

A NEMATOID WORM IN AN EGG. BY DANIEL J. TROYER.

THE GEOLOGIC RELATIONS OF SOME ST. LOUIS GROUP CAVES AND SINKHOLES.

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Before discussing the geologic relations of the caves, sinkholes and subterranean channels of St. Louis limestone to each other and to the strata in which they occur, it will be necessary to define the limits of that formation in Indiana. The Warsaw bed, as exposed at Spergen Hill and elsewhere, is recognized as the equivalent of the Bedford oölitic limestone, and the lowest member of the St. Louis. The fossils found in it are abundant and characteristic, and its lithologic peculiarities obvious. But the upper limits of the group are not so well settled. When Prof. James Hall first fully defined the Kaskaskia group, as seen on the banks of the Mississippi River, he included as its lowest member a stratum of sandstone. In Indiana the first sandstone stratum above the St. Louis has been recognized as forming a part, at least, of the Kaskaskia group, but not always as its lowest limit. The classification of Prof. Hall* was first applied to the geologic formations of Indiana by ex-State Geologist E. T. Cox, in 1872, in a report on the geology of Perry County,† in which he made the first sandstone above the St. Louis the base of the Kaskaskia group, and by the law of priority, his identification should be recognized unless there is sufficient reason for a change. Since that time the dividing line has been placed at a lower level; one observer finding it at a small coal seam in the limestone strata;‡ others at the top of the upper fossiliferous chert member of the St. Louis;§ and others have included with the Kaskaskia extensive strata of limestone under the sandstone, without indicating by a section or otherwise where the one terminated and the other began.§ Much of this confusion has grown out of an effort to limit the upper St. Louis group to such strata only as contain *Lithostrotion canadense* Castelnau and *L. proliferum* Hall, characteristic fossils

* Hall's Geol. of Iowa, pt. 1, p. 109, 1858.

† Geol. Sur. Ind., 1872, pp. 76, 77.

‡ Geol. Sur. Ind., 1873, p. 365; 1878, pp. 305, 425.

§ Geol. Sur. Ind., 1875, pp. 207, 216.

‡ Geol. Sur. Ind. 1895, pp. 231, 232; 1896, p. 300.

of the undisputed St. Louis formations. But if this palæontologic test is to be applied to the upper strata it is hard to understand how the Bedford oölitic can be retained as a member, as these fossils are not found in it.

At the top of the sinkhole division of the St. Louis in Lawrence, Orange and Washington Counties, and doubtless in Harrison County, there is a constant stratum of chert from ten to twenty inches thick. Above this chert other thin flinty layers may be found, but so far as known, they are not fossiliferous. The heavy chert may be seen in place at Paoli in the north bank of Lick Creek, at the Wesley Chapel Gulf, and on Lost River near Orangeville. Because of its frequent occurrence on that stream it is suggested that it be named the Lost River chert. It is generally highly fossiliferous, very rich in bryozoans and occasionally oölitic. *Above, and conformable with it, there is found from sixty to ninety feet of massive, close-textured limestone, slightly broken at the top by beds of calcareous shale, and near the middle by included chert nodules; generally the ground mass is lithographic. This stratum includes all the rocks found below the first Kaskaskia sandstone and above the Lost River chert, and as it is well exposed at that place it is proposed that it be known as the Paoli limestone. On palæontologic grounds, which cannot be presented in full here, the Paoli limestone is assigned to the St. Louis group. The fossils that occur in it, at many places in abundance, are of the same species as the more common forms found at Spergen Hill. The chemical composition and general appearance is such as to clearly show that it is a repetition of the strata exposed below it. Its lithologic characteristics are obvious, and the residual clay resulting from its disintegration presents the same physical appearance as the red, plastic and impervious clay of the undoubted St. Louis formations.

