Caves and Cave Formations of the Mitchell Limestone.

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THE MITCHELL LIMESTONE.

The Mitchell limestone, otherwise known as the St. Louis, barren, or cavernous limestone, is a bluish or grayish, hard, compact, even-grained stone, generally having a conchoidal fracture. It is so compact as to make it rather impervious. Intercalated layers of blue-gray shale are frequent. Large concretions or chert are characteristic of certain horizons. When the stone weathers, these masses of chert do not dissolve, but break into more or less angular fragments which strew the ground over the Mitchell area. In Indiana the formation is also characterized by the common presence of a genus of corals known as *Lithostrotion* or *Lonsdaleia.* In some places, such as western Monroe or southern Crawford County, there is a typical white oölite found near the top of the formation.

Analysis shows the Mitchell to be a very pure calcium carbonate, and at Mitchell, Lawrence County, from which place the formation received its name, it is extensively quarried for making lime and cement.

It is found in Harrison, Floyd, Crawford, Washington, Orange, Martin, Lawrence, Monroe, Greene, Owen, Morgan, Putnam, Parke, and Montgomery counties.* It extends south into Kentucky and west into Illinois, where it exhibits similar characteristics.

In the southern part of the State it reaches a thickness of 350 to 400 feet; in the central part of its area, that is, in Lawrence and Monroe counties, the thickness is from 150 to 250 feet, and from here gradually thins toward the north.**

The greater part of the Mitchell lies in the non-glaciated portion of the State, thus exposing an erosion topography unaffected by other agencies. Several factors enter into the cause of its present topographic aspect. During Cretaceous time the area in which the Mitchell is located was eroded to base level, forming part of the great Cretaceous peneplain. After this event had occurred, a period of elevation began so that erosion

*Hopkins, T. C., 28th An. Rept. Ind. Dept. Geol., p. 57.
**Op. cit., p. 58.

again commenced to cut down the surface, and probably during the Tertiary period, it again reached partial peneplanation with a few monadnocks here and there standing above the general surface. It is this Tertiary peneplain which gives the country its level appearance when viewed from a distance. Since this second peneplanation, the country has probably been relatively elevated to the present time. The western edge of the Mitchell area is overlain by the Huron formation, which, by reason of its hard and soft strata, has taken on a very rugged aspect. To the east of this belt level lies the central or slightly rolling area of the Tertiary peneplain, while to the east of this, the eastern edge again becomes rolling, owing to the underlying Salem and Harrodsburg limestones.

The Mitchell has a dip to the southwest which probably averages 20 to 30 feet to the mile. This affects surface streams, though these are very few, owing to the extensive underground drainage.

The general relief of the surface of the Mitchell area becomes greater toward the Ohio River. This is probably due to at least three causes, namely, the dip to the southwest, the increasing thickness of the formation, and the fact that the Ohio River is the largest stream draining the area and has cut down to the lowest level of any stream in the area under consideration. In the vicinity of Wyandotte Cave the general level of the upland is about 300 feet above the level of Blue River.

The Mitchell limestone has long been known as the "Cavernous limestone." Both the Wyandotte Cave of Indiana and the Mammoth Cave of Kentucky occur in its strata. In three counties in the vicinity of Mammoth Cave, over five hundred caves are known to exist. These facts lead us to investigate the general adaptibility of this limestone to cave formation.

The reasons of this adaptibility are numerous. Besides the bedding planes, two sets of vertical joint-planes exist, one set having a general east and west direction and the other a north and south direction. Vertical joint-planes are probably more numerous in this, than any other of the Mississippian limestones. Owing to the fact that the Mitchell is rather impervious and often of a lithographic nature, the down flowing water is forced to follow the joint and bedding planes. The underlying Salem limestone contains joint-planes but is porous enough to become thoroughly saturated instead of confining the water to joint-planes.

The Mitchell limestone has a great thickness of rocks of nearly uniform texture. It is composed of nearly pure calcium carbonate, which renders it soluble to meteoric water. Many of these facts are brought out by Cummings in his paper, "On the Weathering of the Subcarboniferous Limestones of Southern Indiana," in the Proceedings of this society for 1905, pages 85-100. The great central area is practically level, owing to Tertiary peneplanation, thus lessening the amount of run-off. The western part of the area is overlain by the Huron formation, composed largely of porous sandstone which absorbs precipitation and passes, a part of it, at least, downward into the underlying Mitchell. The area as a whole is wooded, which also tends to hold meteoric water rather than to give it up to such surface drainage as exists. The area in Indiana lies in a section of country which is one of relatively great humidity.

