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AN UNUSUAL OCCURRENCE OF STALACTITES AND STALAGMITES.

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INTRODUCTION.

Since few cases are on record of stalactites and stalagmites growing above ground, under normal atmospheric conditions, it occurred to the writer that a brief paper on the subject might be worth while. During the Summer and Fall of 1931 the author conducted a careful investigation of the rate and mode of growth of stalactites, and obtained some data on stalagmites.

The writer does not assume from the data obtained that one is able to arrive at a definite figure as to the length of time any large stalactite or stalagmite has been growing. As pointed out by Allison[1] and others, there are a number of factors which affect the rate of growth, and one can hardly expect to secure uniformity in results from stalactites and stalagmites growing under diverse conditions. It is interesting to note that the rate of vertical growth of the stalactites, in the early stages of development, compare closely with those of Allison,[2] in spite of the fact that those here cited grew above ground, where evaporation would be more rapid as a result of better circulation of the air, and where the Summer temperatures are higher. One would expect the stalactites of Allison to grow slower because they developed in a mine tunnel, underground, where humidity was high and the summer temperatures lower.

[1]Allison, Vernon C. The Growth of Stalagmites and Stalactites. Journal of Geology, Volume 31, 1923, pp. 106–125.

[2]Idem., p. 111.

CONDITIONS UNDER WHICH THE STALACTITES GREW.

The photograph, Fig. 1, is a view of the steel bridge of the Pennsylvania Railroad, where it crosses Bever Street in the city of Wooster, Ohio. According to railroad officials this bridge was constructed in part in 1908 and the remainder in 1912. It is approximately 200 feet long and 75 feet wide and rises about 20 feet above the paved street. Steel, lattice-work pillars support a superstructure made of thick, steel plate riveted together in an imperfect fashion to form a series of rectilinear, box-like structures, about a foot wide and about that deep. After the completion of the steel framework, concrete was poured into the boxes or troughs, filling them and covering them with several more inches, making a fairly smooth surface of the whole. On top of this steel and concrete base was laid approximately four feet of crushed limestone which was obtained from quarries located near Dunkirk and Bloomfield in northwestern Ohio. Some of this stone has a comparatively low magnesium content. Mixed with the rock ballast, but in small amount, are the usual cinders and fine coal found along railroad tracks. Due to poor drainage, much of the rain water accumulates in pools and gradually seeps into and through the rock ballast and cracks in the cement and out through the joints between the steel plates. The stalactites hang from the edges of the rectangular boxes where the joints occur, or from the steel girders just below them. More than three hundred were counted, varying from a fraction of an inch to twelve and one-half inches in length. New ones are forming at all times and most of them are in process of growth. After a heavy rain the drip is most active and least during a period of drought and during the cold winter months when the ground is frozen.

It is clear that the conditions here, above ground, are quite different than those in a cave, where the humidity is higher and summer temperatures lower. The temperature underground varies little throughout the year, whereas above ground it varies from as low as 10 degrees below zero in winter to as much as 100 degrees in summer. During this season, when the pavement is hot and automobiles are constantly passing beneath the bridge, the circulation of warm air must necessarily be favorable to rapid evaporation. Underground, stalactites and stalagmites grow all the year round, whereas above ground in this latitude their growth must vary more or less with the seasons. The conditions are unusually favorable for rapid growth during the summer when evaporation is high, provided the rainfall is normal. Organic acids derived from decaying vegetation and the roots of growing plants are said to aid in dissolving limestone. Here, there is high concentration and no vegetation present; organic acids are therefore of no consequence in this case. The water in its downward journey through the limestone and cement picks up its load; how much is obtained from the limestone and how much from the cement is impossible to determine. The stalactites described by Allison[3] developed as a result of percolation of water through concrete. He arrives at the conclusion that carbonic-acid charged water abstracts limestone more easily from young or green concrete.

ANALYSIS OF THE STALACTITES AND STALAGMITES.

An analysis of the stalactitic and stalagmitic material was made by J. W. Ames, associate in agronomy at the Ohio Experiment Station located at Wooster, Ohio, and is as follows: Calcium Carbonate, 93.88%, Magnesium Carbonate, 1.53%. The total carbonate content is 95%. This signifies that the Calcium and Magnesium are practically all in the form of carbonates. The remaining 5% is Aluminum and small amounts of insoluble material, Silica and Iron. The solution has a bitter taste.