Mr. C. E. Siebenthal has proposed the name Mitchell limestone for "A series of impure limestones, calcareous shales and fossiliferous limestones" overlying the Bedford oölitic limestone, and says: "The topographic *tendency* of the Mitchell limestone expresses itself in plateaus perforated at short intervals by sinkholes."* As he does not define the upper limits of his "Mitchell limestone" it is suggested that his definition be amended to include all the St. Louis limestone below the Lost River chert and above the Bedford oölitic. Its upper and middle strata are largely

* Geol. Sur. Ind., 1896, pp. 298, 299.

lithographic, and quite often include chert nodules and plates. The upper members are the equivalent of the true "Cavernous limestone," and the "Barrens." In the lower portion sinks are not so common, and the strata become argillaceous and in many places hydraulic.

A section through Orange and Washington counties will show the following succession of formations:

Kaskaskia, sandstone—

St. Louis.	<i>Ft.</i>
Paoli limestone, calcareous shale and lithographic limestone	90
Lost River chert, fossiliferous.....	1
Mitchell limestone, lithographic limestone and calcareous shale with chert inclusions, the lower portion argillaceous and hydraulic.....	160
Bedford oölitic limestone—Warsaw.....	60
Keokuk.	

Total	311
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The caves of the impure, lower Mitchell limestone stratum are peculiar in that they are only incidentally connected with surface sinks, and generally have streams of water flowing from the external opening. The mouth is usually found above the oölitic limestone in the side hill of a deep valley. The interior shows the erosive effects of running water, the passage diminishes in size as it recedes from the mouth, and its side branches are low, narrow reproductions of the main cave. To this class belong Donnehue's, Hamer's and Donnelson's caves in Lawrence County. Clifty and some of the caves near Beck's Mill, Washington County, and nearly all those found elsewhere near the eastern limits of the St. Louis group.

Where the clay shales and argillaceous limestones are the surface rocks the country is very much broken by valleys that are quite different from the circular and oval depressions of the sinkhole region proper. Sinks are not wholly absent, but they are not characteristic. At many places the landscape is further modified, and the rock exposure obscured by a mantle of Loess clay that is continuous from East White River, north of Mitchell, over the oölitic and eastern argillaceous limestone area

to Salem, and on the east side of Harrison County. West of the Loess belt the lower Mitchell limestone is still the surface stone. Springs are not infrequent, and their waters combine to form small creeks that flow over the exposed edges of the strata until they reach the upper drainage level of the sinkhole area.

Small caves are common over the true cavernous limestone area and clearly show their connection with one or more sinkholes. The best known, and perhaps the largest, example of this class of caves in Orange County is found three miles west of Orleans, on the Peacher farm. Here the roof of the original cave has fallen at some period in the past and made two caves of what was once but one. The mouth of the west cave is large and opens into a wide room that terminates at the other end in a small but characteristic sinkhole. The outer roof of the east cave is low, and it can only be entered by crawling for quite a distance. Once inside, the explorer finds a capacious passage in which the sides below the middle converge to a narrow channel. The walls are covered with mud, and after a heavy rain both caves are filled with muddy water. Such so-called caves are a part of the underground drainage system of the country, and are peculiar in that they are near muddy passages, devoid of stalactites or other features that make caves so interesting to most persons. If it is kept in mind that sinkholes proper are circular basins, whose sides form a gradual slope from the rim to the bottom, they will be readily distinguished from another class where one or more of the sides is a precipitous wall of rock. The first are doubtless due to the slow chemical and mechanical forces that have tunneled the subterranean channel, the latter to the collapse of the roof of a vast cavernous opening whose arch had become weakened by a vertical fissure. At places there is evidence that the roof of the cave has fallen as much as ninety feet. This class of depressions impart to the landscape a peculiar, rugged, broken aspect, and impress the beholder with a feeling that old earth may at any moment slip from under his feet. Occasionally, at each end of the fallen mass, an opening may be found to the cave below. But usually the openings are small and do not appear to be anything more than woodchuck holes, until some winter morning the moist air of the cave, as it rushes out, is touched, as if by fairy fingers, and the shrubbery growing near hung with festoons of hoar frost. The angular depressions are found west of the small circular basins, and near the foot of the Kaskaskia group sandstone hills. Great blocks of Lost River chert cum-

