ON THE FORMATION OF STALACTITES AND GYPSUM INCRUSTATIONS IN CAVES.

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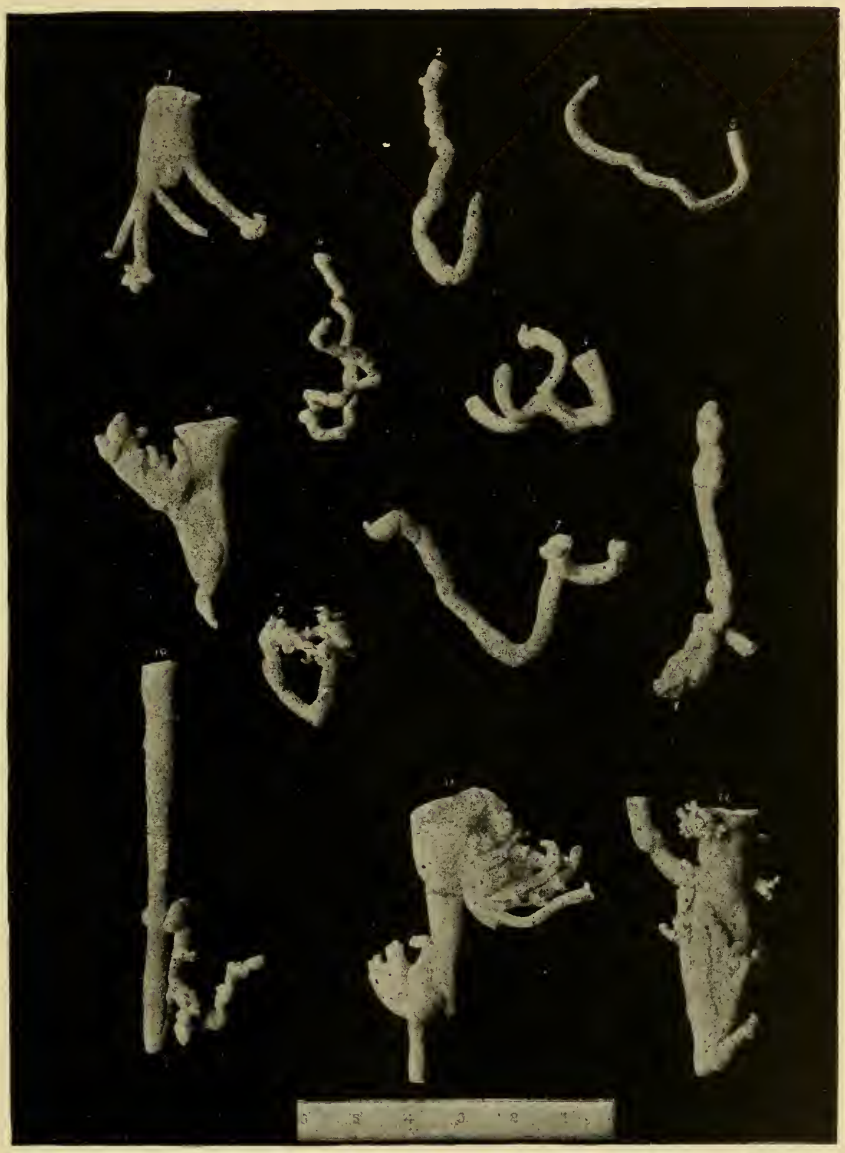
During the season of 1893 work in connection with the World's Columbian Exposition took the writer into a considerable number of the limestone caverns of the eastern United States and afforded him opportunity for observations regarding the methods of formation of the interesting deposits noted in the title. The results of these observations are given herewith, it having seemed to me that, while no new principle is involved, the subject as a whole has not received all the attention it deserves.