MODE OF GROWTH OF THE STALACTITES.

The stalactites start as slender tubes about 0.4 cm. to 0.5 cm. in diameter at the tip, widening sharply near the base to a diameter varying from 0.8 cm. to 1.5 cm. The walls vary from an extremely thin fragile shell, .2 mm. to .45 mm. in thickness to more than a quarter of an inch in the larger ones. They are all symmetrical, tapering off uniformly to the tip and showing no variations or inequalities in diameter. A great number of specimens, large and small, were measured and found to have diameters at the tip of 0.35 cm. to 0.5 cm., the average being 0.4 cm. It is the diameter of the drop, regardless of the length and diameter of the stalactite, which here controls the diameter of the tube at the tip of the growing stalactite.

[3]Idem., 1.

The writer had adequate opportunity to make a careful study of the development of stalactites in their early stages of growth. A great number of them were studied in all stages of development, from the fragile rim deposited at the periphery of the initial drops, to those twelve and one-half inches long. The manner of growth, from the first drops of solution which hang from the steel girders first commands our attention. The size of the initial drop is determined to a large extent by the nature of the surface from which it hangs. Those measured were found to vary from 0.8 cm. to 1.5 cm. in diameter. The shape and diameter of the initial drop determines the shape and diameter of the base of the initial stalactite. Observation of a number of drops suspended from a flat surface reveals a conical form. The sides curve up concavely from the rounded tip. As the drop grows in size, and becomes more elongated, the sides become more concave. When the weight of water (gravity) becomes greater than the surface tension, a drop falls. As the drop hangs from the surface, it loses water by evaporation, and carbon dioxide as a result of less pressure. Particles of calcium carbonate are precipitated and form a translucent film over the drop. This film breaks if the evaporation is good and the particles go whirling to the rim of the drop, where they become attached to the wall of the growing stalactite. This spinning motion observed in drops on actively growing stalactites is due to surface tension and to the fact, as pointed out by Allison, that the down-flowing current is at the center of the drop and the up-flowing current at the periphery. The first deposition takes place at the periphery of the initial drop, the diameter of which is much greater than the stalactite which develops later. The addition of successive zones of carbonate of lime gives the base of the stalactite a conical shape, like that of the initial drops. The writer examined a number of stalactites in their very earliest stages of growth and found that the conical base takes the shape of the initial drop. In some cases a translucent film forms over the entire drop, enclosing it in a thin delicate shell. These shells all have the shape of the drop; conical with concave sides. They serve to hold the water and have the appearance of large blisters, which when broken are found to be full of water. They are horizontally banded, indicating that their vertical growth was by the addition of calcium carbonate to the rim. An examination of the interior of the delicate, conical shells reveal horizontal zones of minute, rounded botryoidal excrescences, a form frequently taken by calcium carbonate. These excrescences are also present inside the fragile shell, in zones or bands of growth, at the tip of the growing stalactite. When the drop is "alive" and the stalactite continues to grow, which is usually the case, the tip of the basal cone is open. The constant push of the water from above ruptures the film. The opening at the tip of the cone has the diameter of the drop which is about to fall. The diameter of the stalactite at the tip of the cone is therefore determined by the diameter of the drop at that point. As the stalactite lengthens, its diameter at the tip is constant or nearly so, because the diameter of the tube governs the diameter of the drop. It appears that the drops from all the stalactites are nearly the same diameter, measuring at their tips 0.35 cm. to 0.5 cm. in diameter, the great majority measuring 0.4 cm. This would indicate that surface tension is the controlling force which determines the diameter of the drop. The force would be equal to, or slightly exceeding the weight of the water in the drop. If the force of surface tension were constant, the size of the drop would be the same in each case. This would explain the uniform diameter of the tips of the growing stalactites.