ber the ground in marked contrast to the smaller fragments of the eastern margin of the typical sinkhole limits. It is possible that some of the circular depressions may have been exposed by the roof of a cave falling, but if such was the case there is no evidence of it left. The roof must have been composed of limestone as their rims are several feet below the geologic horizon of the Lost River chert. If limestone fragments of the roof were ever present they have disappeared; and the more probable theory seems to be that the depression is the result of erosive forces acting equally upon all the sides. The rocks exposed in place where the sinkholes are common in Lawrence, Orange, Washington and Harrison counties are always members of the upper or middle portion of the Mitchell limestone, and the angular chert masses and fragments scattered over the surface and mixed with the red residual clay come from the same strata or from the Lost River chert stratum.

The sinkhole area, as a rule, has no surface creeks and branches, and such as reach its limits from without soon find an opening and disappear wholly or in part, except Blue River and Buck Creek. Occasionally the creek or branch is replaced by a dry-bed channel. The dry-beds only come into use after heavy rains or when the subterranean passages are burdened beyond their capacity. Lost River through a part of its surface course is a typical dry bed. When it reaches the eastern edge of the sinkhole region it finds a number of underground channels that take in all the water of the perennial stream east of the Orleans and Paoli road. If the first openings are overtaxed, the overplus of water passes through a dry-bed channel farther west into other sinks, but after an excessive rainfall all the sinks fail, and water runs on the surface through the whole extent of the dry-bed system and again becomes a part of the perennial stream a short distance below the Orangeville "rise." Indian Creek for a part of the year runs underground, but, unlike Lost River, the greater part of its water passes over a surface channel and a dry bed is only exposed during the summer months. It sinks two miles southwest of Corydon and "rises" again five below on an air line, and twice that distance following the meanderings of the creek bed. There is ample evidence that Lost River, like Indian Creek, at some period in the past was wholly, or for the greater part of the year, a surface stream over its dry-bed channel.

Contrary to what might be expected, the subterranean channels do not greatly increase in capacity as they unite and pass under the Kaskaskia

Hills. This is shown four miles west of Orleans at what is called the "wet-weather rise" of the dry-bed. Here water flows out as it is flowing into the upper sinks, hence water may be flowing through two miles of the upper and lower course of the dry bed and not through the middle channel. As soon as the flood-water begins to recede at the "wet-weather rise" the direction of the flow changes, and, instead of running out, flows back into the opening from which it came. At times the whole underground system of channels is overtaxed and the water finds an outlet at many places, and occasionally through artificial openings, such as the well at Brookstown and another east of Orleans.

The underground channel of Lost River can be reached at three places through cavernous openings. At the first of these, near the first sinks, the superincumbent limestone is about forty feet thick; at the second opening the channel is not less than sixty feet below the Lost River chert; at Wesley Chapel Gulf it is thirty feet below the chert stratum, and the same at Orangeville. This indicates that the subterranean channel closely follows the dip of the strata to the west.

Comparatively speaking, sinkholes are rarely seen in the Upper Paoli limestone, and when they do occur are rough, angular openings in the limestone, of limited area. They are not an important feature in the surface drainage of the country, except in the valleys when located near the level of the Lost River chert.

The tendency of the subterranean channels to unite and diminish in capacity gives rise to a number of remarkable artesian springs that burst forth in great volume near the western limits of the Mitchell limestone exposure. The mouth of these springs seems to open into a vertical tunnel in the rock, and is always full of water that ordinarily flows gently away at one side. The deep blue of their water has given rise to the report that they are without bottom. After a heavy rain the volume of water discharged is very greatly increased and shows the effect of increased pressure. They are very unlike the wet-cave springs seen on the eastern limits of the St. Louis group limestone. The Orangeville and Shirley "rises" of Lost River and the Spring Mill head of Lick Creek are examples in Orange County. Those near Hardinsburg, Washington County, and the Harrison Spring and Blue Spouter, in Harrison County, are others of note.

