CHAPTER 5.

MERAMEC GROUP

WARSAW FORMATION

Name and Limits. The Warsaw formation was named from Warsaw, Illinois, where it is well exposed. The name was first published by Hall[28] in 1857, although it had been in use by Worthen and others before.

In central Kentucky the Warsaw includes three members of local though considerable areal extent. These are here named, in ascending order, the Wildie sandstone member, the Somerset shale member, and the Garrett Mill sandstone member. They are described under separate headings, following the description of the formation as a whole.

The Warsaw succeeds the rocks of Keokuk age, and possibly in much of its area there is a slight unconformity between them. The lower limit of the Warsaw in Jefferson County, Ky., is placed at the top of the Holtsclaw sandstone of the Keokuk, while in southern Kentucky, where the Holtsclaw is absent, the lower limit is readily determinable by the differences in the characters of the rocks and fossils of the Keokuk and Warsaw. In the southern country this line of separation is very sharp and can be located within a few feet from the fossils scattered over the ground. On the slopes a mixture of Keokuk and Warsaw fossils can be traced up to a certain level, above which the Keokuk fossils, mainly corals and crinoids, do not go, while the Warsaw forms can be found still higher on the slopes unmixed with the Keokuk forms. Furthermore, none of the Keokuk forms have ever been found in the same layers or loose slabs which in very many places are crowded with the Warsaw fossils. The writer found, too, just such association of fossils under the same conditions as far north as Bloomington, Ind. And this leads to reverting to the discussion of the Keokuk-Warsaw boundary in Jefferson County, Ky., in the section devoted to the description of the Keokuk, p. 73. The doubt about the placing of the boundary at the top of the Holtsclaw arises from the fact that, in Jefferson Co., rocks similar to those of Keokuk type extend

[28] Hall, James, Am. Assoc. Adv. Sci. Proc., Vol. 10, Pt. 2, p. 56, 1857.

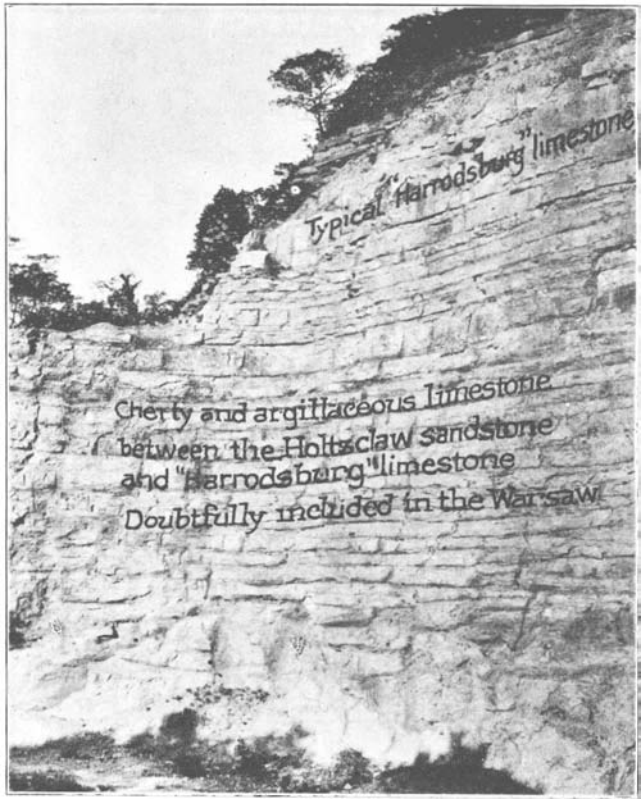


Plate 33. Quarry at West Point, Jefferson County, Ky. Limestone of "Harrodsburg" type above cherty and argillaceous limestone below to top of Rosewood shale a few feet below bottom of quarry. This part doubtfully included in the Warsaw. Looking northeast.

above this contact and carry a few fossils which, at the south, are found only in the Keokuk, such as a large coral, *(Zaphrentis),* calyx plates of a large *Actinocrinus, Brachythyris suborbicularis,* and a *Syringothyris,* the last, however, having peculiarities allying it with a form found near Ste. Genevieve, Mo., in rocks about which Ulrich was uncertain whether they are Keokuk or Warsaw. Such fossils have not been found more than 35 feet above the Holtsclaw, and, at one such locality Mitchell Hill, 12 miles south of Louisville, the beds with such fossils are immediately overlain by beds with a Warsaw fauna.

At West Point, Ky., in the old quarry (Pl. 33), the Keokuk type of limestone seems to extend about 60 feet above the probable horizon of the Holtsclaw, and fossils of the Keokuk type were found about 30 feet above. At 50 to 60 feet above the Holtsclaw, typical Warsaw (Harrodsburg) limestone with a profuse Warsaw fauna comes in. On the other hand the oolite bed just above the Holtsclaw, which is included in the Warsaw, carries, along with forms common in the Keokuk rocks, fossils more characteristic of Warsaw. The points of the foregoing discussion are illustrated by sections 3, 6 and 8, of the section chart and by the fossil lists Nos. 25 to 30, inclusive.

It is possible that but a brief interruption in sedimentation marked by the oolite and glauconite took place in a small area in the Jefferson County region, and that, later, rocks of the Keokuk type were laid down and some of the Keokuk fossils lived on for a time in that basin. In much larger areas, where the rocks and fossils seem to be much more sharply separated, as mentioned, it is possible that there was a longer interruption of sedimentation, and that when those areas were finally resubmerged or the conditions of sedimentation and life returned the Keokuk species had entirely died out and the sea was inhabited only by Warsaw forms.

Distribution. The Warsaw extends throughout central Kentucky and south across Tennessee into Alabama. In eastern Kentucky it was identified as far northeast as a point about 8 miles east of Berea (Secs. Nos. 35 and 36 of section chart), but it is not present at Irvine, about 10 miles farther northeast. It is not present at Pineville or at Cumberland Gap, nor was it detected at Jellico, Tenn., on the west escarpment of Pine Mt. It is present in the north end of Sequatchie Valley, in Cumberland County, Tenn., which locality is in direct continuation of the line of Pine Mt. southwestward. Within the limits outlined the Warsaw is present wherever its horizon has escaped erosion and is exposed to view.

Character. The Warsaw, like the Keokuk, is composed of limestone, shale, and sandstone in varying proportions. Changes from one to the other take place at the same stratigraphic level within short distances. The predominating type of rock, especially in southern Kentucky and northern Tennessee, is a coarse,

highly crinoidal, dark, steely-blue limestone. On weathered surfaces the crinoidal fragments stand out in conspicuous relief, generally exhibiting distinct, although as a usual thing, gently oblique, cross-bedding, which is only brought out by the etching in weathering. This feature is well shown in the photograph plate 34. The layers of the limestone are usually thick and in places even massive. (See Plates 35 and 36.) In Hardin County, Ky., between Colesburg and Tunnel Hill, where the Warsaw has its maximum thickness, there is, in the upper half, a thickness of about 40 feet of rather thin-bedded but coarse,

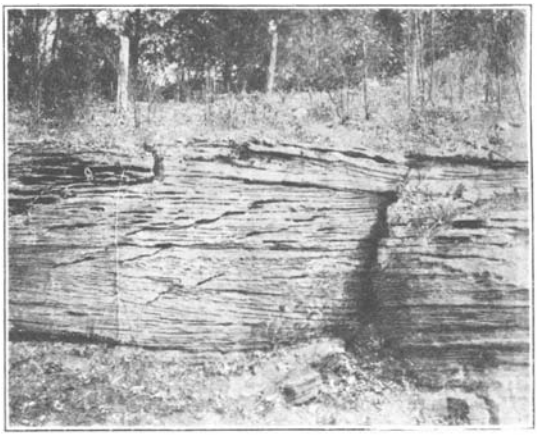


Plate 34. Nearer view of limestone shown in Plate 35, showing the rough surface and cross lamination characteristic of the limestone of the Warsaw.

bluish or gray limestone, the features of which are shown in Plate 37. As stated in the discussion of the lower boundary of the Warsaw, there is, in Hardin, Bullitt and Jefferson counties, in the lower 30 to 60 feet of the Warsaw, siliceous limestone with chert layers closely resembling parts of the underlying rocks of Keokuk age in southern Kentucky and northern Tennessee. A photograph of the lower part of these beds is shown in Plate 38. With the exception of this lower part of the Warsaw, so far as known limited to the counties named, the limestone of the Warsaw throughout Kentucky and Tennessee is practically identical in lithologic character with the "Harrodsburg" limestone, of Warsaw age, at its type locality, Harrods-

Plate 35. Massive bed of Warsaw limestone in cut on Louisville & Nashville Railroad about midway between Maretburg and Brodhead, Ky. Looking east. Garret Mill sandstone member (very thin) at top of limestone.

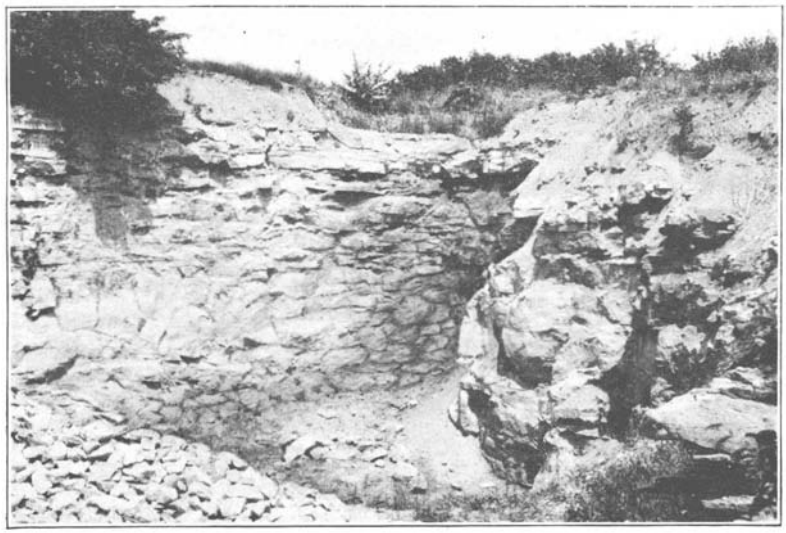


Plate 36. Quarry in Warsaw limestone at Glasgow, Ky. About 50 feet of coarse, crinoidal limestone. Looking north. This is a good exhibition of the limestone facies of the Warsaw. The rock here has the same aspect as the Warsaw has southward into Overton County, Tenn., and northward to Harrodsburg, Ind., the type locality of the "Harrodsburg" limestone, which is the partial equivalent of the Warsaw. (See Plate 39).

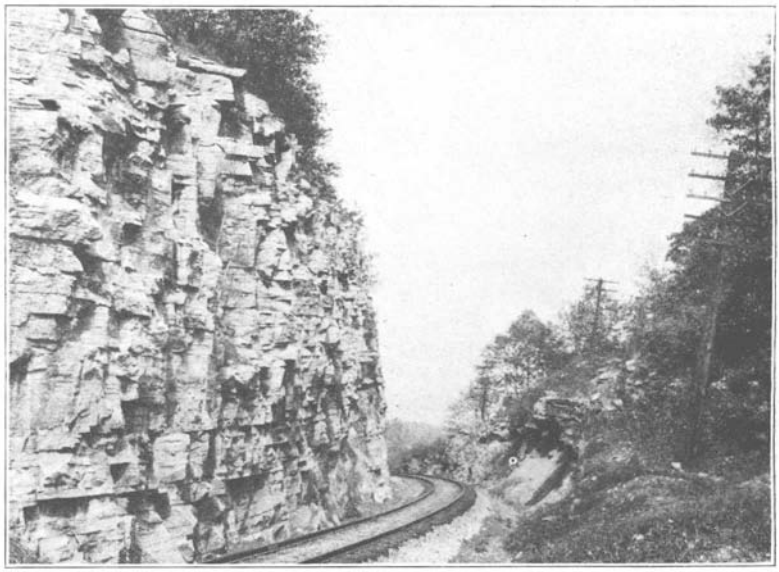


Plate 37. "Harrodsburg facies" of the Warsaw limestone extending up to the Somerset shale member shown in Plate 49. Cut on the Louisville & Nashville Railroad one-half to one mile north of the tunnel at Tunnel Hill. Looking north. The shaly layer shown in Plate 43 appears at base of cut at the farther end.

burg, Ind. (See Plate 39.) Toward the thin northeast edge of the Warsaw, in Rockcastle, Madison, and Jackson counties, the limestone of the formation is thick-bedded, non-fossiliferous, and yellow, resembling in some respects the lower beds of the Warsaw in Jefferson County, etc. (See photographs, Plates 40, 41 and 42.)