As the stalactite lengthens, its diameter above the tip increases. Successive, concentric rings of growth are added to the exterior of the initial tube. The calcium carbonate is very porous, resembling calcareous tufa. Spaces are present between the rings of growth and openings occur in the walls. The water is held in the tube and spaces by capillarity. The pores allow the water an easy exit to the exterior of the stalactite where evaporation is responsible for additional deposition. Carbonate of lime is also deposited interstitially. In the large stalactites taken from caves, the rings of growth are present but no spaces are present between them. The tubes in the larger ones are closed by carbonate of lime. As the stalactite increases in length and diameter by additions to the exterior, its evaporating surface increases. As a result, much of the carbonate of lime is deposited interstitially and added to the exterior to increase the diameter, and a smaller proportion reaches the tip to increase its length. In this case the spongy, porous, calcareous material holds part of the solution. As a stalactite increases in diameter its vertical growth is slower.

The stalactite tubes are frequently sealed over at the tip by a film of calcium carbonate. This explains why many of them when bisected longitudinally, exhibit tubes subdivided into sections by transverse, rounded partitions, concave upward. After the end is sealed by the film, the water, not able to break it, passes through the walls or flows down the outside of the stalactite and continues to lengthen it.

RATE OF GROWTH OF THE STALACTITES.

On August 8th, 1919, the bridge was given a coat of paint, and the stalactites that had accumulated were removed. Therefore none of the stalactites are older than the above date, more than twelve years ago. It is not known definitely whether any of them started to grow immediately after the bridge was painted, but it is probable that some time elapsed before the water could make its way through the paint which doubtless filled the joints between the steel plates. Many new stalactites have been forming at all times and it is possible that all of them are less than twelve years old. Some that have been observed during the past few years are several inches long. If we assume that the largest stalactite of the group, which measures twelve and one-half inches in length, started to grow immediately after the bridge was painted, the average growth per year would be a little over one inch. If we take an average of twenty-one of the largest stalactites, varying from 8.33 cm. to 31.75 cm., averaging 18.54 cm. in length, on the assumption that they started to grow shortly after the bridge was painted, the rate of increase in length would average for all about 1.72 cm. per year. This figure does not represent the actual increase in length per year, for stalactites increase in length much faster during their early stages of growth. This is to be expected, for as the stalactite increases in size there will be a much larger evaporating surface and a part of the solution evaporates before it reaches the tip.

It was possible to get the rate of growth for this growing season because the portion of the stalactite recently added shows up as a white deposit. The older portion has been colored by dust and grime thrown up by the constant procession of automobiles during the last year. Some of the stalactites of the growing season of 1931 are at least four inches long and the variations in length of the recent additions indicate a great difference in the rate at which they increase in length.

After two months, July and August, 1931, the group of twenty-one stalactites, included in the accompanying table, were measured again to determine what increase in length had taken place. It was found that their increase in length was extremely variable, ranging from .18 cm. to 1.98 cm. Several areas of growing stalactites were removed and in twenty days new ones developed on the site of the old ones. Three of these were .32 cm. long, one .55 cm., two .63 cm., one .72 cm., one .80 cm., one .87 cm. and another 2.14 cm. On October 20,

TABLE I.

Stalactite	Length	Diameter at Base	Diameter at Tip	Rate of Drip
1.......	8.34 cm.	0.08 cm.	0.4 cm.	One drop in 2 min.
2.......	18.76 cm.	1.12 cm.	0.4 cm.	" " " 1 min., 22 sec.
3.......	14.45 cm.	1.18 cm.	0.4 cm.	" " " 15 sec.
4.......	15.95 cm.	1.04 cm.	0.4 cm.	" " " 16 min., 40 sec.
5.......	15.40 cm.	1.35 cm.	0.4 cm.	" " " 9 min., 58 sec.
6.......	17.86 cm.	0.88 cm.	0.48 cm.	" " " 6 min.
7.......	16.20 cm.	1.18 cm.	0.48 cm.	" " " 7 min., 15 sec.
8.......	16.59 cm.	0.88 cm.	0.48 cm.	" " " 9 min., 11 sec.
9.......	23.66 cm.	1.44 cm.	0.48 cm.	" " " 11 min., 30 sec.
10.......	15.24 cm.	1.5 cm.	0.48 cm.	" " " 45 sec.
11.......	20.32 cm.	1.12 cm.	0.48 cm.	" " " 1 min., 5 sec.
12.......	16.51 cm.	1.27 cm.	0.48 cm.	" " " 15 min.
13.......	15.07 cm.	1.04 cm.	0.4 cm.	" " " 24 sec.
14.......	16.12 cm.	1.27 cm.	0.48 cm.	" " " 8 min.
15.......	17.94 cm.	1.04 cm.	0.48 cm.	" " " 7 min.
16.......	17.14 cm.	1.04 cm.	0.4 cm.	" " " 7 min.
17.......	20.23 cm.	1.04 cm.	0.48 cm.	" " " 5 min., 15 sec.
18.......	20.72 cm.	0.88 cm.	0.48 cm.	" " " 10 min.
19.......	23.50 cm.	0.88 cm.	0.4 cm.	" " " 18 min., 35 sec.
20.......	31.75 cm.	1.12 cm.	0.48 cm.	" " " 30 sec.
21.......	23.64 cm.	1.27 cm.	0.48 cm.	" " " 37 sec.

