (Hall).
Pedicle view of a large and nearly complete specimen. Keokuk. After Weller.

Fig. 7. *Productus asterias* Hall.

Fig. 8. *Tetraclina subrigida* (Meek and Worthen).

Figs. 9, 10. *Spisifer keokuk* Hall.
Brankeal and lateral views of a nearly perfect specimen. Keokuk. After Weller.

Figs. 11, 12. *Spisifer costellatus* Hall.
Pedicle and brachial views of the holotype. Specimen from Warsaw, Illinois. After Weller.

Fig. 13. *Myelinia keokuk* Worthen.
Bed No. 6, Keokuk.
PLATE VI

TYPE ST. LOUIS AND PELLA FOSSILS

Fig. 1. *Triplophyllum dacti* (Milne-Edwards and Haime),
Calycinal view of a fine specimen from St. Louis limestone.
Henry county, Iowa.

Figs. 2-4. *Triplophyllum pellacensis* (Worthen),
Lateral views and a calycinal view of three typical specimens. Note
the spine bases.
Pella beds; Pella.

Fig. 5. *Lithostrotion canadense* Castellan.
Part of a perfect colony from St. Louis limestone.
Mt. Pleasant.

Fig. 6. *Archimurina worthii* Hall.
Portion of the screw-shaped axis of this peculiar fenestellid bryozoon.
Upper Warsaw limestone. Keokuk.

Fig. 7. *Lingula varoviciensis* Worthen.
View of the holotype.
Warsaw beds; Warsaw, Illinois. After Weller.

Figs. 8, 9. *Orthotetes kuskiakensis* (McChesney).
Brachial and pedicle views of somewhat broken specimens.
Pella beds; Fort Dodge.

Figs. 10-12. *Teatrnucula armstrongi* (Swallow).
Pedicle, brachial and lateral views of a specimen from Salem limestone.
Booneville, Missouri. After Weller.

Brachial, pedicle, anterior and lateral views of specimens from the Pella beds at Fort Dodge.

Figs. 17-19. *Girtyella sidnauensis* (Girty).
Brachial, pedicle and lateral views.
Pella beds; Pella. After Weller.

Fig. 20. *Spirifer pellacensis* Weller.
Brachial view.
Pella beds; Fort Dodge.

Figs. 21, 22. *Allorisma marionense* White.
Casts of two specimens viewed from the hinge and from the left side, respectively.
Pella beds; Ottumwa.
A GEOLOGICAL MAP OF IOWA
1922
GEORGE F. KAY,
STATE GEOLOGIST

CRIPACEOUS
PERMIAN
PENNSYLVANIAN
MISSOURI
DES MOINES
MISSISSIPPIAN
MERAMEC
OSAGE
KINDERHOOK
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
PROTEROZOIC