At some horizons in the Warsaw, in different localities, are argillaceous limestone layers that weather to an ochreous condition. In Tennessee similarly are sandy layers that weather to friable sandstone by the solution of the limy part, although in the fresh condition they look like pure blue limestone. Fine cross lamination is a characteristic feature of such sandy limestone.

The shale in the Warsaw in some localities makes up a large part of its thickness; usually, however, the limestone predominates. The shale is of a bluish color and does not differ greatly in its appearance from that of the underlying shale of Keokuk age. Shale near the bottom of the formation is shown in Plate

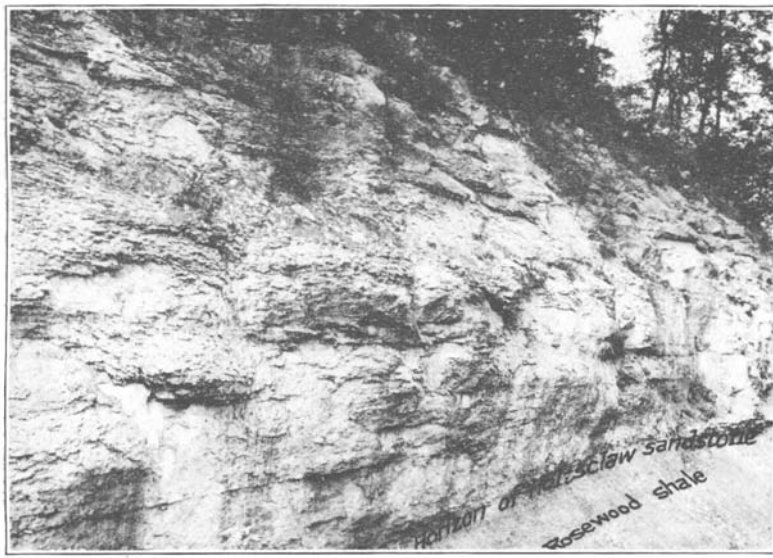


Plate 38. Contact of Warsaw limestone on the Rosewood shale. Limestone 60 feet thick, and overlain unconformably at least locally by typical "Harrodsburg" facies of the Warsaw. It is a matter of doubt whether this limestone is of Keokuk age or Warsaw. Has been regarded as Warsaw by the author in his report on Jefferson County. Louisville & Nashville Railroad about one mile south of Colesburg. Looking north.

Plate 39. Highway cut one mile south of Harrodsburg, Ind., exposing Warsaw "Harrodsburg" limestone. This is the type section of the "Harrodsburg." Looking northwest.

Plate 40. View of tunnel at Hummel on Knoxville branch. Louisville & Nashville Railroad. 4½ miles northeast of Mt. Vernon. Wildie sandstone member of Warsaw at bottom and thick-bedded yellow Warsaw limestone at top. Looking north. Compare Plates 41, 42, and 46.

Plate 41. View in highway at head of Owsley Branch. Basal heavy limestone of St. Louis with large *Bellerophon* and fucoids at top. Warsaw yellow limestone and shale below. Wildie sandstone member six inches thick just below shale in lower right corner. Looking east.

Plate 42. Cut on Louisville & Nashville Railroad about midway between Maretburg and Brodhead. Top of Fort Payne (Keokuk) at bottom showing at far end of cut. Glauconitic shale overlain by yellow Warsaw limestone. Looking west.

42. A thickness of over 20 feet of such shale, forming the lower 20 feet of the Warsaw, is exposed in a shale quarry by the roadside at the crossing of South Fork of Beaver Creek, 1 mile south of Glasgow, Barren County.

Another notable feature of the Warsaw at various points in Kentucky and Tennessee is the geodes. These are hollow bodies of silica of irregular, spheroidal, or discoidal shape, that form in the argillaceous or siliceous layers and are liberated on weathering. Such geodes are abundant in the ravines on the knobs in the southern part of Jefferson County, where they are generally spheroidal and reach a diameter of 4 to 6 inches. Very large discoidal geodes, as much as 3 feet in longest diameter, occur near the top of the Warsaw in a considerable area a few miles northeast of Somerset. There is a horizon of large spheroidal geodes about the same horizon near Gunters, Fentress County, Tennessee.

Another lithologic feature is a thin layer of fine conglomerate near or just below the middle of the Warsaw, which was observed only in a road cut at the east end of the bridge across Pitman Creek a few miles northeast of Somerset.

Some Conditions of Warsaw Deposition. The change from shale to limestone, or vice versa, in short distances, of common occurrence in the Warsaw, has been mentioned. Such changes are generally supposed to be gradual transitions from one kind of rock to the other through beds of intermediate character, and that may be the manner of change in some cases but evidently not in all, as demonstrated by exposures along the L. & N. R. R. between Colesburg and Tunnel Hill, shown in Plates 43 and 44. Here such changes are seen to be abrupt, as if

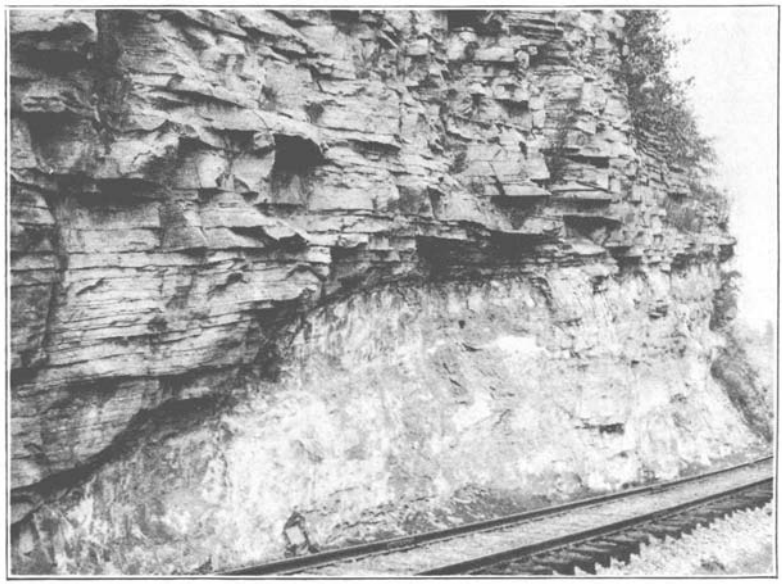


Plate 43. Local bed of shaly argillaceous limestone replacing a part of the 40 feet of thin-bedded gray limestone in the upper half of the Warsaw. Common in the Warsaw of this part of Kentucky. Louisville & Nashville R. R. about one mile north of Tunnel Hill. Looking northwest. Same exposure shown in plate 37, a few rods farther north.

brought about through irregular deposition, first of one kind of rock, then of another, for such abrupt changes would hardly be possible if deposition of the two kinds of material were simultaneous.

Such conditions in the rocks, combined with the universal cross-bedding in the Warsaw limestone, probably indicate shallow water affected by strong waves and currents caused by winds

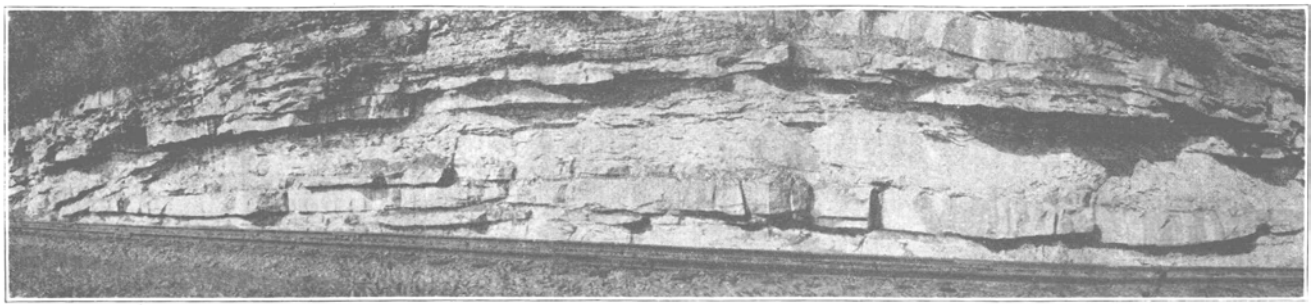


Plate 44. Spally bed in the Warsaw like that shown in Plate 43 and accompanying irregularities in the heavy compact layers. Louisville & Nashville Railroad about two miles north of Tunnel at Tunnel Hill. Looking west.

and tides. Through such agitation of the water, shifting and redeposition of sediment was continually taking place, tending to local irregularities in the bedding. By shifting of load, increasing pressure in some spots and lessening it in others, slight displacements may have taken place, producing small faults in the semi-lithified lime muds. What appears to be a small fault is shown at the left end of Plate 44, and may have been produced in such a manner. Furthermore, considerable uplifts seem to have taken place locally, followed by beveling off the up-swelled layers which were then covered by the immediately succeeding sediment, resulting in local unconformities. Such an unconformity is shown in Plate 45.

This plate is a view of an exposure on the L. & N. R. R. about 1 mile south of Colesburg, Hardin County, Ky., and the unconformity was supposed to mark the boundary between the Warsaw and St. Louis limestones. The section had been hurriedly examined, at a time before the writer had become thoroughly familiar with the characteristics of the two formations, and the conclusion stated was based on the similarity of the succession from the Warsaw to the St. Louis farther west, at Brandenburg, Meade County. The writer is glad to take this opportunity to correct the mistake.

That the unconformity here is probably not of much significance is believed from the fact that it is not present in other exposures of the same beds, as in the quarry at West Point (Plate 33.) Then, too, a short distance beyond the point shown on the left end of Plate 45, the exposure being continuous, the coarse bed above the unconformity pinches out; the beds above and below become parallel and identical in character, even to the chert layers that stand out like ribs from the face of the limestone. It is a fact, however, that the typical, coarse, fossiliferous layers of the Warsaw of "Harrodsburg" type begin at this unconformity, the beds below, about 60 feet thick, down to the well-defined contact with the Rosewood shale, probably belonging to the doubtful basal beds included in the Warsaw, already sufficiently discussed.

Thickness. The Warsaw is about 240 feet thick between Colesburg and Tunnel Hill, Hardin County, and this seems to be about its maximum thickness. It is about 200 feet on the Ohio

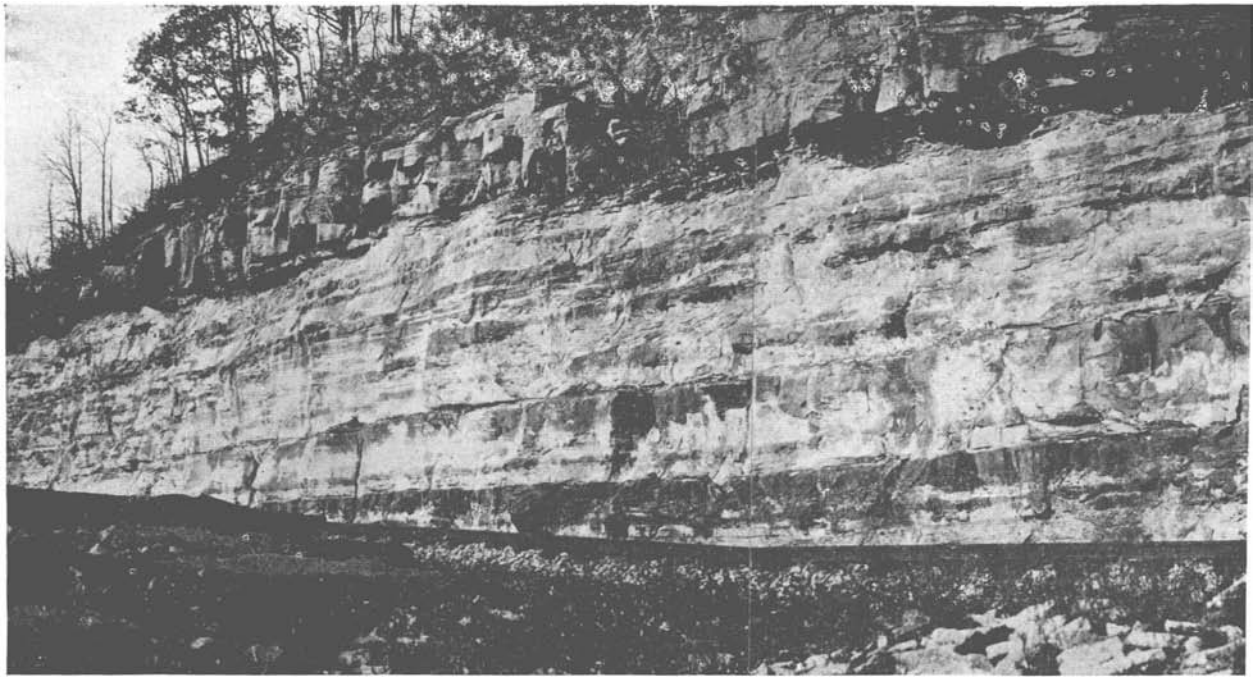


Plate 45. Local unconformity in the Warsaw formation. Cut on the Louisville & Nashville R. R. about one mile south of Colesburg, Hardin County. In the report on the Mississippian series in Western Kentucky where this photograph was published as Plate 9 the unconformity was erroneously placed between the Warsaw and St. Louis.