1931, two months after the stalactites were removed, thirteen were measured to obtain their length. The following figures in centimeters shows their growth: 1.7, .9, 1.92, 1.87, 1.37, 1.5, 1.8, .71, 1, 1.76, 1.7, 1.77 and 1.87. The average increase in length per month is .76 cm. which compares favorably with the readings obtained by Allison[4] who reports growths varying from 0.10 cm. to 1.44 cm., averaging for all .71 cm. That the two results are so nearly alike seems remarkable, in view of the fact that the conditions under which both groups were developed are so different. One would expect those above ground to grow much faster.

[4]Idem. I, p. 111.

It was found that in general the small stalactites have a faster rate of drip than the larger ones. The average drip taken from a number of those in the early stages of development indicate about one drop in fifteen seconds. The rate for the larger ones is much less and quite variable. Allison comes to the conclusion that rapid vertical growth is favored by high air circulation, high temperature and high concentration and is opposed by rapid drip and high humidity. Large diameter, he remarks,[5] is favored by low air circulation, low temperature, high concentration and high humidity, and opposed by rapid drip. In this case the small stalactites, in their early stages of development, grow faster vertically and drip faster.

The average large stalactite here certainly does not weigh more than one-half ounce. On the assumption that the largest ones started to grow twelve years ago, shortly after the bridge was painted, it would take 3,840 years to produce one weighing 10 pounds and 38,400 years to grow one weighing one hundred pounds. These figures cannot indicate more than the fact that large stalactites are old. We are assuming that the length of time for accumulation was the maximum, twelve years, when a closer approximation would probably be less; how much less is impossible to determine.

THE GROWTH OF STALAGMITES.

The stalagmites which have grown on the steel girders and rock walls since 1919 vary considerably in length. Most of them are broadly rounded and others are narrow or of the mushroom type, varying from a fraction of an inch to two or three inches in height. One measured 2.22 cm. and another 3.1 cm. They are in some instances very porous with cavities in them which are lined with excrescences. They are made up of concentric shells or layers of growth. Some of the stalagmites are growing fast and others slowly, as indicated by their shape and width. Allison[6] observes, "A sharply convex face means a rapidly growing stalagmite and a blunt face means a slowly growing stalagmite." Several have splash cups which differ in width and depth; others have no splash cups. According to Allison, the deeper the splash cup the faster the drip, and the better the evaporation and the wider the splash cup,

[5]Idem. I, p. 113.
[6]Idem. I, p. 118.

the greater the fall. The stalagmites formed where the distance of fall was small had excellent but small splash cups, whereas those formed twenty feet below on the walk and curb are quite broad, several inches across, with gently convex surface and no splash cup.

