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STALACTITES WITH "INTERNAL" AND "EXTERNAL" FEEDING.

by

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ABSTRACT.

The conventional classification of stalactites by their feeding mechanisms seems to be wrong. The central channel of carbonate stalactites, with rare exceptions, is shown to have no special role in the stalactite feeding, appearing as a consequence of the growth mechanism and not as a cause. In the case of conical stalactites even partial feeding through the channel seems to be prohibited. Non-carbonate stalactites (except those growing from melts), have a structure and texture corresponding to that of tuflactites, corlactites, or crystlactites, not to real stalactites. Of these, there is a significant feeding role for the central channel only for tubular tuflactites.

INTRODUCTION.

It is normally considered that stalactites have internal feeding (tubular or soda-straw), and external or mixed feeding (cone stalactites) (Hill and Forti, 1997; Maximovich, 1965; Stepanov, 1971, Moore, 1962). However, most visitors to a karst cave with actively growing stalactites will probably have noticed the following: if a cone stalactite, with a central channel, has been broken at some time in the past, but new growth has started at its end, the new stalactite nearly always appears at the lowest point of the broken surface, always has a channel, and this channel almost never continues the old channel (Figure 1). In addition, if the broken object consists of a pair of a soda-straw and a drapery and the lowest point of the break is within the drapery, the new growth will have started at this point, where any feeding channels are impossible, the growing object will be a soda-straw (a stalactite with "internal" feeding), and there will be no communication between the channels of the old and new soda-straws. Other evidence about the central feeding of stalactites will be considered below.

This paper will consider in detail the case of carbonate stalactites, outlining other cases, which have different crystallization physics and chemistry and thus produce stalactites with very different structure, only in general.

SODA-STRAWS

Soda-straws are a good object to begin the study as they are the "clearest" type of stalactite with a feeding channel and their monocrystalline structure is quite simple. Other types of tubular stalactites, granular tubular stalactites or tubular tuflactites[1] (Stepanov, 1997, Maltsev, 1997), principally differ from soda-straws in their structure, texture, crystallization mechanisms and feeding mechanisms and will be considered below.

Soda-straws have been proved to appear within environments with low values of feeding speed (Maximovich, 1965; Stepanov, 1971) and low values of oversaturation of the solution by CO_2. In many cases, soda-straws grow in large quantities, separately from other types of stalactites, and are spread uniformly over the roof. This uniformity, locally controlled

[1] For definitions of unfamiliar terms, see Stepanov, 1997.

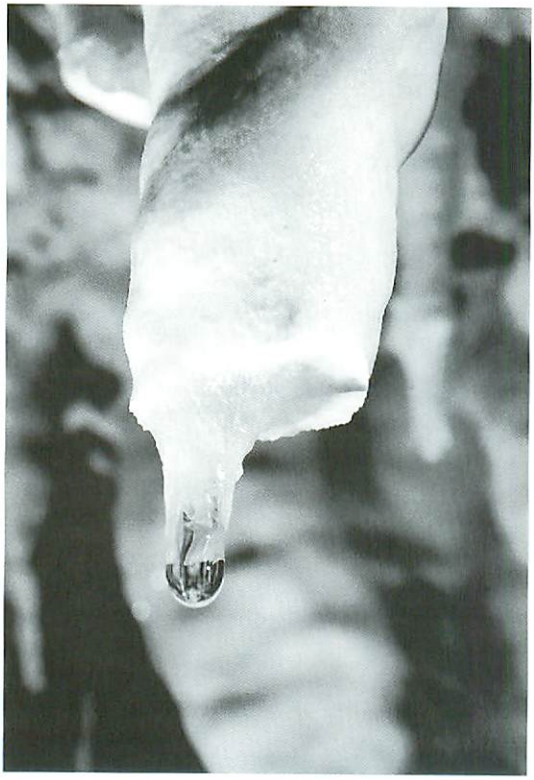

Figure 1. *Young stalactite growing on older, broken one.*

not by the geometry of feeding fractures, but by their growth at points which are favorable for dripping (as in the example of the broken stalactite), can be taken to statistically disprove the idea of their feeding via their channels. Also, the fact that some of them are followed by draperies, having their volumes greater than soda-straws, directly shows presence of external (surface) feeding. This was confirmed by examination of the substrate under soda-straws; studied in dozens of samples by the author. Not one sample was found which showed a feeding channel, even a capillary one.

Now let us consider the crystallization physics at the dripping point. In non-hydrothermal cave conditions the only mechanism for creating oversaturation of a solution by Calcium is by CO_2 loss during bicarbonate decomposition (Sokolov, 1962). It is also known that mechanical agitation of the solution is frequently the reason for bicarbonate decomposition occurring in balanced solutions. This is the same thing, because mechanical agitation simply produces local pressure irregularities and the solubility function of CO_2 gas is very steep, thus major saturation irregularities occur in localities with minor pressure irregularities (Stepanov, 1971). This is the reason, for example, for the growth of gours caused by turbulence on their overflows. The dripping frequency typical of soda-straws, about 1-0.001 drops/second, is too low to cause significant turbulence. Thus, there are only two possibilities left to consider as causes of crystallization:

1) an initially oversaturated solution. In this case, stalactite growth will take only part of the $CaCO_3$, the falling drops would be saturated or oversaturated and stalagmites will definitely appear because of the explosive mechanics-caused degassing, and these stalagmites would most likely be travertine ones, not crystalline. The paragenetic pairs soda-straw-stalagmite are known, but they are rare, and the stalagmites are always crystalline. This means that as the drops land it is slightly undersaturated. Thus the initial solution is approximately balanced;

2) local degassing, occurring at the moment of the drop's disconnection, and caused by mechanical reasons: the meniscuses gap.