River bluff in Indiana opposite West Point, Ky. It is less than 100 feet at Edwardsville, Ind., several miles northwest of Louisville. In the southern counties of central Kentucky and in northern middle Tennessee it is 80 to 100 feet thick. Its thickness at Burnside, Pulaski County, is 60 feet; on the railroad between Maretburg and Brodhead, Rockcastle County, it is about 50 feet thick; and at the head of Owsley Branch in the western part of Jackson County, it is about 18 feet thick. No determination of its thickness was obtained at any point farther northeast, but it feathers out between the head of Owsley Branch and Irvine, where it is absent. (See sections Nos. 33 to 37, section chart.)

Wildie Sandstone Member. On Town Creek, about 3 miles northeast of Mount Vernon, and 1 mile west of Langford, in the London quadrangle, a thin sandstone comes into the section. This sandstone is here named the Wildie sandstone member, because it is best developed and is extensively quarried in the vicinity of Wildie, Rockcastle County, Ky. At Langford the section described below is exposed. Beneath the sandstone is 15 inches of highly glauconitic shale with black nodules having the appearance of phosphatic nodules. Below the glauconitic layer is about 2 feet of impure fossiliferous limestone. The fossils while quite plenty are poorly preserved, but a few fair specimens were obtained. One species is *Brachythyris suborbicularis* and the other the form identified in the Fort Payne lists as Sp. aff. *montgomeryensis.* There seems no reason to doubt that the limestone layer is Fort Payne. Below the limestone is typical New Providence green shale and sandstone with *Taonurus*, (See Plate 23,) Above the Wildie sandstone member is a few feet of shale and sandstone, above which is about 20 feet of thick-bedded yellow limestone. (See Plate 40.) One mile west of Langford, where the Wildie sandstone member first appears in the section, *Spirifer lateralis* and *Spirifer washingtonesis*, Warsaw species, occur in a layer of gray limestone in the middle of the yellow. All the circumstances point to the correlation of the glauconitic layer in this section with the glauconitic layer at the base of the Warsaw in Jefferson County, so that the Wildie sandstone member is of Warsaw age.

The Wildie sandstone is thick-bedded, very uniformly fine-grained, bluish and of medium hardness. It is a free working stone and makes an excellent building stone and has been and is now utilized for that purpose. It is known to the trade as the "Rockcastle freestone." Present quarrying operations are located somewhat south of Wildie. The Wildie sandstone member and underlying layers are well shown in the Photograph Plate 46.

From the point of its first appearance in the section it thickens to 6 feet at Hummel Station, just north of the Tunnel at Langford. This thickness evidently holds or even increases to

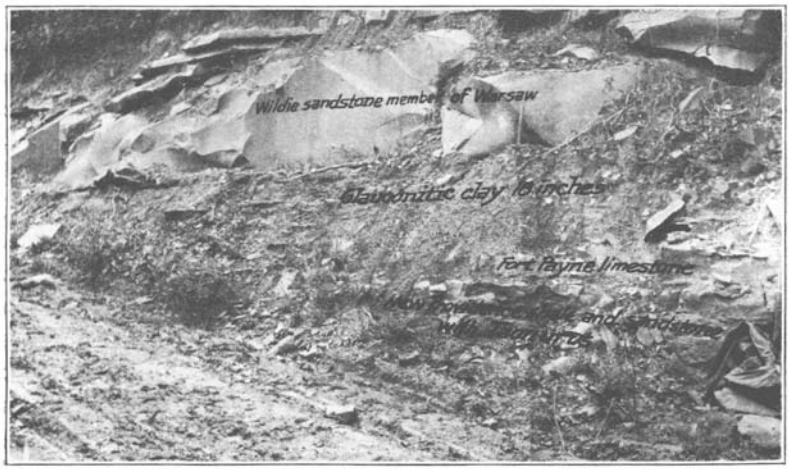


Plate 46. Road cut at west end of highway bridge at Langford about four miles northeast of Mt. Vernon. Shows Wildie sandstone member of Warsaw underlain by about 18 inches of glauconitic clay, below which is a thin layer of Fort Payne limestone, which is underlain by New Providence shale and sandstone with *Taonurus.* Looking west.

the vicinity of Wildie. At the next nearest northern point where examined, near Morrill, about 5 miles southeast of Berea, and 10 miles northeast of Wildie, the Wildie sandstone is only 1 foot thick, and on Owsley Branch, and on the north side of the ridge between Redlick Creek and Owsley Branch, it is reduced to 6 inches in thickness. It dies out with the remainder of the Warsaw between Owsley Branch and Irvine. Its entire known northeast-southwest extent is about 16 miles and may be 20 miles.

It is a matter of interest that on the escarpment just south of Parksville, in Boyle County, is a soft, thick-bedded sandstone 5 feet thick in the position of the Wildie member and probably to be correlated with it. (See Sec. 25 of section chart.) There is also a sandstone, but apparently at a slightly higher horizon in the Warsaw, at Kings Mountain, showing on the slope above the south portal of the Tunnel. At that point, however, no glauconite was noted and a layer full of Warsaw Bryozoa occurs below the sandstone. It is possible that this too is the Wildie sandstone. It is absent from the section between Maretburg and Brodhead, but this point is south of the latitude of Kings Mountain, and the absence may be accounted for by the fact that the southern margin of the sandstone deposition was approximately along a line drawn from near Kings Mountain to the point north of Mt. Vernon, where the southern edge of the Wildie member appears to lie. A line drawn from Parksville due east will also fall near the known northern limit of the Wildie sandstone member between Owsley Branch and Redlick Creek.

The Wildie sandstone member being the only sandstone of that type in the section is easily recognized from its fragments and is an excellent horizon marker throughout the areas underlain by it.

The glauconitic layer underlying the Wildie sandstone has been observed over almost the whole area of the sandstone, but was not noted at Parksville or Kings Mountain. In the section midway between Maretburg and Brodhead glauconite is plentifully distributed in the 15 feet of shale probably lying above the horizon of the Wildie and the glauconite extends eyen into the overlying yellow limestone. (See Plate 42.) The richest bed of glauconite is on the head of Owsley Branch. Here the glauconite is concentrated in an 18-inch layer, 4 1-2 feet below the Wildie member, making a hard green rock yielding large, dark green pebbles to the streams.

Somerset Shale Member. The Somerset shale member is named from Somerset, Pulaski County, where it is well displayed in a railroad cut a short distance north of the railroad station. (See photograph Plate 47.) The main reasons for separating this out as a member are that it is the source of the

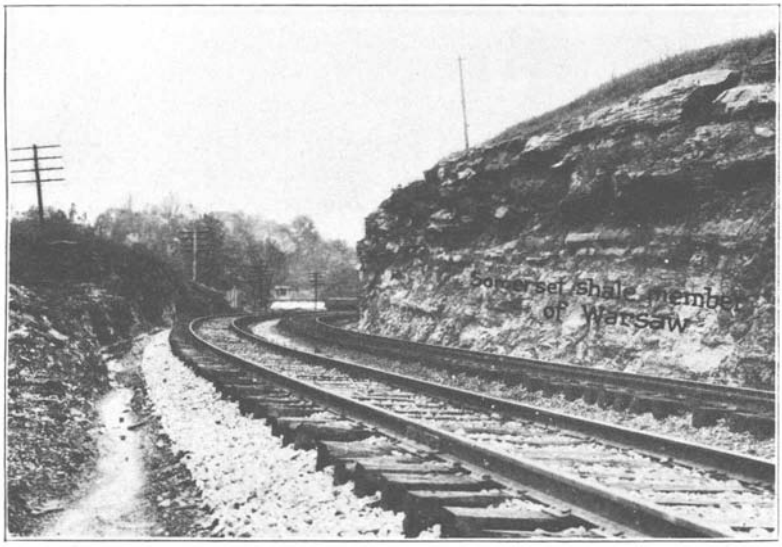


Plate 47. Cut about one-fourth mile north of railroad station at Somerset, showing Somerset shale member at the Warsaw. Layers of St. Louis limestone at top. Looking north.

many Warsaw fossils at such well known localities as Colesburg and Glasgow, and that it is believed to be persistent throughout most of the Warsaw areas in central Kentucky. Shale with thin limestone layers, highly fossiliferous, believed to be the same as the Somerset, has been observed in the Warsaw near or at the top, at such widely separated localities as Rock Haven, Meade County; Illinois Central R. R tunnel, 4 miles north of Muldraugh; (See Plate 48); southwest of Colesburg; Tunnel Hill, 4 miles north of Elizabethtown, Hardin County; (See Plate 49.) ; Glasgow, Finney, and other localities in Barren County; between Spurlington and Campbellsville, Taylor County; and a mile or two southeast of Parksville, Boyle County.

The best exhibition of the member is in the glades on the hill tops 2 miles southwest of Colesburg, and it would have been named Colesburg if that name had not been preoccupied.

The Somerset member is a calcareous shale or shaly limestone with a variable amount of highly fossiliferous limestone

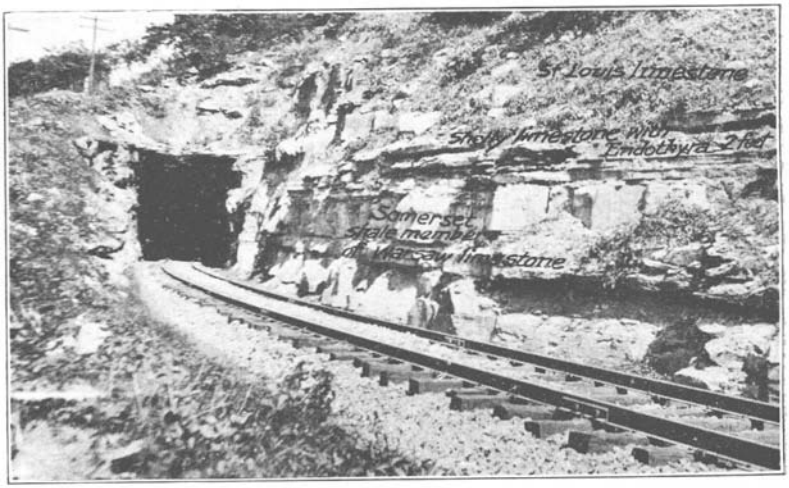


Plate 48. South portal of tunnel on Illinois Central Railroad about four miles north of Muldraugh, Ky. Cut in Somerset shale member of the Warsaw. Looking north.