The writer collected six stalagmites, four of which are reproduced as pen sketches. Number one is 3.33 cm., number two, 3.81 cm., number three, 4.13 cm., number four, 2.85 cm. in height. Number five, not shown in the sketch is 4.93 cm. high. Number one and two have hollow tubes running part way through them. The tube in number two is unobstructed, but the other in number one has transverse shells which divide the tube into partitions as in the stalactites. The writer is unable to offer an adequate explanation as to the origin of the tubes. All the stalagmites shown in the sketches were formed a few inches below the stalactites. It may be that solution removed enough of the interior of the stalagmite to produce the tube. Or perhaps a portion of the stalactite above broke off and fell in an upright position in the splash cup, allowing the stalagmite to grow around it. Another possible explanation; it may be that in this case, where the water fell but two or three inches, instead of spreading out as would certainly be true if it fell a great distance, the water would form a drop. Around its periphery and over its surface would form a delicate film of calcium carbonate. Drops from above would rupture this film at the top but the sides of the tube would be built up by constant addition of calcium carbonate at the periphery of the drop. In case the drip ceased sufficiently long, the film would form over the entire surface of the drop and ultimately become resistant enough to prevent its rupture by the falling drops. When this took place the growth would be by the addition of lime over the entire surface of the stalagmite. These explanations all have defects and the writer welcomes a satisfactory interpretation of the hollow tubes in the stalagmites. The stalagmites which formed on the curb and sidewalk, twenty feet below, are less than an inch thick and are broad, gently convex, almost flat on top and without splash cups. This condition, one might say, is due to the walking of pedestrians who would wear them down and prevent them from forming a narrow column. But this is not the case, because a number of typical stalgmites are forming on the curb where nothing interferes with their growth.

Stalagmite number three weighs an ounce. Assuming that it began to grow immediately after August 8, 1919, when the bridge was painted, it has taken twelve years for its accumulation. At that rate it would take one hundred and ninety years to form one weighing a pound and nineteen thousand, two hundred years to produce one weighing one hundred pounds. A closer approximation as to the rate of growth would be to take the average of a number of stalagmites. Because of the complex factors involved it is impossible to determine the rate at which stalactites and stalagmites accumulate over a long period of time. But we can say that large ones require a long period of time, not measured in hundreds but thousands of years.

CONCLUSIONS.

The rate of growth of stalactites and stalagmites is extremely variable, depending on such factors as the concentration of the solution, rate of drip and evaporation and loss of carbon dioxide from the solution. The rate of evaporation depends on the temperature, humidity and air movement. These factors, including the others mentioned, are so variable as to make it impossible to determine with any degree of certainty the age of a large stalactite or stalagmite.

The mode of development of stalactites and stalagmites, in their early stages, is well exemplified here. Furthermore the unusual conditions under which they are growing is worthy of the attention of those interested in their growth in caverns and elsewhere beneath the surface.