Stalactites.—The manner in which the carbonate of lime in the form known as stalactite and stalagmite is deposited is, in brief, as below: Water filtering through the roof of a limestone cavern, is, in virtue of the carbonic acid it contains, enabled to dissolve a small amount of the lime carbonate, which is again deposited when the excess of carbonic acid escapes either through relief from pressure or the evaporation of the water. Conditions favorable to either process are furnished by the water filtering through the roof and dripping slowly to the floor beneath. In cases where the water filters sufficiently slowly, or evapooration is correspondingly rapid, the deposit of lime carbonate from the roof takes at first the form of a ring around the outer portion of the drop, a natural consequence of the evaporation of a suspended drop of liquid, as may readily be shown by laboratory experiments. This process may go on until the ring becomes prolonged into an elongated cylinder, or tube, the diameter of which may not exceed five millimeters, though usually ranging from five to ten, and of all lengths up to 50 cm. In exceptional cases this length may be exceeded, but owing to the delicacy of the material, the stalactite usually breaks of its own weight and falls to the floor before a length of even 100 or 150 mm. is reached, to become imbedded in the stalagmitic material there forming. Lengths of even these dimensions are comparatively rare for the reason that the tube becomes shortly closed, either at its

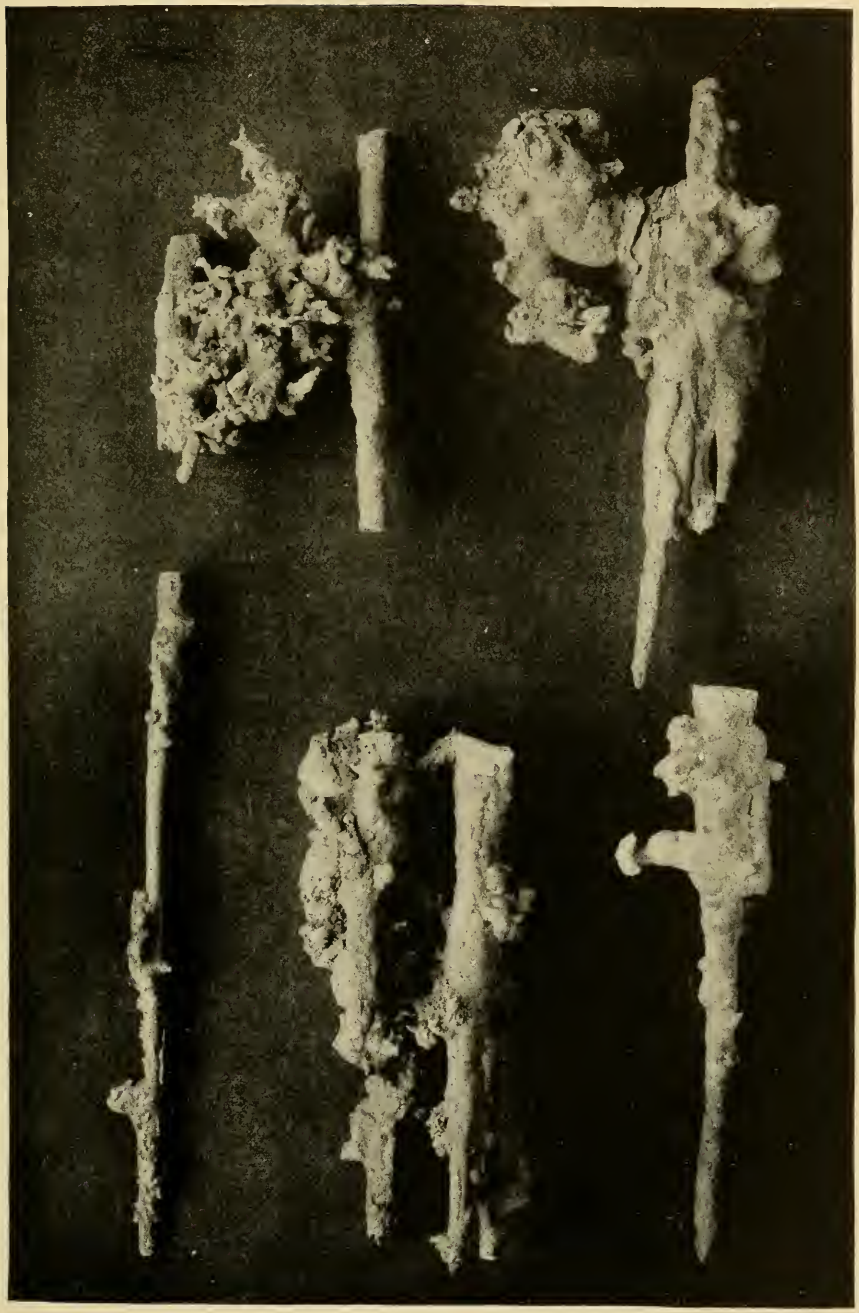
upper or lower end, usually the upper, and all growth from the extremity alone ceases, subsequent deposition being wholly exterior, and taking place in the form of concentric coatings of the carbonate on the outer surface and at the same time from the top. There is thus formed around the original tube a compact cylindrical mass, in its typical form constricted at point of attachment but thickening rapidly, and then tapering gradually into an elongated cone. The material of the stalactite is not always wholly carbonate of lime, but in some cases thin intervening coats of iron disulphide are met with; these are rarely more than a millimeter or so in thickness. Such forms have been found in the caverns of Luray, in Virginia. The presence of a magnesian carbonate in these deposits has not been detected in any amount. Through a crystallization which must be nearly contemporaneous with deposition, or at least while the stalactite is still saturated with the carbonated waters, the mass of the material undergoes an arrangement which is sometimes distinctly fibrous (aragonite), the fibers radiating from the center outward, and not infrequently being curved downward —that is, curved in such a manner that when the stalactite is broken across it shows a concave and convex fracture, the concavity being uppermost—toward the top of the stalactite. In other cases the structure is granular throughout, through the development of calcite rhombs. In the stalactites from Weyer's Cave, Shendun, Virginia, the entire center is sometimes occupied by large (10 mm.) rhombs of clear calcite, from which radiate horizontally elongated forms of the same mineral. It is safe to assume that such crystallizations are wholly secondary.