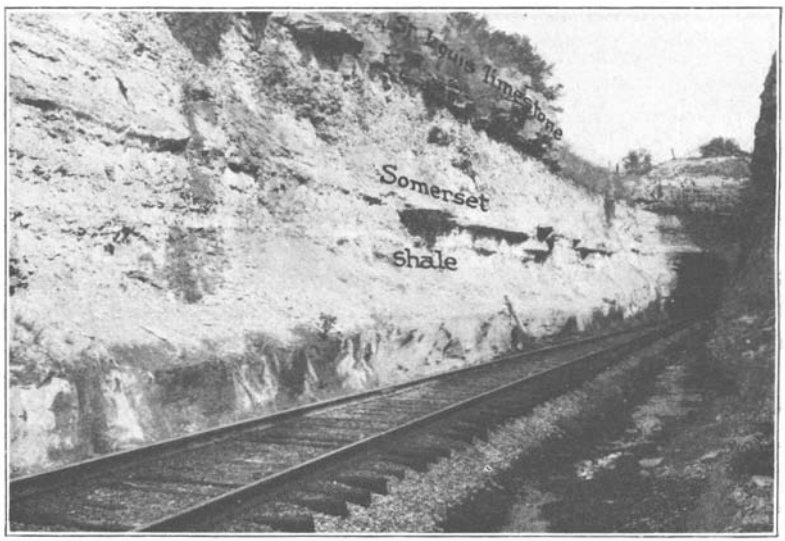


Plate 49. Cut at south end of tunnel on the L. & N. R. R. at Tunnel Hill, about four miles north of Elizabethtown, Hardin County. Cut in the Somerset shale member of the Warsaw formation. Looking northwest. This is the highly fossiliferous bed yielding the fossils in the glades on the hill at the well-known locality about 2½ miles southwest of Colesburg, Ky. The light colored bed above the portal is the base of the St. Louis limestone; the thick, dark bed just above the shale is in the Warsaw. See Plate 48.

of the usual Warsaw "Harrodsburg" type intercalated in it in thick or thin layers. It is these limestone layers that carry the most of the fossils which are liberated as free specimens on weathering. The shale also is fairly rich in fossils, especially bryozoans and brachiopods. Overlying the shale in most localities are a few feet of thick-bedded limestone with Warsaw fossils, and this is everywhere succeeded by St. Louis limestone, into which none of the characteristic Warsaw forms enter. This thick-bedded limestone making the top of the Warsaw section and, overlying it, the light colored, yellow, basal layer of St. Louis limestone (above the portal) are shown in the photograph Plate 49.

At Somerset the Somerset shale member seems to be about 20 feet thick, at Tunnel Hill it is 25 feet thick, and on the hills southwest of Colesburg it is 50 feet thick. It seems to be nearly as thick on the river bluff in Indiana opposite West Point. In Barren County and at other points mentioned it does not appear anywhere, except possibly just east of Glasgow, to exceed 10 feet in thickness.

The fossiliferous character of the Somerset shale has been mentioned. The shaly beds of the glades southwest of Colesburg and the shaly beds just east of Glasgow have yielded many of the Warsaw fossils that have been described from Kentucky. (See lists 32, 33 and 34.)

Garrett Mill Sandstone Member. The Garrett Mill sandstone member is named from Garrett Mill, on Eagle Creek, 3 miles north-northeast of Livingston, Overton County, Tenn., in the Standingstone quadrangle. The mill stands upon the sandstone, which is a notable water table in the region, upon which a strong spring or underground stream emerges and supplies the power for the mill.

The Garrett Mill sandstone member is generally a flaggy sandstone 5 to 10 feet thick. It is persistent throughout northern Overton County and thence as far north as Pulaski County, Ky., where it is represented by a few inches of sandy limestone at the top of the Warsaw in the bluff of Cumberland River just north of Burnside. Probably too a fine quartz conglomerate at the top of the Warsaw at Mt. Vernon, Rockcastle County, and two miles or so to the northeast, is the Garrett Mill member,

which there may be an outlier or a lagoon-like extension of the main area of the Garrett Mill. Being thin and the only sandstone in a considerable thickness of limestone and thus easily and certainly identifiable and extending over several counties it is of importance as a horizon marker and a datum plane for working out oil structures in those counties which are oil-bearing or prospectively oil-bearing territory. Furthermore, it has been very useful in marking the boundary between the St. Louis limestone and the Warsaw, for the immediately succeeding basal St. Louis sequence, determined for many sections starting at the bottom with the Garrett Mill sandstone member, has been found to extend beyond the areal bounds of the sandstone, so that a sure basis for discriminating the St. Louis from the Warsaw over all of central Kentucky has been acquired. Indeed, the same basal St. Louis features have been found to extend as far north as Bloomington, Ind.

Age and Correlation. The Warsaw age of the rocks designated as Warsaw formation in central Kentucky is unquestioned except, of course, the lower 30 to 60 feet in Jefferson County, Ky., as already discussed. Pp. 89-91. Lists 26 to 31, inclusive, are of fossils from these lower beds. Lists Nos. 26 and 30 are from the oolite bed just above the top of the Holtsclaw sandstone. Nearly all the species identified here occur in both the Keokuk and the Warsaw. Some of the forms of lists Nos. 27 and 28 have not been recorded from the Warsaw. The fossil evidence therefore for these basal beds in Jefferson County and neighborhood is inconclusive. The lithology of the beds also is more like that of the Fort Payne than that of the Warsaw outside of the area outlined. There remains therefore only the oolite layer and the glauconitic clay at the top of the Holtsclaw, and these are believed to indicate physiographic changes and conditions which precede the initiation of a new epoch of deposition and of formational history. The basal Warsaw beds under consideration, with their surviving Keokuk fossils, can be explained by assuming that they were the initial deposits in a rather small area in which deposition was only temporarily suspended, while deposition in the rest of the Warsaw area, in which no such transition beds are present, was not resumed un-

til somewhat later, so that there is an abrupt change from the Keokuk to the Warsaw, with a larger stratigraphic break between. The completeness of the faunal break in such areas, so far as characteristic Keokuk and Warsaw forms are concerned, has already been stated, Page 89.

A number of lists of Warsaw species follow. Only some of the collections from the more important localities have been identified by myself with the help of Ulrich. List No. 25 is a general one to show the Warsaw forms that come in at the very bottom of the Warsaw yet almost without intermixture of Keokuk forms.

LIST NO. 25.

General list of fossils from the bottom and lower part of the Warsaw formation in central Kentucky and northern middle Tennessee.

Metablastus wortheni (Hall).
Talarocrinus simplex (Shumard).
Tricoelocrinus woodmani Meek and Worthen.
Athyris densa Hall.
Orthotetes keokuk (Hall) (occurs in Keokuk.)
Productus corrugatus n. sp.
Productus magnus Meek and Worthen.
Spirifer keokuk Hall, abundant; occurs in Keokuk but not abundant.
Spirifer lateralis Hall, abundant.
Spirifer washingtonensis Weller, abundant.

As stated on Page 89, most of these forms can be found abundantly or occasionally on weathered banks and slopes mingled with very large crinoidal stem plates, bases, and calyx plates, of a large species of *Actinocrinus*, specimens of *Agaricocrinus*, probably *A. nodulosus* and possibly also *A. americanus*, and large corals of the *Triplophyllum daiei* type, none of which occurs in Warsaw beds. The Warsaw forms too occur invariably higher on the slopes above any of the Keokuk forms, not excepting the big stem plates. The Warsaw forms of the latter rarely exceed 1-2 inch in diameter, while the Keokuk forms up to 3-4 of an inch in diameter are everywhere abundant, and a good many reach nearly an inch. The ordinary circular forms are most common, but the elliptical plates of Platycrinus over an inch in longest diameter occur. Not only do these Keokuk

forms not extend up the slopes as high as the Warsaw forms, but they never have been found in association in the same rock with species like *Athyris densa, Spirifer lateralis,* and *Spirifer washingtonensis,* which are confined to the Warsaw. In places limestone crowded with these fossils, and more especially with *Spirifer washingtonensis,* lies directly on top of the siliceous limestone or shale of the Keokuk. An example of such an occurrence is on the top of the south bluff of Skeggs Creek about 1 mile southeast of Mathews Mill, in Barren County. Another is on the road between Glasgow and Oil City, a short distance east of the crossing at the railroad trestle across Beaver Creek. At this place *Productus magnus, Productus corrugatus* n. sp., and *Orthotetes,* a big species like *O. keokuk,* and probably that species, occur in association with *Spirifer lateralis.*

The most profuse development of the Warsaw fauna is in the Somerset shale member. The fossils of this member, so far as represented in the writer's collections and identified, are named in lists Nos. 32, 33 and 34.

The only comment on this fauna that will be made here is in regard to its upward range. A very large proportion of the forms listed do not pass above the top of the Warsaw, that is, above the horizon of the Garrett Mill sandstone member, into association with such characteristic St. Louis forms as *Lithostrotion proliferum,* which comes in places not more than 15 or 20 feet above the horizon of the Garrett Mill sandstone member, as will be shown in the description of the St. Louis limestone. This statement applies to such species as *Triplophyllum compressa, Palaecis cuneiformis, Metablastus wortheni, Pentremites conoideus, Talarocrinus simplex,* the species of *Glyptopora, Athyris densa, Brachythyris subcardiformis, Spirifer lateralis, Sp. washingtonensis, Spiriferella neglecta.* This list could probably be extended to include most of the species listed from the Somerset member, at least so far as central Kentucky and middle Tennessee are concerned. It is true that such forms as *Pentremites conoideus* and other Warsaw forms are elsewhere listed as derived from the St. Louis*, but that is probably due to the fact that where the St. Louis is present great numbers of silicified coralites of *L. proliferum* roll down the slopes and

*U. S. Geol. Survey, Bull. 688, p. 56, 1919.

become mingled with the Warsaw forms. Not a single case, however, of the occurrence of the two forms in the same beds has ever been found by the writer in the regions named, although observation has been constantly and specifically directed to the determination of this point. Ulrich, though, reports such an association in western Kentucky, and conditions may be different there. In central Kentucky and middle Tennessee then the Warsaw and St. Louis can be unfailingly separated by the use of these fossils. The Warsaw extends as high on the slopes as any of the species named above is found, and the presence of St. Louis limestone higher on the slopes or on the tops of knobs and spurs may be surely inferred from the presence of Lithostrotion in such situations. Any limestone carrying Lithostrotion proliferum or L. Canadense is placed in the St. Louis.

LISTS OF WARSAW FOSSILS.

LIST NO. 26.

Hill top just east of Mt. Carmel School, Jefferson County, Ky., about 10 miles south of Louisville. From oolite bed just above Holtsclaw sandstone.

Section No. 8, Section Chart.

Palaeacis obtusus Meek and Worthen.
Archimedes negligens Ulrich.
Bactropora simplex Ulrich.
Cyclopora fungia Prout.
Fenestella serrulata Ulrich.
Fenestella tenax Ulrich.
Glyptopora sagenella Ulrich.
Leioclema foliatum Ulrich.
Leioclema punctatum (Hall).
Polypora biseriata Ulrich.
Proutella discoidea (Prout).
Stenopora tuberculata Ulrich.
Streblotrypa radialis Ulrich.
Worthenopora spinosa Ulrich.
Reticularia setigera (Hall).
Rhipidomella dubia (Hall).

LIST NO. 27.

Old quarry at West Point, Jefferson Co., Ky., 10 to 25 feet above bottom of Warsaw formation.

Section No. 3, Section Chart.

Amplexus, large species. Same at Mitchell hill, at same horizon.
Archimedes negligens Ulrich.
Fenestella serratula Ulrich.
Fenestella sp.?
Brachythyris suborbicularis (Hall).
Spirifer aff. montgomeryensis Weller.
Syringothyris sp., distinct septum in dorsal valve. Same or closely related form from Ste. Genevieve, Mo., in beds referred by Ulrich with doubt to upper Keokuk.

LIST NO. 28

Mitchell Hill road, on south side of hill, about 12 miles south of Louisville, Ky., in the Kosmosdale quadrangle. Thirty to 25 feet above the Holtsclaw sandstone.

Section No. 8, Section Chart.

Amplexus, large special. Same at quarry at West Point at same horizon.
Triplophyllum (Zaphentis) dalei (E. & H.)
Platycrinus.
Fenestella several species, probably undescribed.
Brachythyris suborbicularis (Hall).
Chonetes illinoisensis Worthen.
Chonetes sp., coarse costae about 4 to MM and shallow mesial sinus, nearest to *C. ornatus.*
Productus sp.? rather large.
Rhipidomella dubia (Hall)?
Rhynchopora beecheri Greger.
Spirifer keokuk Hall.
Spirifer tenuicostatus Hall.
Spirifer washingtonensis Weller?
Spiriferina norwoodana Hall? much larger.

LIST NO. 29.

Mitchell Hill, 35 to 45 feet above Holtsclaw sandstone.

Section No. 8, Section Chart.

Triplophyllum compressa (E. & H.)
Talarocrinus simplex (Shumard).
Reticularia setigera (Hall).
Spirifer keokuk Hall.
Spirifer tenuicostatus Hall.
Spirifer washingtonensis Weller.
Spiriferella neglecta (Hall)?

LIST NO. 30.