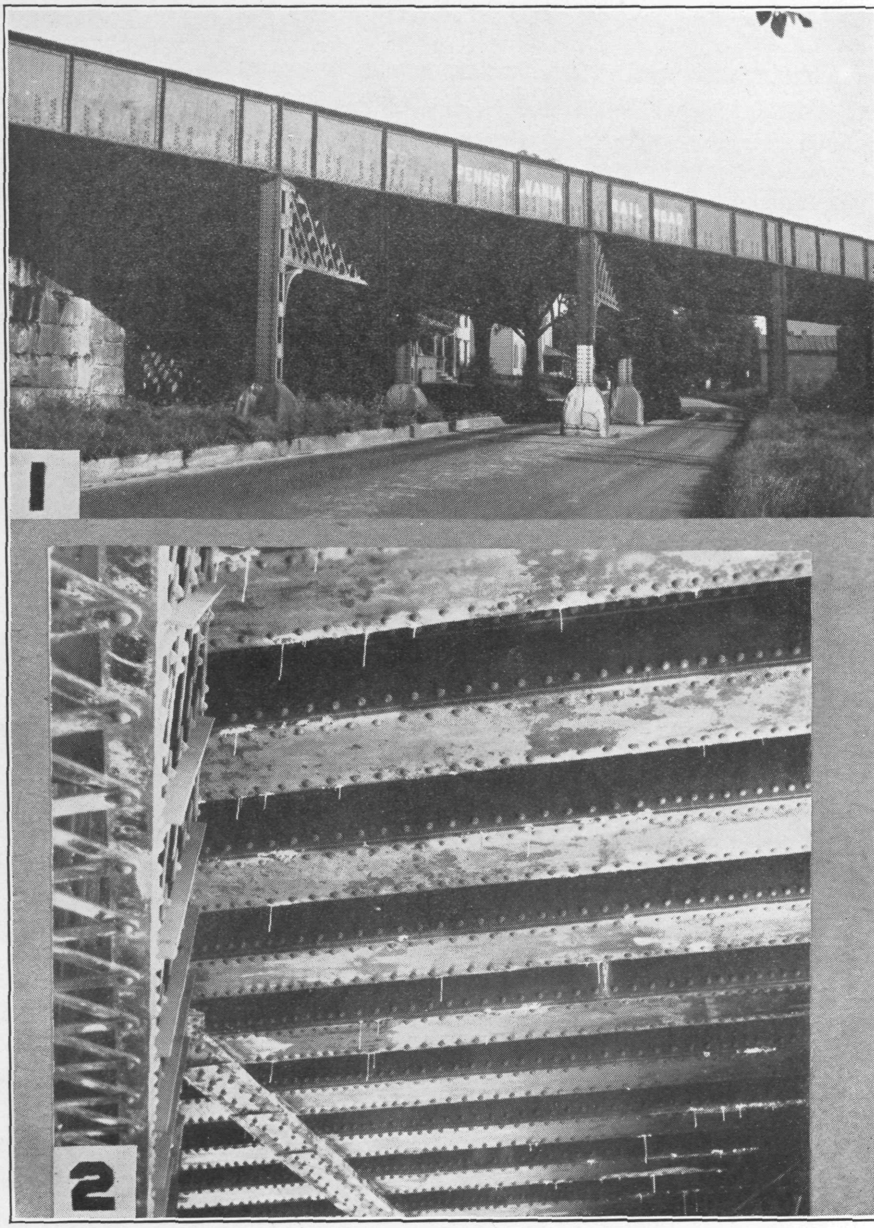
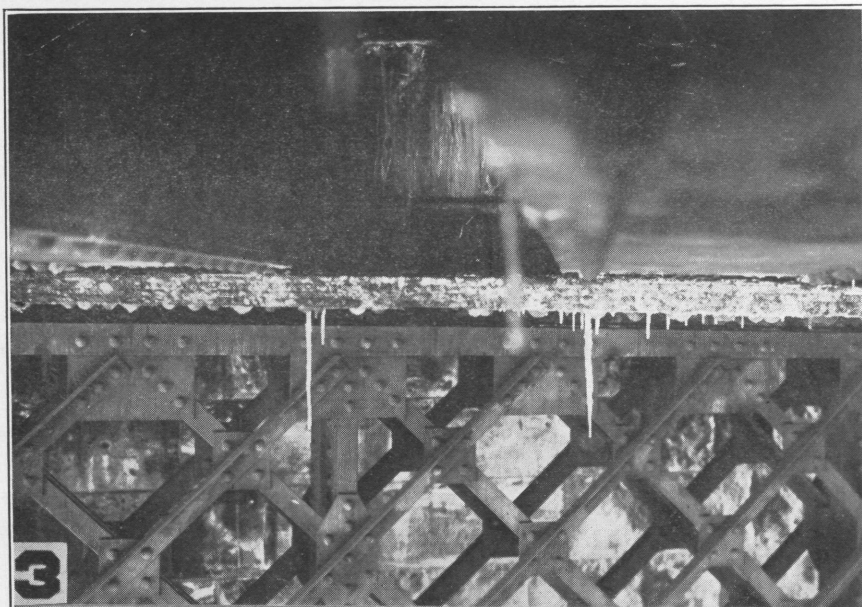


FIGURE 1. Railroad bridge crossing Bever Street, Wooster, Ohio.
FIGURE 2. A section of the bridge, showing stalactites.