It is a natural consequence of their method of deposition that stalactites of the type described above are as a rule nearly straight, and hang approximately perpendicularly from the roof. Exceptions to this rule will be noted below.

In the Wyandotte Cave, and to a less extent in some others, a peculiar vermiform stalactite is found which is quite at variance with those described above. They occur in clusters or groups both on the walls and ceiling and are remarkable for their peculiar fantastic twistings and turnings, which in extreme cases are almost Medusa-like. Their appearance can best be understood by reference to Pl. I, the scale being in inches. This shows a number of detached stalactites both simple and branching. The point of attachment is uppermost in the figures, with but one exception. In order that there be no misunderstanding I have placed the numbers always at the broken end. It will be observed that the processes of deposition already described fail to satisfactorily account for these forms, in which the law of gravity seems to have been set at defiance. In fig. 2, it will be noticed, the stalactite after growing irregularly downward for about 4 inches turned upward and grew in this direction for half its length. No. 3 grew downward for an inch or so, and then in a nearly horizontal and upward direction for three or four inches. Number 4 is a singularly contorted



IRREGULAR STALACTITES, WYANDOTTE CAVE, INDIANA.



IRREGULAR STALACTITES, LURAY CAVES, PAGE COUNTY, VIRGINIA.

form, having turned on itself and grown irregularly upward till its free, growing end, was within an inch and a half of the starting point, or point of attachment. This stalactite weighs, entire, only some 21 grms Number 5, after growing downward a short distance turned to the left for about the same distance and then threw out three branches, which, when the specimen was collected, had grown upwards until they nearly touched the roof. (Cat. No. 68140.)

In the caverns of Luray, Virginia, are likewise occasionally found peculiar distorted forms, though of a nature quite different from those of Wyandotte, as may be observed by reference to Pl. III. These lack entirely the vermicular forms characteristic of the last named, and may be best compared with the peculiar wart-like excrescences and knurly branches which sometimes appear on trees, as a result of injury from insects. Such have been called helictites (from the Greek ἕλιξ a spiral.)

