On the Weathering of the Subcarboniferous Limestones of Southern Indiana.

By E. R. Cumings.

The subcarboniferous (Mississippian) limestones of southern Indiana comprise three formations known in the ascending order as the Harrodsburg, Salem (Bedford) and Mitchell limestones, and having a combined thickness of at least 350 feet. These rocks are in the main very pure carbonate of lime. Some shaly layers are to be found in the Harrodsburg and Mitchell limestones which may contain very little lime; and the Harrodsburg is rather lower in the per cent. of lime carbonate than the other two formations. Analyses of the Salem limestone show from 97.9 per cent. to 98.4 per cent. $CaCo_3$, with the balance consisting of magnesium carbonate, and oxides of iron and aluminum, with traces of silica and other substances. Analyses of Mitchell limestone show from 96.65 per cent. $CaCo_3$ to 99.04 per cent., with the balance consisting of magnesium carbonate, iron, aluminum, and silica as in the Salem limestone. Satisfactory analyses of the Harrodsburg limestone are not at hand. Of these limestones the Salem is the most constant in composition and is on the average the highest in per cent. of $CaCo_3$.

In texture the three limestones vary widely. The Harrodsburg is rather thin bedded, coarse-grained, fossiliferous, in some cases decidedly crystalline in structure, and contains geodes abundantly, in the lower portion especially, and bands and knots of chert. There are layers and lenses of shale. The Salem limestone, on the contrary, is, as is well known, almost without bedding planes. It is a massive, oölitic or granular-crystalline, close-grained rock frequently cross-laminated and quite free from geodes and chert. Its fossils are usually minute, foraminifera and small ostracods predominating. The Mitchell limestone is in the main thin-bedded, hard, fine-grained, sometimes almost lithographic, with frequent alternations of shaly layers. It is in general unfossiliferous. Bands and knots of chert are very common, but geodes are infrequent.

All these limestones are conspicuously jointed. The Mitchell shows the cleanest and most numerous joint planes; but the best examples of deeply opened joints are to be found in the Salem. The joints run nearly east and west and north and south. In other words, one set runs with the dip, and the other with the strike. The dip joints are the most conspicuous.

The weathering of these limestones does not differ in essential features from that of limestones in general, except as it is influenced by local conditions of temperature, rainfall and drainage, and by the exceptional purity of the rocks. It is to be expected that a nearly pure carbonate of lime, in a region of rather copious rainfall and mild climate would weather almost entirely by solution and other chemical processes, rather than by mechanical processes. The limestones in question exhibit the effects of solution on such an extensive scale as to warrant calling particular attention to them; and it is for this reason that the present paper has been prepared. To this end attention has been called to the composition, texture and structure of these rocks, even at the expense of repeating descriptions already many times recorded in the literature of Indiana geology. It is only by understanding the intrinsic nature of a rock that we can correctly appreciate and explain its metamorphism, whether it be in the zone of weathering or in the deeper zones.

The chief agent of weathering in the present case is meteoric water charged with CO_2 and with organic acids (humic acids). The normal annual rainfall in the region under consideration is 42 inches (somewhat more in the southern counties), rather evenly distributed throughout the year. The largest average precipitation has been in the month of July, while the minimum has been in the fall months—September, October, November. The mean annual temperature is 52° F. The topography of the limestone region excepting its eastern and western borders is undulating, and of rather mild relief. Rolling uplands in which the larger streams are rather deeply intrenched are the characteristic features. The conditions are therefore such as to admit of a comparatively copious entrance of water into the rock and free egress at lower levels into the main streams. Such conditions favor solution. Solution has also been favored in the past by the heavily forested condition of the region before its settlement by the white race.