One mile north of Farabee, Ind. Oolite just above Holtsclaw sandstone.

Section No. 30, Section Chart.

Athyris sp.
Camarotoechia sp.?
Chonetes illinoisensis Worthen.
Eumetria verneuiliana (Hall).
Dielasma sp.?
Paraphorhynchus? Striated Rhynchonellid.
Productus sp.? cf. *P. burlingtonensis* Hall.
Pustula biseriata Hall.
Reticularia pseudolineata (Hall).
Spirifer tenuicostatus Hall.
Spiriferina norwoodana Hall? larger.
Syringothyris sp.?
Tetracamera subcuneata (Hall).

LIST No. 31.

Three-fourths of a mile west of Borden, Indiana just above Holtsclaw sandstone.

Section No. 2, Plate 50.

Cystodictya lineata Ulrich.
Cystodictya pustulosa Ulrich.
Fenestella serratula Ulrich.
Hemitrypa proutana Ulrich.
Rhombopora attenuata Ulrich.
Worthenopora spinosa Ulrich.
Chonetes illinoisensis Worthen.
Spiriferina norwoodana Hall? larger than typical.
Cypricardinia sp.?

LIST NO. 32.

Top of bluff of Ohio River in Indiana, opposite West Point, Kentucky. Somerset shale member of Warsaw formation.

Section No. 5, Plate 50.

Syringopora? monroense Beede.
Triplophyllum calcariformis (Hall).
Triplophyllum compressa (E. & H.)
Pentremites conoideus Hall.
Platycrinus boonevillensis Miller?
Synbathocrinus swallowi Hall.
Talarocrinus simplex (Shumard).
Brachythyris subcardiformis (Hall).

Cliothyridina hirsuta Hall.
Composita trinuclea (Hall).
Reticularia setigera (Hall).
Rhipidomella dubia (Hall).
Spirifer keokuk Hall.
Spirifer lateralis Hall.

LIST NO. 33.

Hill about 2 miles southwest of Colesburg, Hardin Co., Ky. Somerset shale member of the Warsaw formation, the Upper 50 feet of the Warsaw.

Section No. 11, Section Chart.

Bordenia zaphrentiformis Greene.
Cystelasma sp.
Monilopora beecheri Grabau?
Palaeacis cuneiformis Edwards and Haime.
Syringopora? monroense Beede.
Triplophyllum calcariformis (Hall).
Triplophyllum compressa Edwards and Haime.
Batocrinus decoris Miller.
Batocrinus icosodactylus Casseday.
Batocrinus irregularis Casseday.
Batocrinus sacculus Miller and Gurley.
Metablastus wortheni (Hall).
Pentremites conoideus Hall.
Pentremites cavus Ulrich.
Platycrinus boonvillensis Miller?
Synbathocrinus swallowi Hall.
Talarocrinus simplex (Shumard)
Cystodictya lineata Ulrich,
Cystodictya pustulosa Ulrich.
Dichotrypa flabellum Rominger.
Dichotrypa lyroides Ulrich.
Fenestella compressa var. *nododorsalis* Ulrich?
Fenestella serratula.
Fenestella sp.?
Fistulipora spergenense Rominger.
Hemitrypa proutana Ulrich.
Fenestralia sancti-ludovici Ulrich.
Polypora biseriata Ulrich.
Polypora varsoviensis Prout.
Rhombopora sp.?
Stenopora tuberculata (Prout)
Worthenopora spinosa Ulrich.
Athyris densa Hall.
Brachythyris subcardiformis (Hall).

Camarotoechia grosvenori (Hall).
Cliothyridina hirsuta (Hall).
Composita trinuclea (Hall).
Dielasma formosa (Hall)?
Eumetria verneuiliana (Hall).
Girtyella turgida (Hall).
Productus altonensis Norwood and Pratten.
Pustula biseriata (Hall).
Reticularia setigera (Hall).
Rhipidomella dubia (Hall).
Spirifer keokuk Hall.
Spirifer lateralis.
Spirifer tenuicostatus Hall.
Spirifer washingtonensis Weller
Spiriferella neglecta (Hall).
Spiriferina salemensis Weller?
Tetracamera subcuneata (Hall).
Bellerophon sublaevis Hall?
Cyclonema leavenworthana Hall.
Euomphalus, high spired form.
Orthonychia acutirostre (Hall).
Platyceras circulare Rowley.
Coiled cephalopod.
Griffithedes bufo Meek and Worthen?

LIST NO. 34.

Hill about 1 mile east of Glasgow, Barren Co., Ky. Somerset shale member of the Warsaw formation.

Section No. 12, Section Chart

Cyathaxonia?
Michelinia sp.?
Monilipora beecheri Grabau?
Palaeacis cuneiformis E. & H.
Syringopora sp.?
Triplophyllum calcariformis (Hall).
Triplophyllum compressa (E. & H.)
Batocrinus decoris Miller.
Batocrinus icosodactylus Casseday.
Batocrinus irregularis Casseday.
Batocrinus sacculus Miller and Gurley.
Forbesiocrinus saffordi Hall.
Metablastus wortheni (Hall).
Pentremites conoides Hall.
Platycrinus.

Synbathocrinus swallowi Hall.
Talarocrinus simplex (Shumard).
Cystodictya lineata Ulrich.
Dichotrypa flabellum Rominger.
Dichotrypa lyroides Ulrich.
Glyptopora n. sp. with large deep cups.
Hemitrypa proutana Ulrich.
Brachythyris subcardiformis (Hall).
Eumetria verneuiliana (Hall).
Orthotetes?
Reticularia setigera (Hall).
Rhipidomella dubia (Hall).
Spirifer keokuk Hall.
Spirifer lateralis Hall.
Spiriferella neglecta (Hall).
Spiriferina aff. *transversa* (McChesney).
Platyceras circulare Rowley.
Pleurotomaria sp.

LIST NO. 35.

Road short distance east of crossing of Beaver Creek on road from Glasgow to Oil City, Barren County, Ky. Warsaw formation, very bottom.

Section No. 12, Section Chart

Athyris densa Hall? this species or very close to it.
Orthotetes keokuk (Hall)?
Productus magnus Meek and Worthen.
Productus corrugatus n. sp.
Spirifer lateralis Hall.
Spirijer sp. very short and broad form like *sp. mundulus.* Seems to be same as such form at Spurlington in upper part of Fort Payne.
Spiriferella neglecta (Hall).

LIST NO. 36.

Monroe County, Ky. Fountain Run road midway between Flippen and Mudlick. Probably from Somerset shale member of the Warsaw Formation.

Ceratopora agglomerata Grabau.
Palaeacis cuneiformis E. & H.
Triplophyllum calcariformis (Hall).
Triplophyllum compressa (E. & H.)
Talarocrinus simplex (Shumard)
Dichotrypa lyroides Ulrich.
Athyris densa Hall.

Cliothyridina hirsuta (Hall).
Pustula biseriata (Hall).
Rhipidomella dubia (Hall).
Spirifer keokuk (Hall)?
Spirifer lateralis Hall?
Spiriferella neglecta (Hall).

LIST NO. 37.

Cut on Louisville and Nashville railroad midway between Maretburg and Brodhead, Rockcastle Co., Ky. Massive limestone bed in top of Warsaw formation.

Section No. 29, Section Chart.

Monilipora sp.? cf. *M. Beecheri* Grabau.
Triplophyllum calcariformis (Hall).
Metablastus wortheni (Hall)?
Talarocrinus simplex (Shumard).
Cystodictya lineata Ulrich
Fenestella serratula Ulrich?
Glyptopora michilinia Ulrich.
Hemitrypa proutana Ulrich.
Leioclema punctatum (Hall).
Athyris?
Cliothyridina sp.?
Crania sp.?
Eumetria verneuiliana (Hall).
Reticularia setigera (Hall).
Spirifer keokuk (Hall).
Spirifer tenuicostatus (Hall).
Tetracamera subcuneata (Hall).

Relations of the Warsaw Formation of Kentucky and the Spergen and Warsaw ("Harrodsburg") Limestones of Indiana. In south-central Indiana, particularly in Monroe, Lawrence and Washington counties, the limestone between the same upper and lower limits as the Warsaw of Kentucky, as here interpreted by the author, is divided into two formations, the Warsaw ("Harrodsburg") limestone below and the Spergen limestone above, the Spergen being called the Salem limestone by Indiana geologists. The name Spergen, from Spergen Hill, now Norris Station, on the Monon Railroad in Washington County, Ind., has, however, been adopted by the United States Geological Survey. The Spergen is the well-known "Bedford oolite" extensively used for building stone in the eastern United States.

The "Harrodsburg" limestone of Indiana has been generally recognized as of Warsaw age, but the writer questions the generally accepted view that the Indiana Spergen is a distinct formation later than the Warsaw. In order if possible to clear up the doubt the writer examined sections at Harrodsburg, Spergen Hill, and Borden, which tied in fairly closely with sections previously studied at Edwardsville, and south to West Point, Ky. The type section of Harrodsburg is fully described below for the bearing it has on the question in hand as will appear at the conclusion of this discussion:

Section of limestones between the Holtsclaw sandstone (of Keokuk age) and St. Louis limestone 1 mile south of Harrodsburg, Indiana.

		Feet
St. Louis limestone:		
10.	Limestone, blue, slabby, in place?	2
9.	Not exposed slabs of blue limestone with fucoids. *Archeocidaris* and corals	12
Spergen limestone:		
8.	Limestone, gray, shelly, *Endothyra*	2
7.	Limestone, gray, crinoidal, *Pentremites conoideus* and other Warsaw forms	3
	Not exposed	5
6.	Limestone, argillaceous, shaly. Bastard rock of quarrymen	10
5.	Partly exposed, probably to be included in quarry rock	5
4.	Limestone, massively bedded, composed of fossil fragments (coquina) and full of small gastropods (snails) and Pelecypods (clams) and of *Endothyra*, typical Spergen limestone (quarry rock)	60
"Harrodsburg" limestone:		
3.	Limestone, thick bedded, coarse, crinoidal, cross bedded, bluish, bottom 5 feet yellow	56
2.	Shale	4
	Total Spergen and "Harrodsburg"	145
Holtsclaw sandstone:		
1.	Sandstone exposed	1

The three members of this section of especial importance in this discussion for their bearing on Correlation are Nos. 6, 7 and 8. The Spergen holds about the same thickness as in this section as far south at least as Bedford, the center of the quarry-

ing industry. Between Bedford and Spergen Hill, the type locality, the limestone of strictly Spergen type, appears to become thinner, for at Spergen Hill (Norris), so far as exposures afford information, it is only about 20 feet thick. It is possible, however, that it may be somewhat thicker, for there is a considerable unexposed space above the top of the exposed Spergen. The belief of southward thinning is borne out, however, by the section southwest of Borden, in Washington County, where a bed of the Spergen type of rock 5 feet thick lies not over 50 feet below the St. Louis limestone, as shown in Sec. No. 2, Plate 50. Still further south, at Edwardsville, (Sec. No. 3, Plate 50), no limestone of Spergen type is present, although thin limestone layers in a few feet of shale carry *Endothyra* and a few other Spergen fossils. Loose specimens of *Lithostrotion basaltiforme* (*canadense*) occur in the bank just above these layers, and, as the slope above is not very high, it is evident that St. Louis limestone closely overlies the layers with the Spergen fossils. On the river bluff in Indiana opposite West Point, Ky., the layer with *Endothyra* is a thin shaly limestone probably about 2 feet thick between the Somerset shale member of the Warsaw and the St. Louis. At the Tunnel on the Illinois Central R. R., about midway between West Point and Muldraugh Hill station, the *Endothyra* zone with same character and thickness is present. That is the only point in Kentucky and the most southern point at which it was observed. No beds of the Spergen type of lithology, and none of the characteristic Spergen fossils except the *Endothyra* as noted above, have been observed by the writer in Kentucky, and it is certain that the typical Spergen does not extend so far south. Indeed, it probably does not extend far south of Borden, Ind. The writer's interpretation of the evidence is this: The *Endothyra* zone at the top of the Warsaw in southern Indiana and adjoining part of Kentucky is the same as the *Endothyra* zone (No. 8) at the top of the Harrodsburg section, and the Somerset shale member of the Warsaw of Kentucky is the same as the bastard limestone and overlying fossiliferous limestone (Nos. 6 and 7) of the Harrodsburg section. According to this interpretation the Spergen falls within the limits of the upper half of the Warsaw of Kentucky, of which, in Indiana, it is, in the writer's

opinion, a local lithologic facies characterized by the peculiar diminutive fauna widely known as the Spergen fauna. While these small fossils are unknown in the "Harrodsburg" beds at Harrodsburg or in the Warsaw of Kentucky, the Warsaw fauna, such as listed from the Somerset shale member (list Nos. 33 and 34), occurs all through the Spergen limestone in association with its geographically and stratigraphically localized peculiar diminutive fauna.