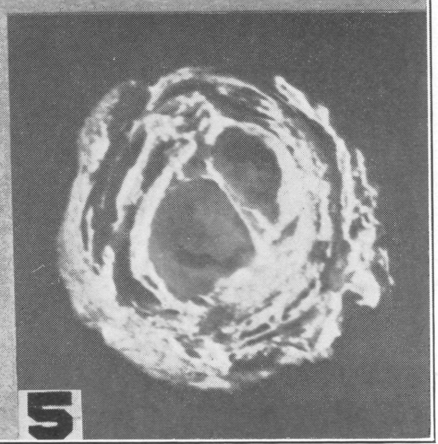
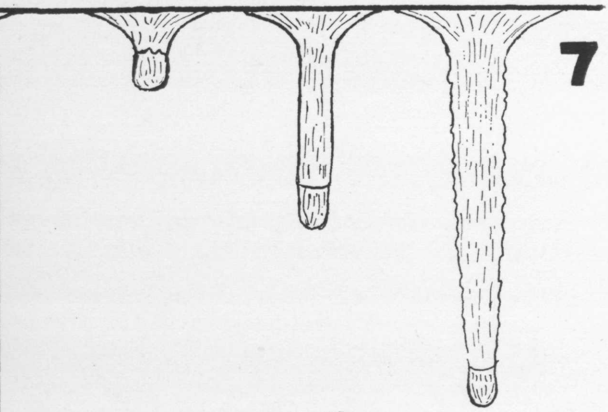


FIGURE 3. Section of the bridge showing two of the largest stalactites. The one on the left is 12½ inches long and about ½ inch in diameter.

FIGURE 4. Enlarged section of the thin shell at the tip of a growing stalactite. View of the inside, showing zones of growth. Note the rounded botryoidal excrescences, arranged in bands.

FIGURE 5. Enlarged cross-section of a stalactite, showing the tube with a transverse, concave partition. The original has a diameter of seven-sixteenths of an inch.



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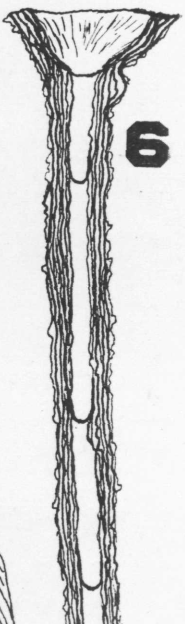

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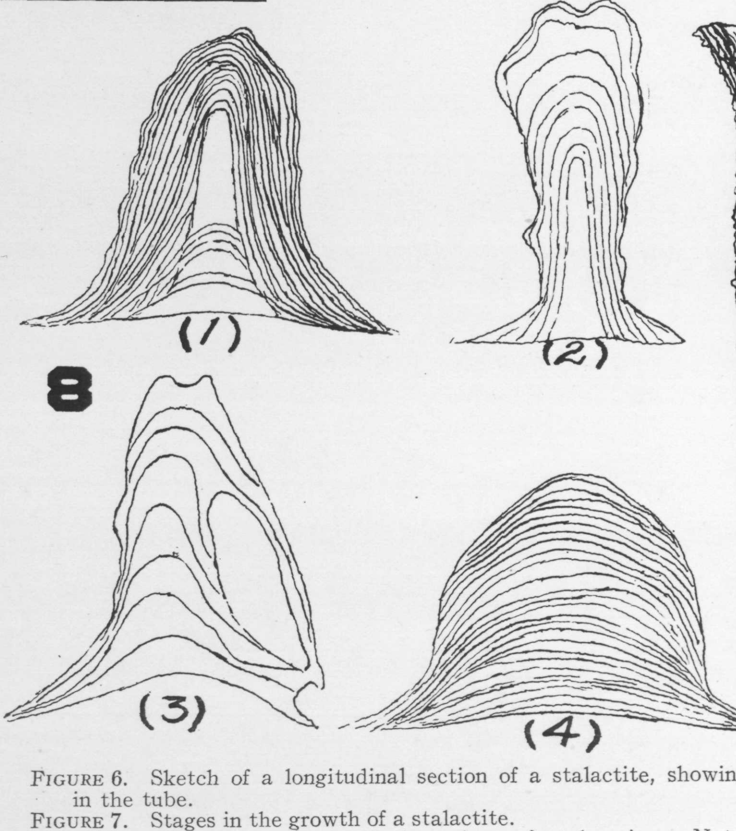

FIGURE 6. Sketch of a longitudinal section of a stalactite, showing partitions in the tube.
FIGURE 7. Stages in the growth of a stalactite.
FIGURE 8. Sketches of longitudinal sections of stalagmites. Note the tubes in 1 and 2. Numbers 2 and 3 have splash cups.
FIGURE 9. Cross-section of a stalagmite, showing tube.