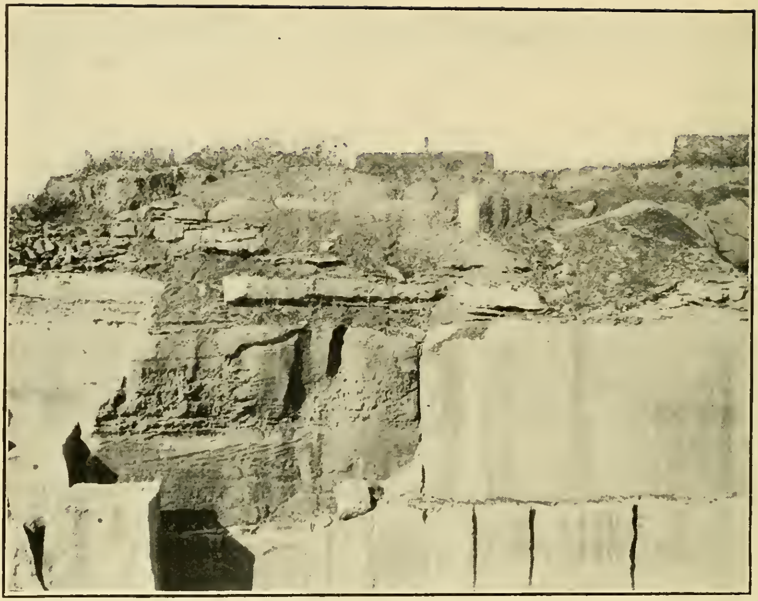
The water which finds its way to lower levels in the rock than can be tapped by the local drainage is frequently returned to the surface along joint planes in the deep valleys on the western border of the region. A notable instance of this is the French Lick Valley, which must derive its mineral waters, now rendered famous by extensive exploitation, from the uplands of the Mitchell limestone, some fifteen or twenty miles to the eastward. These waters, which reach the deeper zones of flow, are always strongly impregnated with mineral salts. Much of the mineral water of the French Lick Valley comes from a depth of 400 to 500 feet. Owing to the depth to which it descends and distance which it travels, the water has been brought into intimate contact through a considerable interval of time with these eminently soluble limestones and its highly mineralized condition is an evidence of the vast amount of material removed from them, most of which, however, has undoubtedly been derived from a comparatively superficial zone.

The most conspicuous effects of solution are those produced at or near the surface of the rock, and it is these that the photographs presented herewith illustrate. In quarry openings where the rock has been taken down along a joint plane, so as to expose the wall of one of these avenues of ground-water, the effects of solution are shown in greatest perfection of detail. The dip joints are often greatly enlarged, their walls pitted and honeycombed, and traversed by arborescent systems of small openings through which the carbonated waters have eaten their way; and the once solid rock is reduced to a crumbling earthy substance stained and rusted with iron. Where two joints (dip and strike) intersect, the enlargement is apt to be greatest, giving origin to funnels, narrowing gradually downward, and showing in a beautiful way the method of formation of sinkholes, which are only such funnels of solution grown large.

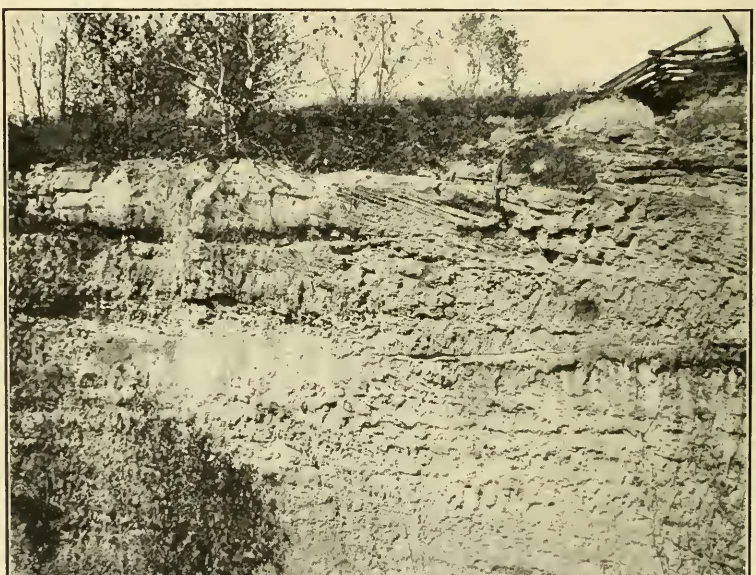
Where the surface of the limestone has been denuded of soil, for quarrying purposes, it is found to be corroded to a remarkable extent. Every dip joint now becomes a ragged furrow, and between joints the rock rises in hummocky ridges, the hog-backs of quarrymen. Points and knobs and mushroom-like projections meet the eye at every turn—bewildering in variety and impossible to describe. The hog-backs frequently stand as high as a man's head, and their flanks are scarred and scored by the all pervasive attack of the dissolving water.