It may be stated in conclusion that the limestone beds in the Kentucky Warsaw are strictly of the type of the "Harrodsburg" limestone and carry its identical fauna from top to bottom.

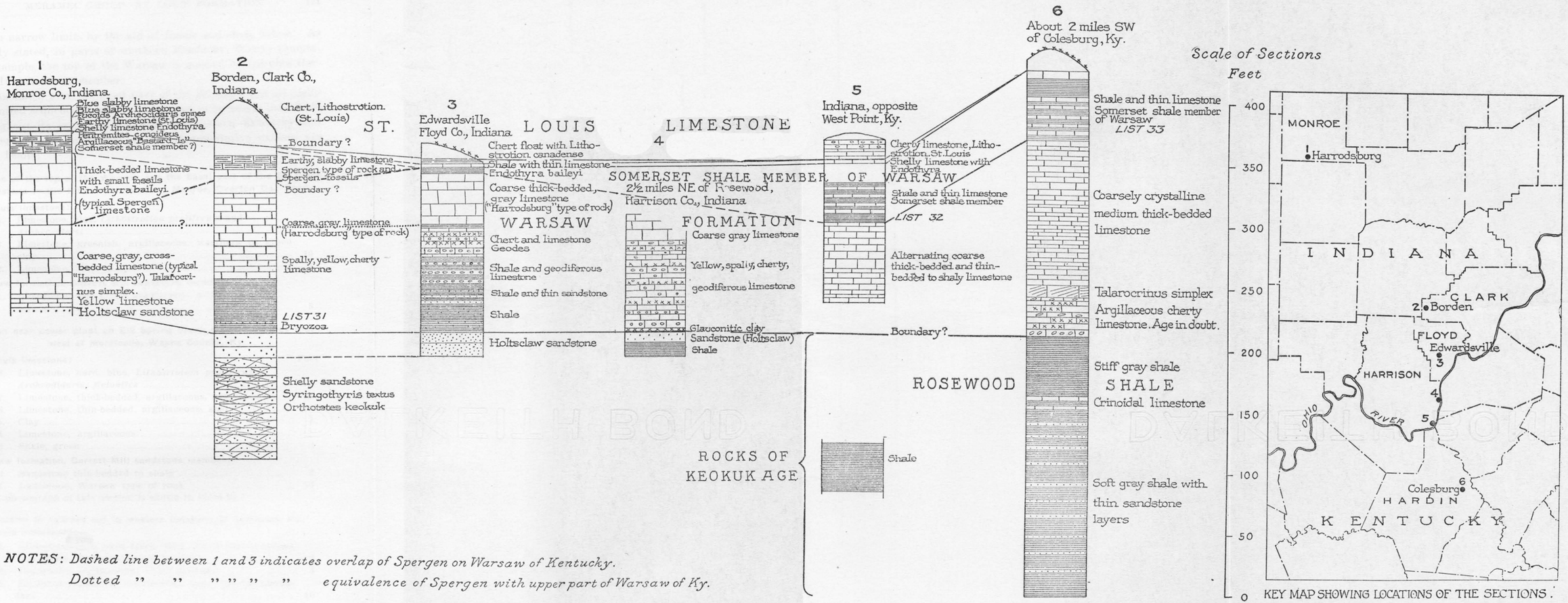
The alternative to the hypothesis advanced above is that the Spergen is a younger formation than the Warsaw overlapping from the west and feathering out above the Warsaw of Kentucky and southern Indiana. If that is the correct interpretation of the situation the Spergen is a lithologic and chronologic unit coordinate with the Warsaw. The final solution of the problem awaits further detailed field work.

The author's interpretation of the correlation is indicated by the dotted line in Plate 50, sections 1 to 3, and the alternative interpretation is represented by the heavy dashed line between the same sections.

ST. LOUIS LIMESTONE

Name and Limits. The St. Louis limestone was named from St. Louis, Mo., the name having been first used by Engleman[28] in 1847. St. Louis is located upon an area underlain by the limestone, which outcrops along the bluffs of the Mississippi, making conspicuous cliffs. As originally delimited or commonly used the St. Louis included the Warsaw limestone, the Spergen limestone, and the Ste. Genevieve limestone, all of which were later separated as distinct units. In various writings on Kentucky geology, also, more particularly by the earlier authors, the name St. Louis included Warsaw and Ste. Genevieve. The boundary between the St. Louis and the Warsaw as here interpreted is, on exposed surfaces, easily enough located by the differences in the lithology and, where not exposed, can be located

[28] Engleman George, Am. Jour. Sci.. 2d Ser., Vol. 3, pp. l19-l20, 1847.



NOTES: Dashed line between 1 and 3 indicates overlap of Spergen on Warsaw of Kentucky.

Dotted " " " " " " equivalence of Spergen with upper part of Warsaw of Ky.

PLATE 50. SECTIONS ILLUSTRATING RELATIONS OF SPERGEN AND "HARRODSBURG" LIMESTONES OF INDIANA TO WARSAW LIMESTONE OF KENTUCKY.

within narrow limits by the aid of fossils and chert debris. As already stated, in parts of southern Kentucky, Wayne County, for example, the top of the Warsaw is marked by the thin Garrett Mill sandstone member.

As stated also, the basal part of the St. Louis has an easily recogn ized sequence of beds, which seems to be nearly invariable throughout its extent in southern and eastern Kentucky and northern-middle Tennessee. A few representative sections are given below:

Section of the top of the Warsaw and the basal part of the St. Louis limestone in the road 1 mile west of Monroe, Overton Co., Tenn.

St. Louis limestone:

4.	Limestone, blue, *Lithostrotion proliferum* and *Archeocidaris*	5
3.	Limestone, greenish, argillaceous, weathers to green clay	10
2.	Limestone, blue	5

Warsaw formation, Garrett Mill sandstone member:

1.	Limestone, sandy and argillaceous with sandstone layers	5

Section near power plant on Elk Spring Creek about 1½ miles southwest of Monticello, Wayne County, Ky.

St. Louis limestone:

		Feet
8.	Limestone, hard, blue, *Lithosrtotion proliferum*, *Archeodidaris*, *Melonites*	10
7.	Limestone, thick-bedded, argillaceous, gray	13
6.	Limestone, thin-bedded, argillaceous, shaly	3
5.	Clay	1
4.	Limestone, argillaceous	1
3.	Shale, green	3

Warsaw formation, Garrett Mill sandstone member:

2.	Sandstone thin-bedded to shaly	3
1.	Limestone, Warsaw type of rock	50

A photograph of this section is shown in Plate 51.

Section in railroad cut in western outskirts of Somerset, Ky.

St. Louis limestone:

7.	Limestone, blue, pure, black chert, *Archeocidaris* spines and plates, *Melonites* plates, fucoids	2
6.	Limestone, argillaceous; shale partings	6
5.	Limestone, massive, argillaceous, gray, fucoids abundant	10

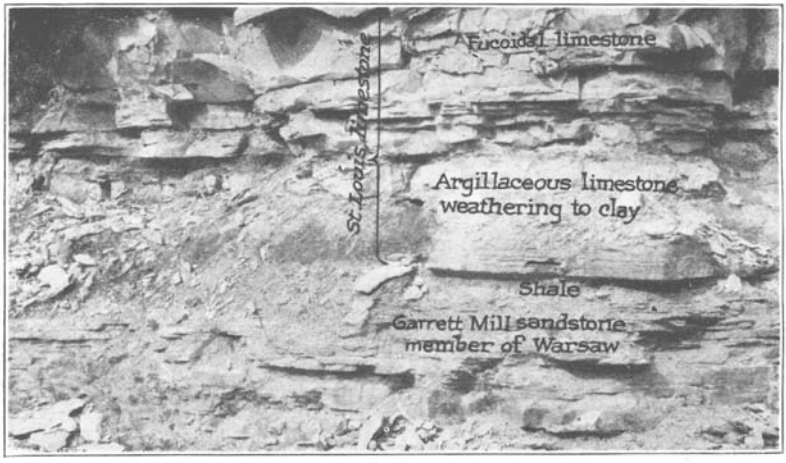


Plate 51. Road cut one-eighth of a mile south of bridge across Beaver Creek on Albany road about two miles southwest of Monticello. Shows Warsaw formation below, with flaggy sandstone (Garrett Mill member) at top, and St. Louis limestone above, with argillaceous limestone at bottom, weathering to clay. Constant features southward into Tennessee. The Garrett Mill sandstone in the Warsaw does not persist northward beyond Wayne County.

4.	Limestone, argillaceous, shale partings, probably weathers to clay	4
3.	Limestone, blue, pure	1½
2.	Clay, red streaks	2

Warsaw limestone:

1.	Limestone, coarse, crinoidal	5

This section is shown in Plate 52.

Section on Slick Rock Creek near Barren-Metcalfe County line, 10 Miles East of Glasgow, Ky.

St. Louis limestone:

5.	Banks with *Lithostrotion*, both species.	
4.	Limestone, dark, thick-bedded, chalky	20
3.	Limestone, argillaceoue, fucoids, *Archeocidaris*	20
2.	Limestone, argillaceous, shaly	15

Warsaw limestone:

1.	Limestone, dark, coarse, fossiliferous	20

Section on the Head of Owsley Branch 8 Miles East of Berea, Madison Co., Ky.

Ste. Genevieve limestone:

St. Louis limestone:

		Feet
8.	Limestone, weathers white or yellow, shelly	5
7.	Limestone, thick-bedded, cherty, *Lithostrotion* bearing bed	10

6.	Limestone, argillaceous, spally, yellow	28
5.	Limestone, massive	5
4.	Limestone, argillaceous	2
3.	Limestone, massive, fucoids, *Bellerophon*	5
2.	Shale, green	2
	Total St. Louis	55

Warsaw limestone:

1.	Limestone, siliceous, yellow, spally, cherty, sponge spicules, large geodes	9

Plate 52. Cut on Cincinnati Southern Railroad about one mile north of the railroad station at Somerset, Ky. The lowest limestone just above track level is the top of the Warsaw formation. The rest of the exposure is St. Louis limestone. Argillaceous limestone bed weathering to green clay next above Warsaw; thick fucoidal bed in middle; and pure blue limestone with *Archeocidaris* spines at top. Looking northwest.

The succession here is shown in Plate 41, Page 96.

The succession from the Warsaw into the basal St. Louis where the Garrett Mill sandstone member is absent is shown in Plates 52 and 53.

The succession from the Warsaw through argillaceous thick-bedded limestone with fucoids and *Archeocidaris* and commonly *Melonites* plates, to pure, bluish limestone with *Lithostrotion* is a constant feature of the basal St. Louis in Kentucky and Ten-

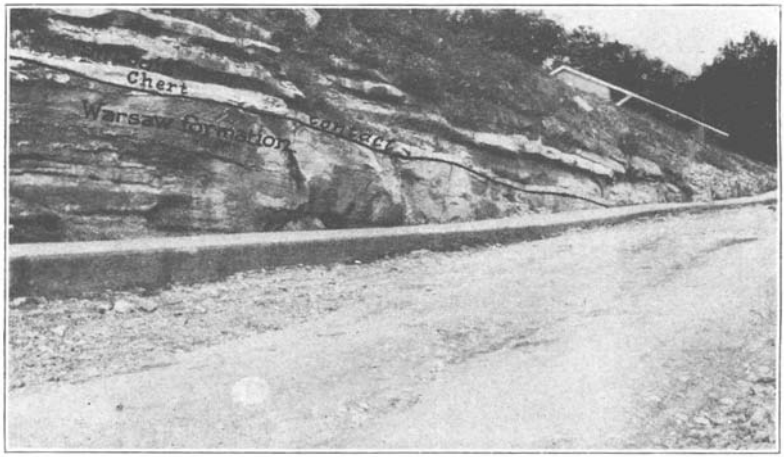


Plate 53. Contact of St. Louis limestone on Warsaw formation. Road from railroad station down bluff at Burnside, Ky. Looking southeast. The difference in the bedding characteristic of the St. Louis and Warsaw is plainly shown. The top bed of the Warsaw is massively bedded and rough surfaced; the St. Louis is in rather thick argillaceous, smooth-faced layers with abundant fucoids.

nessee, and probably also in Indiana, as indicated in the section at Harrodsburg, Indiana, (p. 118, and Sec. No.1, Plate 50.) Accompanying this lithologic and fossil sequence is the absence of all the characteristic Warsaw fossils, which end abruptly with the, coarse crinoidal limestone at the top of the Warsaw. The top of the St. Louis is generally easily recognized throughout Kentucky by the appearance of the white or light gray oolite of the Ste. Genevieve. Oolite does not occur in the St. Louis of central Kentucky so far as the writer has observed. The appearance of the oolite going upward in rock succession is accompanied by fossils that do not occur in the St. Louis, or are very rare, such as *Platycrinus penicillus* (huntsvillae.) The St. Louis and Ste. Genevieve can usually be distinguished also by the chert on the surface, the Ste. Genevieve chert preserving the oolitic structure of the limestone from which it is derived through silicification.