The cause of these singular distortions of form has not, so far as I am aware, been satisfactorily determined. Dr. Hovey, in his Celebrated American Caverns (p. 185) ascribes the Luray forms to "lateral outgrowths, having fungi for starting points," or, in other cases to crystals shooting from the side of a growing stalactite thus transforming it into some grotesque shape. In his later writings he has seemed to incline more to the view of considering them as "tricks of crystallization." Dr. C. S. Dolley* was inclined to regard these horizontal off-shoots as due to spider webs. He says:

> After some time spent in a vain search for an explanation of this anomalous structure, we happened to notice two specimens, the incipient branches of which were directed toward one another; stretched tightly between the branches, and entering the hollow tip of each, was a delicate thread, bearing a string of dew-like drops glistening brightly in the candlelight. Further search revealed numerous specimens in which the lime water trickling down the stalactite met a similar filament, and being partially diverted had formed a drop at point of junction; about this drop beautiful aragonite spicules were forming the hollow horizontal branch, the drop of water in the end being retained in position by the filament piercing it and upon which it gradually pushed along as evaporation deposits the lime behind it."

Dr. Brezina in his "Wie Wachsen die Steine" describes distorted forms as due to currents of air, but inasmuch as those of Wyandotte Cave radiate in every direction, it is obvious that they can not be thus accounted for. Prof. Collett in describing these last, in 1878, speaks of their growing from the bottom outward,† an error which can, I think, be accounted for only on the supposition that at the time of writing his thoughts were fixed upon the peculiar gypsum efflorescences (to be described later) and which are thus formed.

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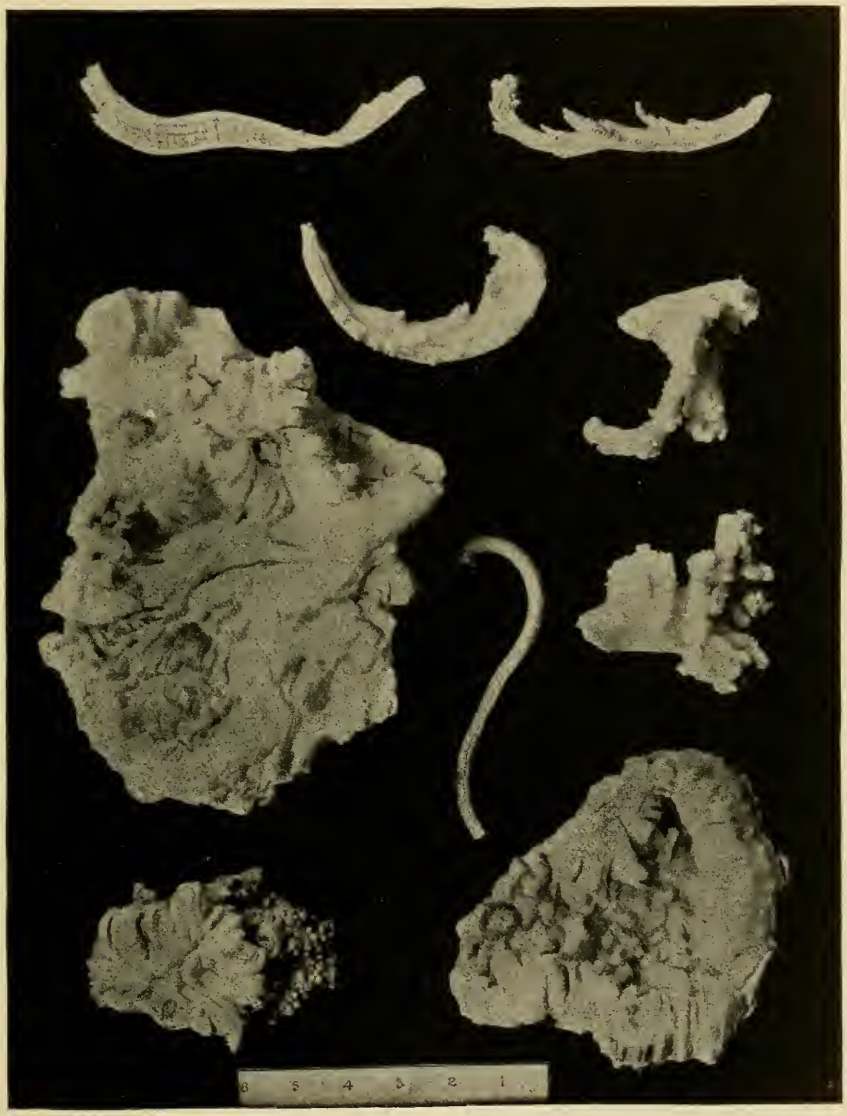
* Proc. Acad. of Nat. Sciences, 1886, p. 351.