Except where the activities of man or nature have removed it, a blanket of red soil overlies and hides this marvelous complex of corroded rock. The red soil or clay is the minute remnant of the original rock, left after the lime carbonate has been carried away in solution by the water. It is the insoluble residue. So complete has been the removal of the lime that this residual soil requires the addition of lime to render it fertile. A handful of soil may be treated with acid without giving an appreciable effervescence, even though the soil be taken from within an inch of the limestone. Analysis of this clay reveals about 67 per cent. to 80 per cent. silica, 8 per cent. to 14 per cent. aluminum, 6 per cent. or 7 per cent. iron oxide (Fe_2O_3), and very small percents of lime, magnesia, soda and potash, etc. The iron is responsible for the intensely red color of the clay. The process which has produced this soil is the solution of the limestone with oxidation of the iron which exists in minute quantities in the original rock as a protoxide. The surface of the limestone beneath the soil, besides being rough and ragged as explained above, is usually minutely roughened, though sometimes fairly smooth, especially in the Mitchell limestone. In some cases, especially in the Salem limestone, the rock in contact with the overlying soil is rotted and discolored beyond recognition and shows a graded passage from sound unmodified rock below to soil above. Where layers of shaly rock occur, as in the Mitchell, they are often so rotted that while they retain much of their original appearance and stratification, they may be removed with pick and shovel as easily as any clay. Sometimes a layer of limestone overlying a layer of shale is left as an isolated chain of boulders in the general mass of residual soil. The deepest accumulation of residual soil seen by the writer is in the cut on the Illinois Central Railroad in the northwest edge of Bloomington, where it is 30 feet deep. Usually it is not more than five or six feet deep. Over the Mitchell and Harrodsburg limestones the soil contains chert, and, in the latter rock, geodes in abundance, because of the relative insolubility of these substances. Where blocks of Salem limestone are exposed at the surface to the rain they become deeply furrowed by the solvent action of the rainwater running over their flanks. The faces of old ledges, long exposed to the weather, are scarred and seamed by this action and extensively honeycombed, owing to the unequal solubility of the rock. In these holes and pockets on the rock surface small plants find lodgment and by the mechanical action of their roots and the chemical action of the products of their decay, greatly aid the process of disintegration.

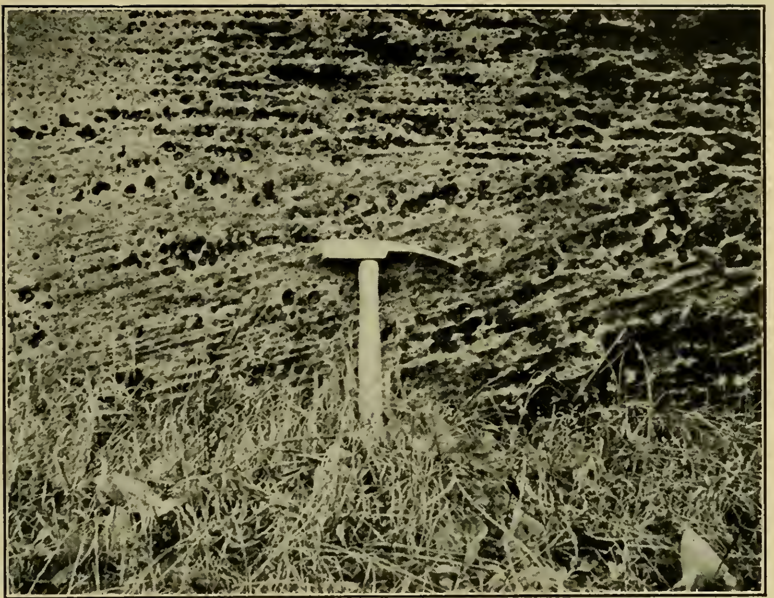
The effects thus far described are seen to best advantage in the exposures of the Salem limestone. The Mitchell shows to a pre-eminent degree the deeper-seated effects of solution in the formation of caverns and underground streams. Everywhere the surface of the country occupied by the Mitchell limestone is dotted over with sinkholes, and the hillsides along the larger streams abound in springs and entrances of caves. Some of the caves, such as Marengo and Wyandotte, have attained wide fame. The Mitchell is, as indicated above, conspicuously jointed but fine grained. The groundwater is compelled to traverse the joints rather than the pores of the rock, and it is this, in the writer's opinion, that has caused the more extensive development of caves in the Mitchell than in the Salem limestone, since the two must be about equally soluble. It is the concentration of solution along joints and bedding planes that gives rise to caves. The Mitchell has both an elaborate system of joints and numerous relatively impervious layers to serve as cave floors. Neither of these conditions would avail, however, without the third condition, adequate drainage, which has been supplied by the intrenching of the main streams as explained above.