Distribution. The St. Louis limestone occupies a belt starting in Meade County, at Ohio River, and passing southward across the state through Hardin, Larue, eastern Hart, northern

Barren, eastern Warren, and Simpson counties. On the east a relatively narrow belt extends through Clinton, Wayne, Pulaski (east of Fishing Creek), and Rockcastle counties; northeast of Rockcastle County the St. Louis makes a relatively small part of the thickness of the limestone capping the escarpment of New Providence rocks as far north as Frenchburg, not far northeast of which it thins out completely. In Virginia the St. Louis is known to extend north as far as northern Russell County, where it is represented in the Newman limestone. According to present knowledge, therefore, the northeast boundary of the St. Louis in Kentucky lies near a line drawn from the vicinity of Frenchburg, Menifee County, to the Breaks of Sandy. The St. Louis is present at Pineville but not at Cumberland Gap. From its northeast boundary southwest to Tennessee, beneath the eastern Kentucky coal field, the St. Louis doubtless forms the basal part of the big lime of the oil well drillers.

Character. Except for the argillaceous layers in the lower part, shown in the sections, pp. 121-123, the St. Louis is mainly a medium thick-bedded, fine-grained, dark to black limestone. Blue and gray layers occur either of which may be compact and some of which are of such fine texture as to constitute a lithographic stone. Several layers of such limestone occur in the St. Louis at Brandenburg, Meade County, and are being utilized to some extent. No such coarse, crinoidal, cross-bedded limestone as that which is so prominent a constituent of the Warsaw formation occurs in the St. Louis of Kentucky. The St. Louis everywhere yields great quantities of compact, yellowish chert, much of which is of chalky texture. All along its eastern outcrop as far north as Mt. Vernon, Rockcastle County, the top 10 feet of the St. Louis is full of nodules of black chert associated in places with numbers of heads of the coral *Lithostrotion.* This bed is shown in the photograph, Plate 54. It is so constant and easily identified that it can be utilized as a datum plane in determining the geologic structure. This upper bed includes dark, drab, or white crystalline layers but no oolite. On the head of Owsley Branch, east of Berea, the middle part of the St. Louis is a yellow spally limestone. It is No. 6 of the section on p. 123. The most southern occurrence of a notably yellow layer in the St. Louis is between Maretburg and

Plate 54. Cut on Louisville & Nashville railroad about one-half mile east of Mt. Vernon. Rockcastle County. Contact of Ste. Genevieve and St. Louis marked by head of hammer. Book lies on cherty bed of St. Louis full of *Lithostrotion Proliferum.*

Brodhead, on the Louisville & Nashville Railroad, the layer there being near the middle of the St. Louis and full of *Fenestellids*. From this point the proportion of yellow limestone seems to increase northeastward, as indicated by its thickness in the section at the head of Owsley Branch. At Irvine neither the Warsaw nor the argillaceous, massive, fucoidal basal layers of the St. Louis are present; but only the yellow limestone, 17 feet thick, lying upon the New Providence and the dark cherty limestone with *Lithostrotion* 8 feet thick at top, the entire St. Louis being only 25 feet thick. The yellow limestone carries fucoids and *Bellerophon.* From Irvine northeastward both the yellow limestone, everywhere lying upon the New Providence, and the overlying dark limestone with black chert and *Lithostrotion* persist to Frenchburg, the most northeastern point at which the St. Louis was observed. At Pineville the St. Louis is composed of thick-bedded fine-grained, dark, greenish, bluish, or gray limestone with considerable chert in black nodules and plates. It is clearly the St. Louis type of lithology. (See Plate 55.)

Thickness. In its western belt from Ohio River to southern Kentucky the St. Louis is in the neighborhood of 300 feet thick.

Plate 55. St. Louis limestone overlying New Providence formation. Quarry just south of Pineville. Ky. Looking northeast.

The best determination has been obtained from well borings in Barren County. No good determination has been obtained near Ohio River, but Ashley[29] has estimated the thickness of the Mitchell limestone of Indiana to be between 350 and 400 feet. As the Mitchell includes the Ste. Genevieve, which is about 160 feet thick, it leaves 190 to 240 feet for the St. Louis. On the eastern belt of outcrop the St. Louis is 100 to 120 feet thick in southern Kentucky, 117 feet at Monticello, 100 feet at Burnside, 120 feet at the base of Green River Knob in the southern corner of Casey County, about 100 feet at Somerset, 65 feet at Mt. Vernon, 55 feet on the head of Owsley Branch, 8 miles east of Berea; 25 feet at Irvine, about 20 feet at Yellow Rock, on Kentucky River, between Irvine and Beattyville (See photographs Plates 56 and 57); 20 feet between Glencairn and Tarrant, Wolfe County, and 30 feet at Frenchburg. In the section at Paragon, 15 miles northeast of Frenchburg, the St. Louis is not present, the Ste. Genevieve there resting upon the New Providence. At Pineville the St. Louis is 115 feet thick.

[29] Ashley. Geo. H., The lower Carhoniferous area of southern Indiana. Twenty-seventh Ann. Rept., Dept. Geol. & Nat. Res. of Indiana, pp. 49-122. 1902.

Fossils and Correlation. The St. Louis in central Kentucky while not to be considered a scantily fossiliferous limestone is yet not as richly fossiliferous as the Warsaw and has nowhere yielded such an abundance of well-preserved fossils. Fenestellid bryozoa, *Fenestella, Polypora, Hemitrypa,* in profusion of individuals but few species, occur in some layers where their exposed edges are conspicuous. *Cystodictya* is common and a species apparently of *Dichotrypa* less so. Casts and moulds of these forms can be obtained in the soft chert, but the surface features desirable for satisfactory study and for determination of species are not preserved. A species of *Hemitrypa* having dissepiments elevated and continuous on the reverse occurs and has not been observed in the Keokuk or Warsaw of the region but the same form occurs in the upper beds of the St. Louis on Ohio River in southeastern Illinois. Species of *Spirifer* of the leideyi or bifurcatus type occur. One species at least seems to be undescribed. A *camarotoechia,* probably *C. mutata* occurs. There are two species of *Myalina.,* a *Straparollus* or two, a *Bellerophon* rather common in some layers and localities, probably *B. sublaevis,* and in one lot, a *Dentalium.* The *Archeocidaris* spines and plates, *Melonites* plates, and fucoids, occurring in the basal beds, have already been cited. The most common, conspicuous, and important fossils, however, are the two species of the coral *Lithostrotion* which occur as compact heads or more or less irregularly sprawling masses in the layers, in which they become silicified and from which they commonly weather out and become scattered over the surface underlain by the St. Louis. These silicified heads or masses are up to a foot or more in diameter, forming curious and striking objects often called fossil hornets' nests. On extreme weathering the heads break down into the individual coralites which roll down the slopes upon the surface of the Warsaw and so become mixed with the Warsaw fossils and thus *Lithostrotion* finds its way into lists of Warsaw fossils or vice verse. In reality *Lithostrotion* does not occur in the Warsaw beds of central Kentucky. These individual coralites remain in the soil on the tops of knobs and spurs and serve to determine the presence of the St. Louis in such situations—a thin layer capping the tops—or the presence of the residuum of such a layer recently removed leaving the silicified

coralites as evidence of its actual or recent presence. *Lithostrotion*, probably both species, ranges through the full thickness of the St. Louis above the basal 15 to 20 feet of predominantly argillaceous limestone. In eastern Kentucky, where observations have been most extensive, heads of one or both species are by far most abundant in the top 10 feet of mostly dark limestone full of nodules of black chert. *Lithostrotion proliferum* is the form most common, if not the only one, in the lower part of the St. Louis. North of the latitude of Berea, where the lower part of the St. Louis is yellow limestone, *Lithostrotion* occurs only in the upper 10 feet of dark limestone with black chert nodules which, with its fossils, persists to the northeast limit of the formation northeast of Frenchburg, Menifee County. *Lithostrotion* is the most characteristic fossil of the St. Louis limestone at St. Louis and in the Mississippi Valley. In southeastern Illinois it is, so far as known, restricted to the St. Louis, and it is confidently believed that the limestone in central Kentucky, to which it is also restricted, is the same as the St. Louis. The lithologic character and stratigraphic relations—Warsaw below and Ste. Genevieve above—are equally strong evidence of the St. Louis age of the limestone here under consideration. In conclusion it is to be emphasized that the St. Louis is a very distinct lithologic unit, with definite and easily recognized upper and lower limits, which are not transgressed by most of the fossils occurring in itself nor by most of those occurring in the bounding formation.

UNCONFORMITY AT TOP OF ST. LOUIS LIMESTONE.

There is, in some areas at least, a break marked by an erosional unconformity between the St. Louis and the overlying Ste. Genevieve. The most notable example of such a break is on Kentucky River about one-half mile east of Yellow Rock station, on the Louisville & Nashville Railroad and about 10 miles by railroad west of Beattyville, Lee County. A photograph of this unconformity is reproduced as Plate 56. A long stretch of the unconformable contact is shown in Plate 57. A detail of the basal Ste. Genevieve bowldery oolite immediately overlying the contact is illustrated by Plate 58. The characteristics of

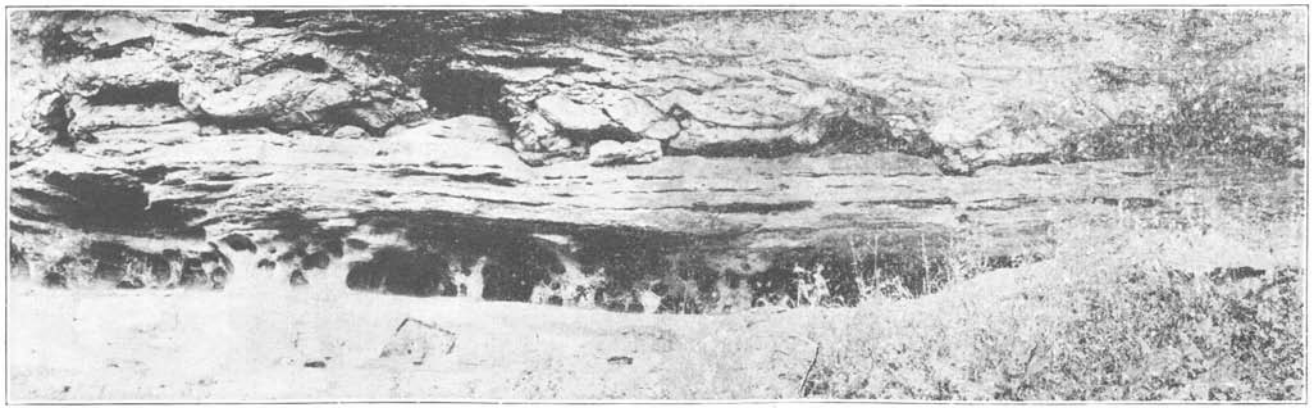


Plate 56. View of erosional unconformity between Ste. Genevieve and St. Louis limestones. Louisville & Nashville Railroad on Kentucky River about three miles west of Heidelberg. Short distance west of place shown in Plate 58. Looking north.

Plate 57. View looking west down Kentucky River from a point about one-half mile east of Yellow Rock station. Same unconformable contact as shown in Plate 56, between the light-colored bed at the bottom and darker bowldery bed of the Ste. Genevieve above shown in Plate 58. The prominent bedding contact next above is the persistent one between the bowldery bed and the thin-bedded or laminated upper siliceous oolite of the Ste. Genevieve. Top cherty bed of St. Louis with *Lithostrotion* absent in unconformity.