† "The Pillared Palace is entered by a broad doorway, flanked by stalacto-stalagmites, while within, ceiling, cornices, and shelves are fringed with stalagmites and frosted with a never ending medley of strange, crooked, writhing, twisting unsymmetrical sprigs of white limestone, pushed out of the solid rock, and still growing by propulsion from the bottom; one cluster is a realization in stone of the horrible, snaky tresses of Medusa." John Collett, in Rep. Geol. Sur. of Ind., 1878, p. 475–76.

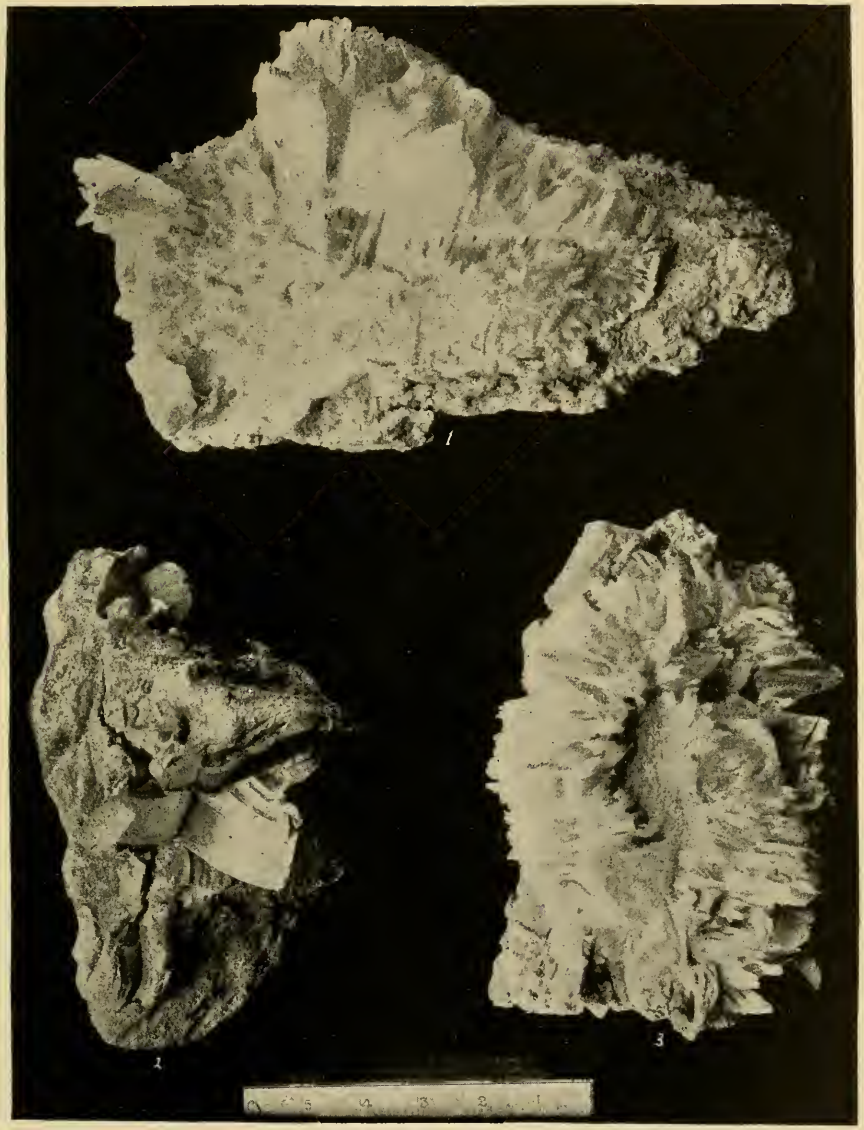
It is probable that the various forms of distortion and departure from the straight tubular forms are to be accounted for in several ways. An examination of the Medusa-like forms of Wyandotte reveals the fact that they occur not as dependents from the naked limestone of the roof, but are offshoots from a stalactitic crust which forms first, and which varies from a mere film to several inches in thickness. They occur sometimes singly, but more commonly in groups, or clusters of several, ranging in sizes from 3 to 10 mm. in diameter. Closer inspection reveals the fact that while in most cases tubular, the tube itself is of almost microscopic proportions, being as a rule less than half a millimeter in diameter. So small is it, in fact, that capillarity, not gravity, is the controlling principle in giving direction to the lime-carrying solution. A small spicule of calcite crystalizing on the extremity is as likely to point any other direction as downward: the direction of the next drop is controlled in part by the first, where the same process is repeated. Or on the assumption that the stalactite increases in length by constant additions to the tube, on all sides, it is easy to imagine that the deposit takes place, for a time, more rapidly on one side than on the other, perhaps partially closing the orifice or giving it a different direction. The essential fact is, however, that it is to capillarity, and not to gravity, that is due the peculiar vermicular forms. Why, at the outset, the stalactite should begin to form through many small capillary tubes rather than through one larger, as is ordinarily the case, I will not pretend to say. It is to be noted, however, that in Wyandotte, the roof forming limestones are nearly horizontal, while in Luray and many other caves they are highly tilted. This results in a more even percolation of the water in the first instance, the roof being more homogeneous. It is possible, therefore, that the water gathers in drops of smaller size, and very likely in smaller amounts. I have no other than hypothetical data for this last assumption, however.