No. 1. Hunter Quarry, Bloomington, Ind., showing fresh quarry face to right and weathered joint face to left. Salem limestone.

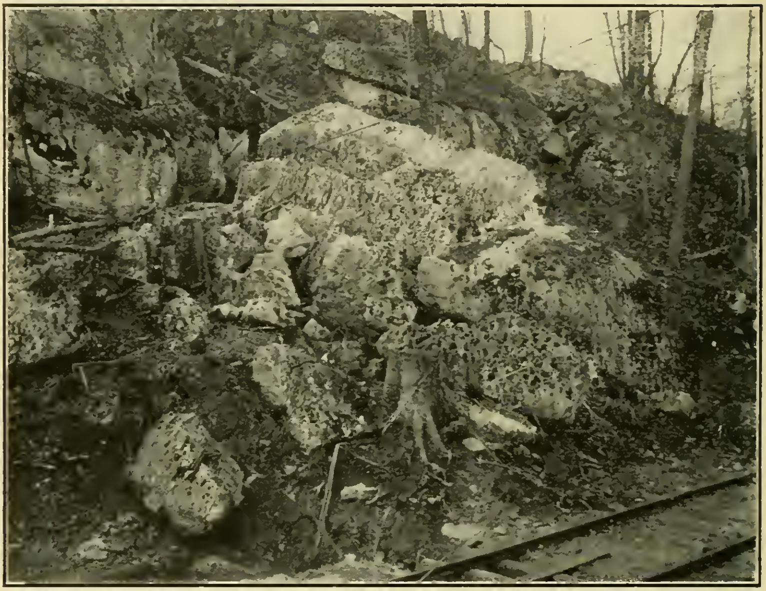


No. 2. Old Quarry, one mile west of Stinesville, showing weathered joint face. Salem limestone.

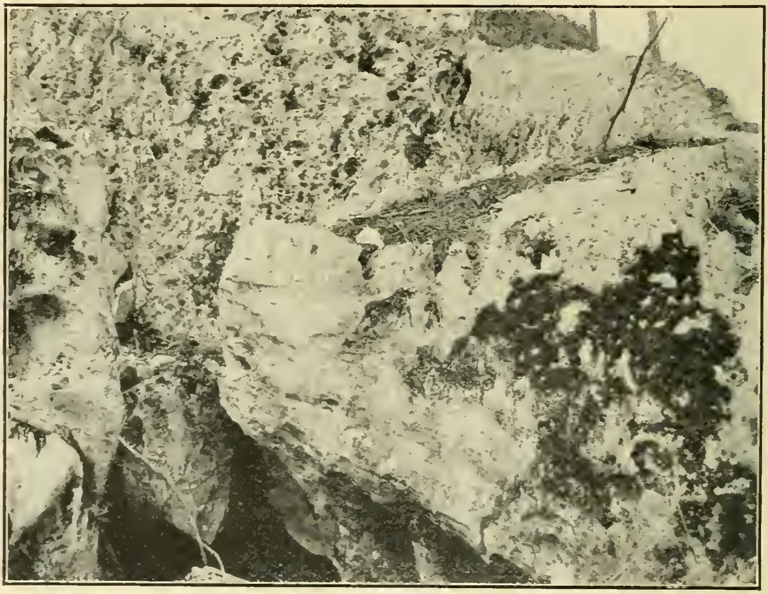


No. 3. Honeycombing and etching out of cross-bedded limestone. Old Quarry one mile west of Stinesville.

No. 4. Honeycombing of Salem limestone and lodgment of plants in solution holes. Oliver Quarry, Clear Creek.