Wyandotte and Marengo Caves belong to a class of caverns noted for their extent and great beauty. They do not seem to occupy a much higher

place in the St. Louis series of rocks than the sinkhole channels, but unlike them they are never inundated with floods of muddy water. Their exemption from overflows is due to the fact that the water-bearing channels terminate as artesian springs soon after they pass beyond the sinkhole plateau and under the Paoli limestone and foothills of the Kaskaskia sandstone. The artesian springs are found east of the Crawford County caves, and, if this was not the case, the deep valley of Blue River as it runs south on the eastern boundary of the county, would terminate the westward trend of the underground drainage system of Harrison County. The entrance to the Wyandotte cave is 150 feet above Blue River; and none of the cave entrances of this class are below or on a level with the creeks of the surrounding country, as they are where sinkholes are common. Where the Mitchell limestone is well protected by the overlying Paoli limestone and Kaskaskia strata, caves of any kind are rare, but when they do occur they are very interesting and should be thoroughly explored.

In Missouri, it is said that when the coal measures strata rest immediately on the St. Louis limestone, deep borings pass through cavernous openings,* which is explained by the theory that the St. Louis was for a time dry land and more or less tunneled before the coal strata were deposited.† There is very little data to show that the Indiana St. Louis is cavernous for any great distance beyond the surface sinks. As the sinks are only common where the Paoli limestone has been removed it is reasonable to suppose they do not occur under other conditions, and this view is confirmed by what has before been stated. Two deep wells have been drilled at Paoli and no caverns noted. At Orleans, in one out of three wells, the drill passed through a cave at one hundred feet below the surface; but the latter town is located on the cavernous limestone and the former is not.

In comparing the caves of Indiana with those of Kentucky it is well to remember that in the immediate vicinity of Mammoth Cave, according to competent authority, the Kaskaskia group strata are wanting, and the capping stone of the St. Louis is one of the sandstone members of the lower coal measures. Some of the Kentucky caves are said to reach up to the sandstone, but if the same is true of the Indiana caves the fact has not been noted, nor is it probable that such will be found to be the case.

* Keyes' Mo. Geol. Sur. XI, p. 252.

† Keyes' Mo. Geol. Sur. IV, p. 73.

The chemie composition gives a hint as to the origin of the St. Louis caves, and bears out the conclusions here presented. Prof. John R. Proctor says* that in the vicinity of Mammoth Cave the subcarboniferous limestone is "a massive, remarkably homogeneous rock with no intervening strata of shale or sandstone, conditions most favorable for the formation of caverns." In the main his statement is true of the equivalent strata in Indiana, but does not take into consideration certain beds of limestone that weather to a calcareous shale or the variable chemical structure of the Indiana stone, both important elements in studying the relations of the strata to the caves they bear. Probably more to the point is the statement of Prof. W. H. Wheeler,† who, in writing of the topography of St. Louis County, Missouri, says: "The limestones of the St. Louis area are very hard, tough, and resist mechanical disintegration, but on account of the prevalent *purity*, they are very susceptible to chemical dissolution." "If the upper portion of the limestone is impure, and especially if high in magnesia, it is much more resistant to chemical dissolution, and the sinkhole method of drainage is frequently absent. In this case the drainage is by surface channels, which are abrupt and irregular and vary sharply from gentle to heavy slopes." But, while it is conceded that homogeneity and purity largely determine whether the dissolution is chemical or mechanical, they do not appear to fulfill all the required conditions. The Bedford oölitic and Paoli limestones, by chemical analyses, are shown to be from 95 to 98 per cent. calcium carbonate, and the Mitchell limestone less rich in lime by 10 per cent., yet the first two formations have but few caves, while the last is undermined with cavernous openings. That the surface exposure of the Mitchell limestone contributes greatly to its disintegration has already been mentioned, but this does not explain its inherent susceptibility to chemical dissolution. If the number of analyses of the St. Louis limestones above the Bedford oölitic are not near so many as one would wish, those which are available seem to be suggestive. Dr. G. M. Levette, under direction of Prof. E. T. Cox, made a number of analyses of hydraulic cement rock from the lower Mitchell limestone strata of Harrison County, and as equivalent beds of cement rock are found at Becks Mill, Clifty, and many other places, one of them is here given.*