The peculiar warty and distorted forms shown on pl. III, from Luray, I believe to be also due to the action of capillarity. In this case, however, the side excrescences are of secondary growth, the stalactite having first formed, in part at least, in the ordinary way. Through a closing of the tube at the lower extremity, the water either oozed through the wall or perhaps ran down over the outer side until some slight irregularity being met, it paused long enough for the necessary precipitation to take place. Such forms are, in brief, but "tricks of crystallization" due to capillarity.

Gypsum incrustations and rosettes.—As is well known, Wyandotte and Mammoth Caves yield in their older, dry, chambers, not stalactites of carbonate of lime, but incrustations of gypsum in botryoidal masses, acicular crystals, and sometimes in the form of beautiful snow-white rosettes composed either of thin blades or acicular crystals of gypsum grouped around a common center and curving outward. The appearance and structure of characteristic forms may be best understood by



GYPSUM INCRUSTATIONS, MAMMOTH CAVE, KENTUCKY.



GYPSUM INCRUSTATIONS, WYANDOTTE CAVE, INDIANA.

reference to Pls. IV and V. The individual blades are rarely more than a few inches in length, six and eight inches being the maximum of the single curved blades such as are shown in Pl. IV. (Cat. No. 68142.) In fig. 2, Pl. V, the longer blades are 90 mm., by about 24 mm. breadth and 5 mm. thickness. This is in many respects the most remarkable specimen of its kind I have ever seen. The method of growth of these forms is plainly by additions to the bottom, or more properly, to the end attached to the wall. They seem to have grown outward precisely as does the hoar frost in loose soil, where the moisture, rising by capillarity, freezes as soon as a certain level is reached, so that the older and first formed portions are ever pushed upward so long as the supply below is continued. As in the formation of hoar frost, particles of earth are lifted upon the tops of the ice spicules, so here the growing gypsum having begun forming in a crevice not infrequently forces off pieces of the limestone of considerable size. In fig. 2, Pl. V, the force of the growing crystals has even ruptured the stone in three directions. In fig. 1 of the same plate we have proof of two stages of growth. The last formed crystals having pushed the first formed nearly an inch out of place, the line of separation between old and new being indicated by the smaller size of the later formed spicules. As the crystals form and are pushed outward they are in most cases in a condition of strain, which causes them to curl and twist in a remarkable manner, as shown. The individual blades or spicules are but slightly attached to the walls of the cave, and except under very favorable circumstances it is nearly impossible to remove a rosette in a condition at all satisfactory.