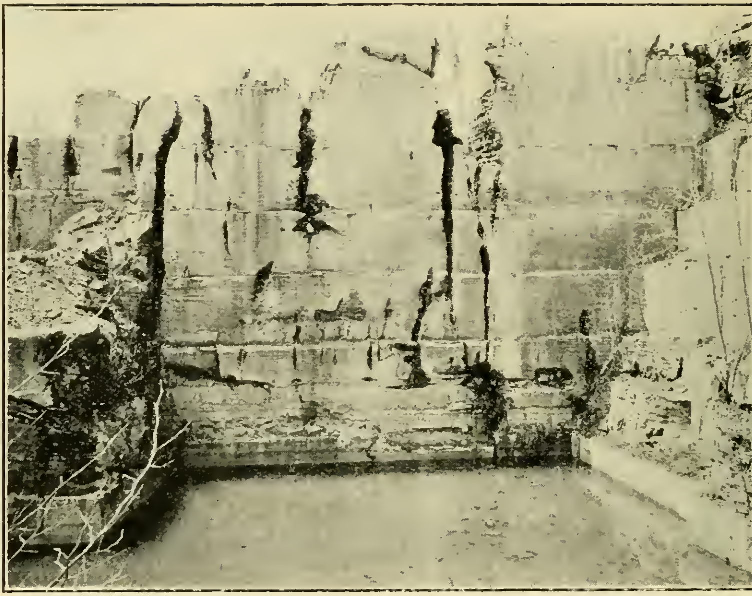
No. 5. Weathered blocks of Salem limestone fallen from cliff on Clear Creek, Ind. Oliver Quarry.



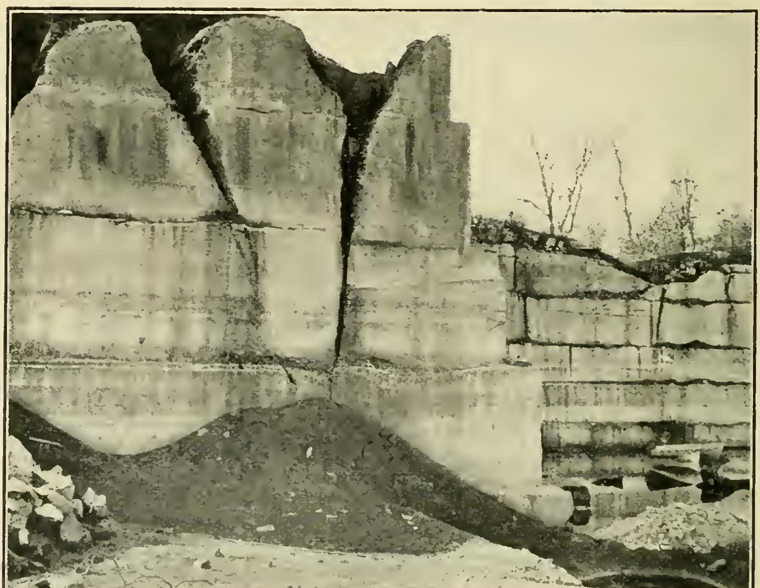
No. 6. Detail of a portion of No. 5, showing honeycombing.

No. 7. Large cavities formed by solution. Salem limestone, Big Creek, near Stinesville, Ind.

No. 8. Large cavity formed by solution and frost action. Harrodsburg limestone, near Stinesville, Ind.

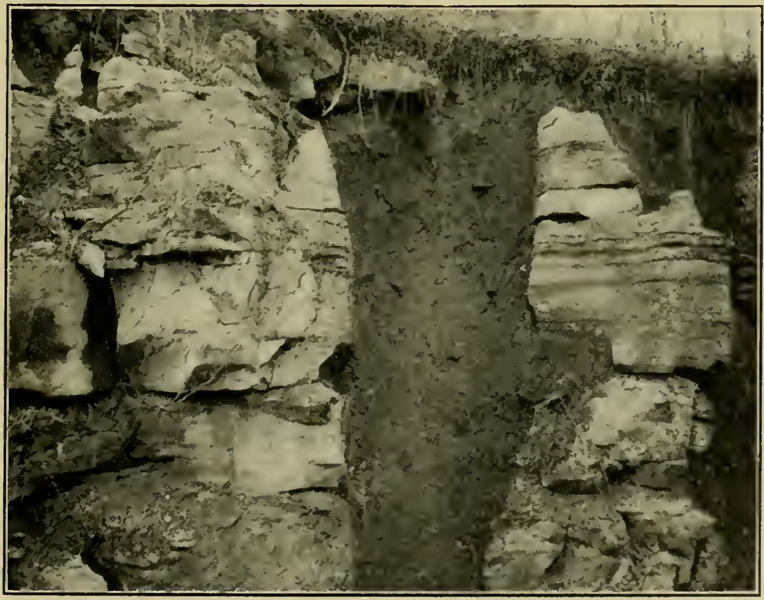


No. 9. Old Quarry on Big Creek west of Stinesville, Ind., showing joints enlarged by solution. Salem limestone.