The individual layers of the formation are comparatively thin and are generally separated by thin layers of impervious shale. This factor tends to weaken the layers when a cave is formed beneath them and allows them to collapse, thus giving the stream the opportunity of enlarging the cave in a mechanical way by removing the debris.

FORMATION OF CAVES.

Limestone ($CaCO_3$) is only slowly and difficultly soluble in pure water, but when water descends through the atmosphere as in rain and snow, a certain per cent. of CO_2 is dissolved, forming H_2CO_3. This is enabled to dissolve calcium carbonate, forming calcium bicarbonate thus: $H_2CO_3+CaCO_3=CaH_2\ (CO_3)_2$. The latter product remains in solution until evaporation takes place. It is owing to this fact that stalactites and stalagmites are formed in caves.

Now when rain-water falls on an area such as that underlain by the Mitchell limestone where the conditions favor a minimum amount of run-off and evaporation, and where the greater amount of precipitation soaks into the soil, it will tend to collect and flow downward through the most available passages. Such passages are furnished by the above-mentioned joint-planes. Where two of these joint-planes cross at right angles, the passage will be freest and it is probably at such points that most of the ground-water passes downward. This downward flow of water may be arrested by several causes, four of which are most important. The joints become tighter as they descend into the earth; the level of ground-water, where the flow in the joints is retarded, may be reached; an unusually impervious layer of limestone or shale may be present; or what is probably most important, a level corresponding to that of the local base level of erosion may be reached and divert the downward moving water. Any or all of these causes may change the downward flow of water into lateral flow, although in time they may cease to have this function, owing to chemical or mechanical erosion.

Locally other factors may enter into the stoppage of the downward flow. These may be greater hardness or impurities of the limestone, etc.

The horizontal flow will naturally follow the line of least resistance, which will be along the line of one of the joint-planes. Thus young caves and many which are older, follow approximately straight north and south, and east and west lines and have right-angled turns. The direction of the cave stream will be determined by local conditions, such as hardness, dip, solubility and nearness to surface streams.

At first the erosion will be by solution, but in time the cave stream will come to be governed by much the same laws as surface streams and corrosion will do its share in enlarging the cave. The original downward opening will become larger and surface material with its hard, angular pieces of chert, and soil will be washed into the opening, and sinkholes such as are characteristic of the Mitchell area, will be formed. In time these become very large, occasionally containing many acres; however, it may be said that the very large sinkholes (and these only) are formed by collapse of caves.

In the young cave there will be no evidence of any erosion except that by solution. The water is very clear and contains a minimum amount of solid matter; the cave will be bounded on all sides by solid rock walls and angular protuberances will be everywhere conspicuous.

So much for the common type of a very young cave. A multitude of factors determine the size and shape of a cave as it grows older. Much depends on the level of the surface stream into which the cave stream flows. If the surface stream is much lower than the level on which the cave stream flows, the latter will cut down rapidly, other things being equal, thus forming a narrow and deep cave such as is seen at the entrance of Shawnee Cave in Lawrence County, or in Wyandotte Cave. If the level of the surface stream is near that on which the cave stream flows, the tendency will be toward lateral erosion, and the cave will cut downward only as rapidly as does the surface stream of which it is a tributary.

Most of the surface streams and probably all of the cave streams of the area had their origin since the Tertiary peneplanation. The Mitchell area has been elevated since then, as was mentioned above, but owing to the fact that this elevation has been more or less interrupted, the surface streams have devloped terraces and the caves near the Ohio and its older tributaries have in some cases four or five levels, probably due to the same cause. Only the lowest of these levels will contain water at the present time. The four or five levels of passages in caves in the region under discussion may have had other local causes, such as differences in hardness or solubility, etc. It is not meant that all caves in this region have several levels, for new caves are continually being formed.

The bedding planes being planes of weakness, the cave will be broader at the bedding planes than between them. (Fig. 1.) Softness or unusual solubility of a particular layer will cause a broadening of the cave, while hardness or insolubility will result in a narrowing. If a cave is following some particular joint-plane, a cross joint (which perhaps carries a larger or smaller stream) will cause a decided broadening, due to the weak spot caused by the cross-joint.

When a particular cave stream reaches temporary base level it will cease downward cutting and begin eroding laterally. In this case the stream is generally supplied with abundant abrasive material. In time this will produce a cave with a sort of an inverted T-shape. (Fig. 2.) Owing to the thinness of the layers, in time this will cause a collapse of the sides and roof, such as has taken place in many parts of Wyandotte Cave. (Fig. 3.)

If such action takes place where two joints cross, the amount of rock precipitated from the roof and walls will be enormous, producing such a mound as Monument Mountain in Wyandotte, where a mound over one hundred feet high has been formed. In the upper part of Shawnee Cave, Lawrence County, the lateral erosion has been very great and in some places in this and also in Wyandotte Cave, this tendency has resulted in the collapse of the floor of an older passage above. Thus it will be seen that the floor of an old cave will be apt to be rough and rocky instead of level, although there are cases where the stream has suddenly found another outlet, leaving an old cave with a smooth and firm floor.