*The Century Magazine, March, 1898, p. 643.

†Keyes' Mo. Geol. Sur. XI, p. 249.

*Geol. Sur. Ind., 1878, p. 75.

No. 1.—Cedar Grove cement rock.

Water expelled at 212° F.....	1.00
Insoluble silicates.....	27.70
Soluble silica	.10
Ferrie oxide and alumina.....	4.00
Lime	35.00
Magnesia	trace
Carbonic acid.....	27.50
Sulphuric acid.....	trace
Organic matter, undetermined and loss.....	4.70
	100.00

The following analyses† were made by Mr. G. A. Kerr for this paper:

No. II.—Bluish-gray, hard limestone with chert inclusions; two miles east of Orleans on the Livonia road. Below the Lost River chert. Specific gravity, 2.68.

Insoluble silica.....	10.670
Iron	0.304
Magnesia	.461
Alumina	3.210
Calcium carbonate.....	84.920
Undetermined	.435
	100.000

No. III.—Gray, weathered, friable limestone, from the surface of a bluish-gray, lithographic limestone, one mile west of Union Church and three miles southwest of Orleans. Below the Lost River chert. Specific gravity, 2.44.

Silica, insoluble.....	5.580
Iron	0.257
Magnesia	0.284
Alumina	3.010
Calcium carbonate.....	89.904
Undetermined	.965
	100.000

† Thanks are due Mr. G. A. Kerr, chemist to the W. W. Mooney & Son's tannery company, Columbus, Indiana, for kindly making analyses Nos. 2, 3 and 4 at my request.

No. IV.—Drab, fine-grained lithographic limestone, Wesley Chapel Gulf, three miles east of Orangeville. Fifty feet above the Lost River chert near the middle of the Paoli limestone.

Silica, insoluble	1.520
Iron, ferrie oxide.....	.278
Magnesia	.712
Alumina	1.555
Calcium carbonate.....	95.001
Water expelled at 110° C.....	.630
Undetermined and loss.....	.304
	100.000

One of the first things to be noted in the Mitchell limestone analyses is the persistent presence of a much larger per cent. of silica than is common to an otherwise pure limestone; and it is at least singular that the quantity of silica should be reduced one-half in the weathered specimen from the same horizon. To test whether the less percentage of silica in specimen No. 3 might not be due to a difference in the chemical composition of the unweathered stone from which it was taken, the soft, gray, broken-down surface of No. 2 was tested, and found to contain but 4.82 per cent. of silica as against the 10.67 per cent. of the unweathered mass. The silica from all the analyses was disengaged as an impalpable powder, and it is singular that the insoluble silica should be the first one of the salts to disappear in the process of dissolution. Another fact of note is the constant presence of alumina and a small quantity of magnesia. The low percentage of magnesia doubtless explains why the Mitchell limestones are so readily disintegrated by carbon dioxide in solution.

SUMMARY.

The caves of the St. Louis group in Indiana may be divided into three classes: The wet caves of the lower and more impure Mitchell limestone; the subterranean channels, caves and sinkholes of the middle and upper Mitchell limestone, and those of the upper Mitchell and Paoli limestone. And as to origin: Those in which mechanical forces were dominant; those in which the mechanical and chemical action was nearly equal, and those in which chemical dissolution was the principal factor.