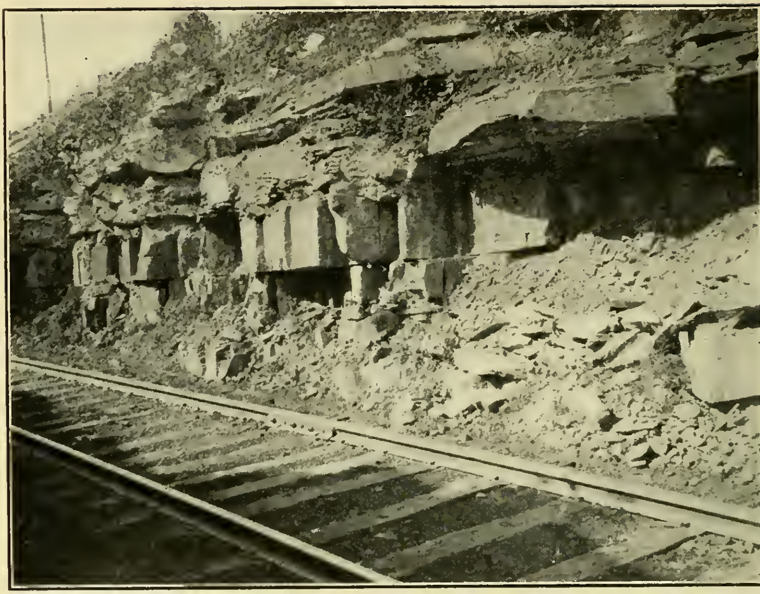


No. 10. Hunter Quarry near Bloomington, Ind., showing joints enlarged by solution. Salem limestone.

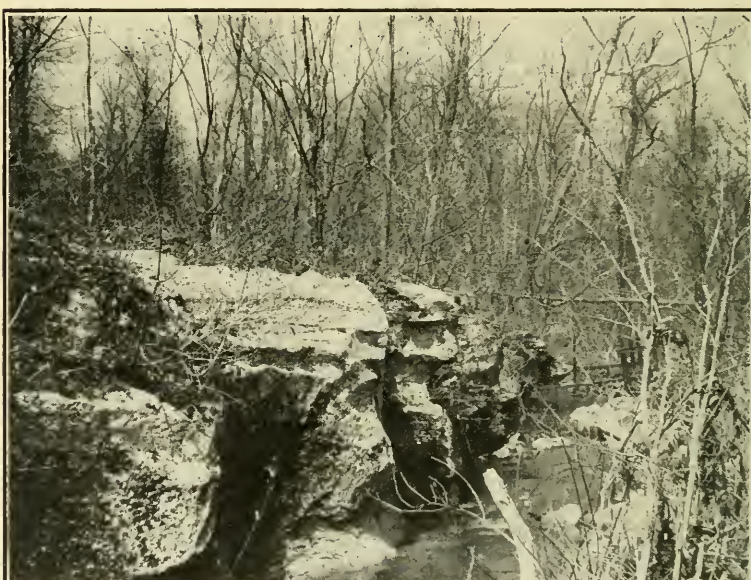
No. 11. Old Quarry one mile west of Stinesville, showing joint enlarged by solution. Salem limestone.



No. 12. Joint enlarged by solution and filled with residual soil, near West Baden, Ind. Mitchell limestone.



No. 13. Cut on the C., I. & L. R. R. in northwest edge of Bloomington, showing jointing of Mitchell limestone.



No. 14. Exposure of Salem limestone on Big Creek near Stinesville, showing jointing.

No. 15. Sinkhole. Whitehall pike west of Bloomington, Ind., in the Mitchell limestone.

No. 16. Entrance to Donaldson Cave, Mitchell, Ind., in Mitchell limestone.

No. 17. Corroded surface of Salem limestone. Quarry near Stinesville.

No. 18. Corroded surface of Salem limestone. Oliver Quarry, Clear Creek.

No. 19. Corroded surface of Salem limestone. Quarry near Sanders, Ind.

No 20. Corroded surface of Salem limestone. Quarry near Sanders, Ind.

No. 21. Pinnacles formed by solution. Top of Harrodsburg limestone in R. R. cut on Clear Creek.

No. 22. Block of Salem limestone furrowed by rainwater