Most of the old caves and some of the younger do not follow straight cardinal lines or have right-angled bends. In young caves this is due to a tendency of the stream to straighten its course just as a surface stream does, although hardness and solubility of the rock play a large part. (Fig. 4.) For example, if on one side of a joint-plane which a cave stream is following, there is a particularly soluble spot, there will probably be a bend or curve developed at the soluble place. (Fig. 5.) In old caves these factors, together with that of collapse from lateral erosion after base level has been reached, change the shape so that a straight line or right-angled bend is seldom seen.

SPECIAL PHASES—PITS AND DOMES.

Many caves are characterized by pits and domes. The former may be formed in two ways. Where there is a particularly soft or soluble place in the floor of a cave, the hard, angular fragments of chert will congregate, and by a whirlpool-like abrasion and solution, a pot-hole will be produced. These sometimes reach large dimensions, as in Wyandotte, where pits twenty or thirty feet deep have been formed. In one particular passage of Wyandotte, the downward erosion has been very rapid, so that the stream has cut down to a lower level, leaving several natural bridges of solid rock.

The second type of pit and the domes are related. Often where two sets of vertical joint-planes cross, the water trickling down will dissolve out an erosion dome. In Mammoth Cave of Kentucky, these domes often reach a height of one hundred feet or more. They may be formed down to the level of the passage along one of the joints, in which case they are simply domes, or they may continue eroding after one passage has been deserted by the stream and continue to erode to a lower level occupied by another stream, thus forming a pit or dome according to the level from which they are viewed. (Figs. 6 and 7.)

CAVE ENTRANCES.

Cave entrances may be formed in four principal ways. A sink-hole may become large enough to serve as an entrance, either by corrosion and solution, or by subterranean solution of the dome-forming type. Ropes, ladders, or steps are generally needed in this type of an entrance. The entrances to Little Wyandotte and Marengo caves of Crawford County are of this type.

Another and common type of entrance is that by way of the mouth of the out-flowing cave stream. In a young cave this is apt to be on the horizontal; but when one mouth is abandoned for another at a lower level, weathering produces a curious change. The rocks above the cave mouth will weather and fall to the floor, thus causing the entrance to progress up the slope and a great pile of debris to collect on the original floor of the cave. (Fig. 8.) The entrances to Wyandotte and Saltpeter caves of Crawford County, and Mammoth Cave of Kentucky are of this type. A shaft was sunk to the depth of sixty feet at the mouth of Wyandotte before the solid rock floor was reached.

A cave stream may undermine the rock beneath a low place such as a sink-hole, causing the overlying strata to collapse. In this case there will be two entrances at the place where the cave-in occurred. Should atmospheric agencies weather back the two entrances the cave stream will flow above ground for a greater or less distance. This action has occurred twice in Shawnee Cave, Lawrence County, and the surface portions of Lost River, Orange County, have probably come about in an analogous manner.

A fourth type of cave entrance is that produced by a surface stream eroding its way into a cave; but this type is probably common only in regions of great relief, such as those bordering the Ohio, since surface streams of sufficient size to accomplish this are rather rare in the Mitchell belt.

MATERIALS DEPOSITED IN CAVES AFTER FORMATION.

It was stated in the second portion of this paper that calcium bicarbonate ($CaH_2(CO_3)_2$ was formed by the action of atmospheric water on limestone. This substance will remain in solution until evaporation takes place, when it will split up as follows: $CaH_2(CO_3)_2 = CO_2 + H_2O + CaCO_3$. The carbon dioxide being 1.5 times as heavy as air sometimes settles in the lower portions of caves, rendering them dangerous, but this is not often the case in the caves of the Mitchell area owing to the presence of air currents which remove the gas. The $CaCO_3$ will remain as stalactitic and stalagmitic deposits. Owing to the fact that in the lower and younger parts of the cave, which contain water, the air is generally saturated so that evaporation is at least not rapid, the calcareous deposits are found in greatest abundance in the higher and drier passages.

In the deposition of calcareous material the joint-planes again play a prominent part, due to the fact that water is able to find its way down through them. Very often the vertical joint along which a cave was formed will be marked overhead by a row of stalactites and sometimes by a row of stalagmites on the floor beneath. Where two joints cross each other the deposition is apt to be greatest. In Wyandotte cave in two places where large piles of rock have fallen (Senate Chamber and Monument Hill) owing to cross joints, the piles of rock are crowned with large stalagmites directly beneath the crossing of the vertical joints.