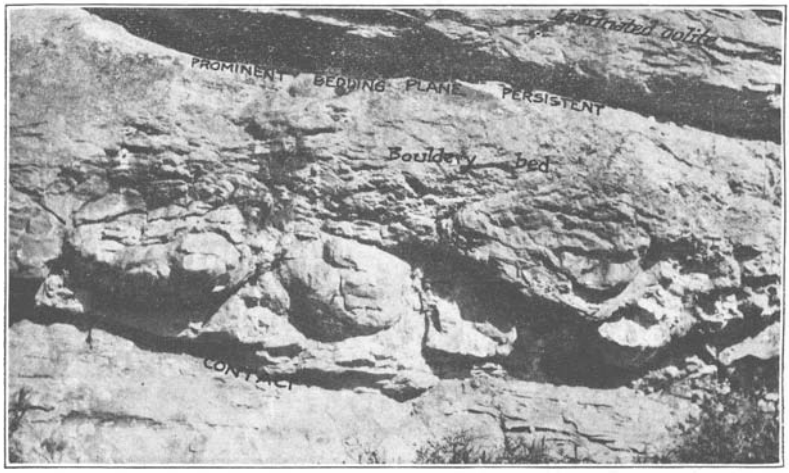


Plate 58. Bowldery oolite, basal bed of Ste. Genevieve oolite resting on St. Louis limestone with an erosional unconformity between. Louisville & Nashville Railroad on Kentucky River about three miles west of Heidelberg. Looking north. Cherty bed with *Lithostrotion,* forming the top member of the St. Louis generally in Eastern Kentucky, absent in the unconformity. See Plate 59.

this bed clearly indicate unusual conditions attending its deposition. Notwithstanding the irregularity of the top of the St. Louis here, the amount of erosion appears to have been slight. This conclusion rests on the fact that the bowldery bed of the Ste. Genevieve rests upon the yellow limestone of the lower part of the St. Louis, whereas at Irvine and elsewhere the bowldery bed rests upon an intervening bed of dark, cherty limestone, 10 feet or so thick, already described as the top member of the St. Louis. (See Plate 59.) At Irvine below the cherty limestone is about the same thickness of yellow limestone as there is below the unconformity on Kentucky river. At Olive Hill and Carter the bottom foot of the Ste. Genevieve is strongly conglomeratic, being full of limestone and chert pebbles, some of good size. This conglomerate rests upon the top of the New Providence, so that there is a break, through the absence of the Keokuk, Warsaw, and St. Louis, amounting to at least 800 feet, mainly limestone. The conglomerate and unconformity are shown in plates

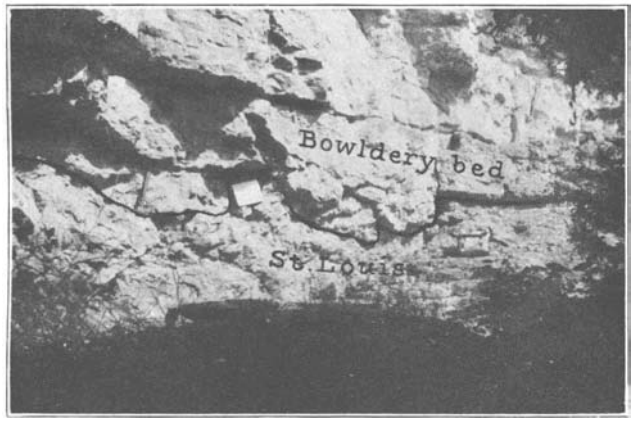


Plate 59. View showing irregular contact of the bowldery bed (see Plate 58) of Ste. Genevieve with the St. Louis limestone. The top six to eight feet of the St. Louis is a cherty limestone with *Lithostrotion*. This is underlain by about 20 feet of yellow limestone (not shown in the photograph) which rests on the New Providence formation. The *Lithostrotion* bed is absent in the unconformity shown in Plates 56, 57 and 58. Ridge about one-fourth mile north of top of Minerva Mountain, Irvine, Ky. Looking northeast.

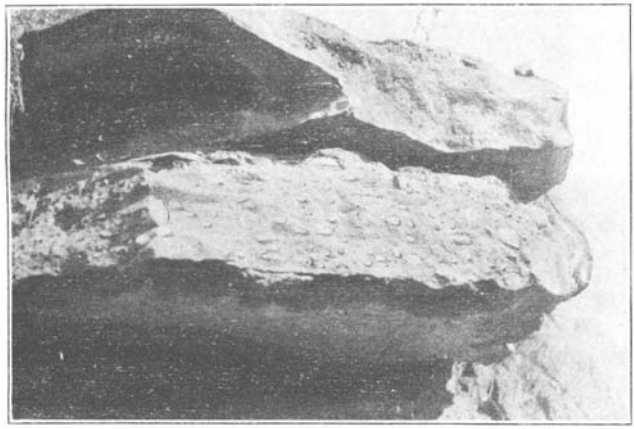


Plate 60. Basal conglomerate of the Ste. Genevieve in contact with the New Providence formation. Cut on Chesapeake & Ohio Railroad, one-half mile west of Olive Hill. Near View of basal bed shown in Plate 61.

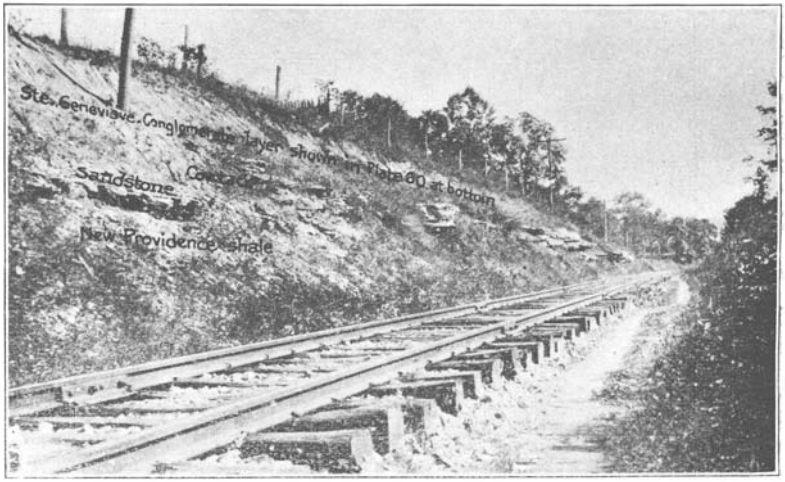


Plate 61. Basal conglomerate of the Ste. Genevieve limestone underlain by New Providence shale and sandstone in cut just east of Olive Hill. Looking east. Keokuk, Warsaw and St. Louis absent, amounting to 800 feet.

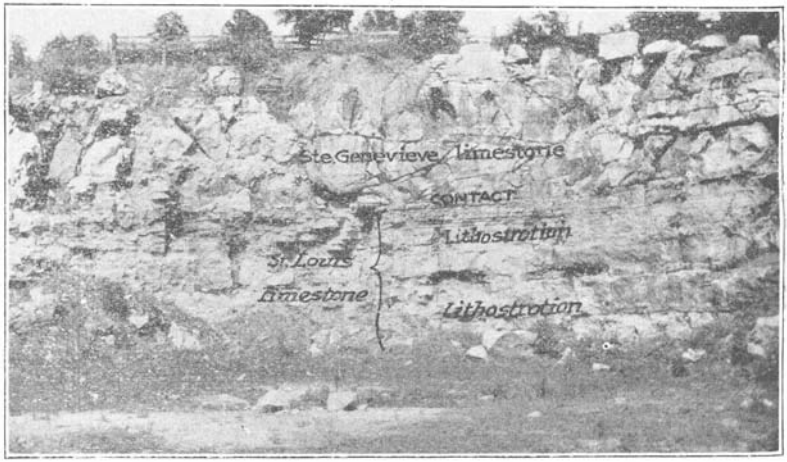


Plate 62. Old quarry one-half mile northwest of Somerset. Looking north. Ste. Genevieve limestone above. St. Louis below. Contact about middle. Layer with *Lithostrotion proliferum* six feet below contact.

60 and 61. Such contact irregularities are not the usual thing, however. At Somerset and Burnside the contact is very regular as shown by Plates 62 and 63.

Another reason for believing that there is a break between the St. Louis and Ste. Genevieve is the presence of abundant angular fragments of black chert, evidently of clastic origin, in the basal 10 feet or so of the oolitic Ste. Genevieve throughout the region from Burnside, Pulaski County, to Mt. Vernon, Rockcastle County, a distance of 30 miles. The chert of these fragments is exactly like that of the nodules in the top cherty member of the St. Louis, and most probably that is its source. They

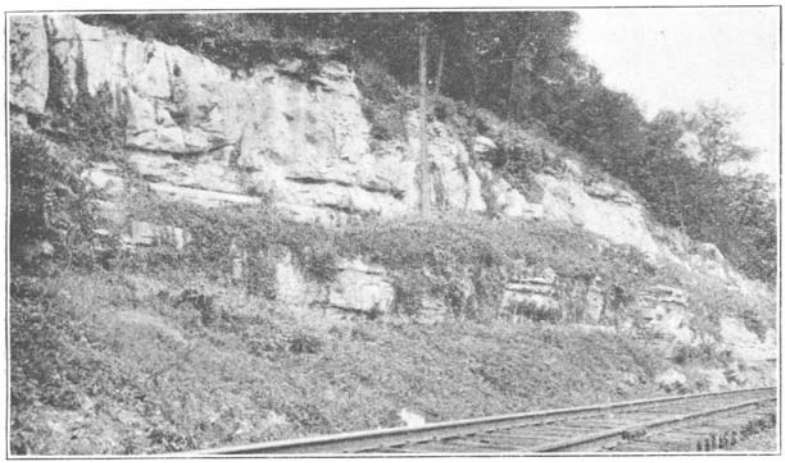
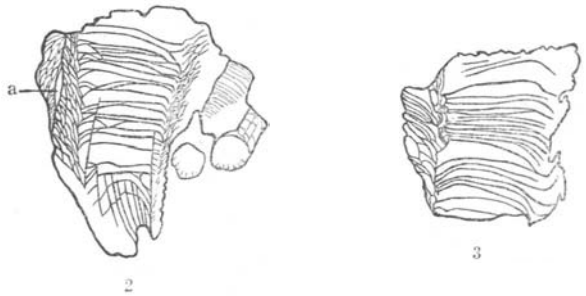


Plate 63. Natural exposure on Cincinnati Southern Railroad about one-half mile south of Burnside. Ky., showing Ste. Genevieve limestone above and St. Louis limestone below. Looking southwest. Contact at upper recess at base of massive bed. Nodules of black chert ad Lithostrotion proliferum and L. canadense in the ten feet of limestone below recess.

are the smaller fragments of chert washed from the old St. Louis land surface tributary to the transgressing waters of the early Ste. Genevieve sea.

Another possible fact points strongly to an unconformity of even greater magnitude than indicated by the facts already related. It is possible that between the St. Louis and Ste. Genevieve, nearly throughout their entire extent, a certain thickness of limestone present locally at the base of

the Ste. Genevieve is absent. Reference is made to 50 feet or more of thin-bedded, gray, non-oolitic limestone which, along Ohio River in Hardin County, Ill., intervenes between the typical St. Louis and the typical oolitic Ste. Genevieve which everywhere, except in the locality named, rests directly upon the St. Louis. Those intermediate beds differ from the underlying St. Louis in their light gray color, in the absence, so far as known, of *Lithostrotion,* and in the presence of an abundance of *Platycrinus penicillus* (*huntsvillae*), which is extremely rare in the St. Louis, but common in the typical Ste. Genevieve. On the other hand, the intermediate beds differ from the typical Ste. Genevieve in their non-oolitic character. If the interpretation here tentatively advanced should be sustained by further observations, it would mean a time break of considerable length between the top of the St. Louis limestone and the base of the Ste. Genevieve limestone.



Figs. 2-3. Campophyllum gasperense n. sp. Natural size. pp. 162-164. Median longitudinal section showing wide tabulate visceral chamber and peripheral vesicular tissue; a. lumen between epithecae of adjacent coralites filled with oolitic matrix. Locality, Nettlecarrier Creek, 3 miles northeast of Livingston. Overton county, Tenn.