Often the water does not evaporate right at the base of the joint but trickles down the side walls, depositing a coating of calcareous material there.

In Milroy's Temple, Wyandotte cave, and in Shawnee cave, Lawrence County, the evaporation has not always taken place at the lower end of the stalactite, but they are curved outward and upward. This is possibly due to the twining tendency in the crystallization of the calcite. Local conditions may give rise to an almost endless variety of these calcareous deposits.

Under certain conditions gypsum and epsomite are deposited in caves, the former as a coating of the walls and as curved crystals or "Oulopholites," and the latter as delicate needle-shaped crystals in the earth of the cave floor. H. C. Hovey in the "Manual of the Mammoth Cave of Kentucky" states that the black deposit on the ceiling of the Star Chamber of this cave is the oxide of manganese. All of these materials are derived from the Mitchell limestone, but owing to its purity are not nearly in such great abundance as the calcite deposits.

The materials deposited on the floors of caves are generally of three classes: fallen rock, chert gravel and nitrous earth. Of the first class there is little to be said, as it has already been mentioned. The chert is derived from the concretions of chert in the limestone. Owing to its insolubility, it remains after all other materials have been dissolved. In Shawnee cave, Lawrence County, it has in places been cemented together by calcite and some oxide of iron to form a hard, firm conglomerate.

The nitrous earth or "saltpeter dirt" is practically always found in passages now abandoned by the streams which formed them. It seems to have been originally the finer portion of the solid matter carried by the cave stream. Some slackening of the current, probably due in most cases to fallen rock, caused this material to be deposited. The deposition then continued until the stream found another outlet. Another source of this fine earth, and probably equally as important, is that of material washed in through crevices and small sink-holes to the passages directly beneath them, which, of course, would be the higher passages of the cave. Now these high and dry passages are the ones most liable to be frequented by bats, and it is probably from the dung of these animals, which, according to Hahn,* spend about five-sixths of their existence in a dormant state, that the potassium nitrate is derived. Inspection of the earth in a

*Hahn, W. L., Some Habits and Sensory Adaptations of Cave-inhabiting Bats. Biol. Bul., Vol. XV, No. 3. Aug. 1908, p. 190.

dry passage of Shawnee cave, Lawrence County, revealed a multitude of bat bones scattered through this earth, a fact that seems to confirm this theory.

In conclusion it may be stated that local causes may and often do exist that affect the formation of a particular cave and that are diametrically opposed to the factors enumerated above, so that no set of rules or conditions can be formulated for determining the formation of a cave or explaining its formation.

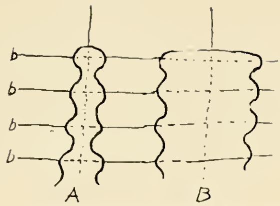

Fig. 1. Showing the effects of bedding planes where the stream has cut down rapidly (A) and slowly (B).

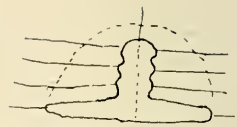

Fig. 2. Showing the effect of long continued lateral erosion. The dotted line shows the curve of greatest strength.

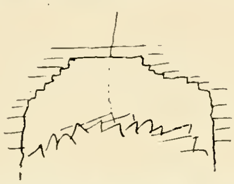

Fig. 3. Showing collapse due to weakness from lateral erosion. The cave has assumed the curve of greatest strength.

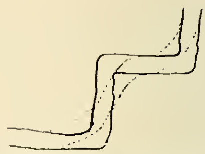

Fig. 4. The solid lines show the original cave and the dotted lines the course the stream will seek to pursue.

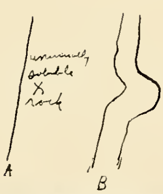

Fig. 5. Effect of unusually soft or soluble rock.

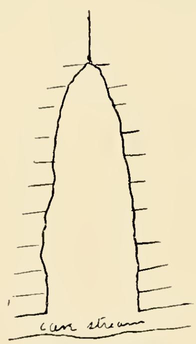

Fig. 6. Dome.

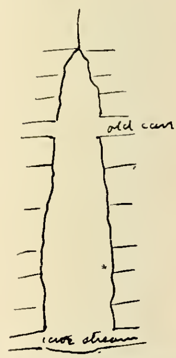

Fig. 7. Pit and dome.

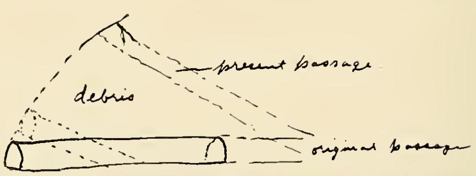

Fig. 8. Progression of a cave entrance up a slope.