It is evident that it is only necessary to consider the second mechanism. For the same reason, it is evident that the main mechanical agitation is at the gap perimeter, where, as the meniscus changes from positive to negative the surface tension force momentarily almost reverses direction. This means that crystallization will be favored on the meniscus perimeter, automatically causing the structure of the growing stalactite to be tubular. Additional evidence for this mechanism may be found in the structure of the soda-straw's growth zone (Figure 2). The immediate crystallization on the meniscus perimeter results not in the main crystal, but in a set of skeleton crystals and dendrites. This is a well-known feature of growth during mechanical degassing (Shafranovskiy, 1961; Stepanov, 1971; 1997). At a distance of 0.5-3 mm from the end of the soda-straw, these skeleton crystals and dendrites are completely replaced by the main crystal which builds the soda-straw body (Maltsev, p106 in Hill and Forti, 1997). This means re-crystallization occurs, also with some peculiarities of the environment. If the solution is oversaturated, some of the skeleton crystals must have overgrowths, conserving their structure. Complete re-crystallization is possible only in the balanced solution (and is necessary, dendrites and skeleton crystals are poorly balanced formations). Thus this structure shows completely the full process of crystallization: crystallization at the moments of the drop's disconnection, and re-crystallization during the periods of its static hanging.

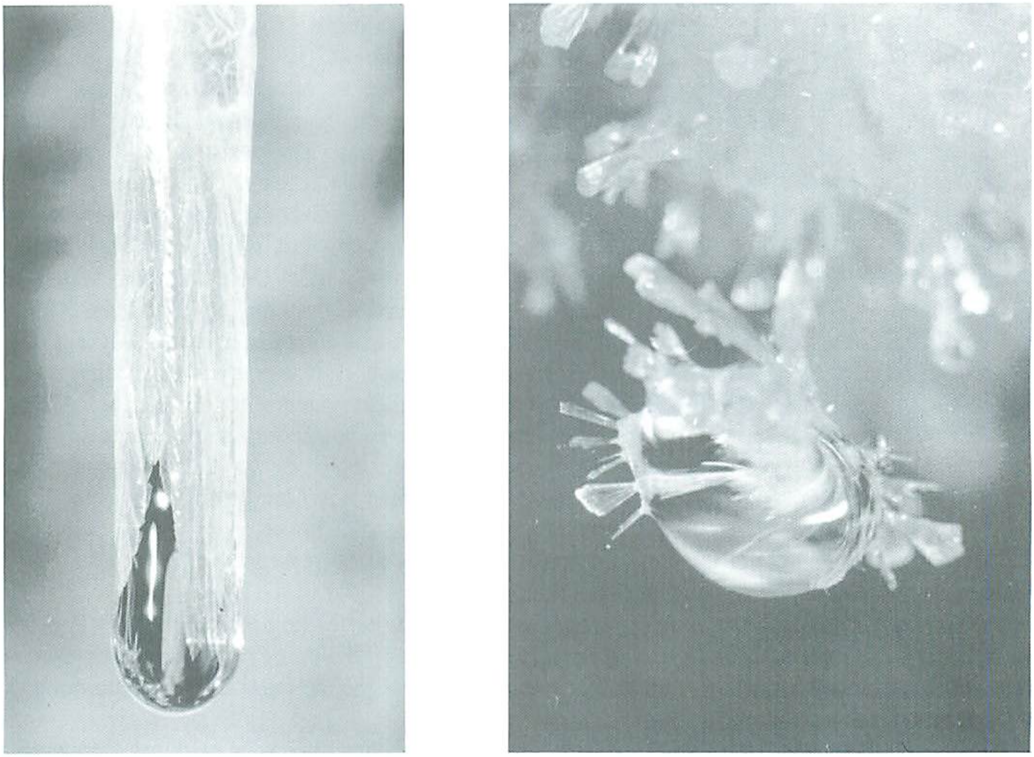

Figure 2. *A calcite stalactite (soda-straw, on the left), and an aragonite crystallictite (on the right): growth zones.*

It should be noted that the process discussed above does not depend on the feeding mechanism. If dripping is rare, and the solution is balanced then the soda-straw must appear with both internal and external feeding, as a result of the crystallization physics. With this, external feeding is evidently preferable for mechanical reasons; the dripping points are controlled mostly by the roof geometry, not the geometry of feeding fractures. The absence of crystallization on the outside surface of the soda-straw is explained by the fact that the solution is balanced and that as the feeding is slow enough, the flow is laminar. So, Maximovich was right, the differences between various stalactites do not depend on feeding structure but only on the feeding speed, and the saturation grade.

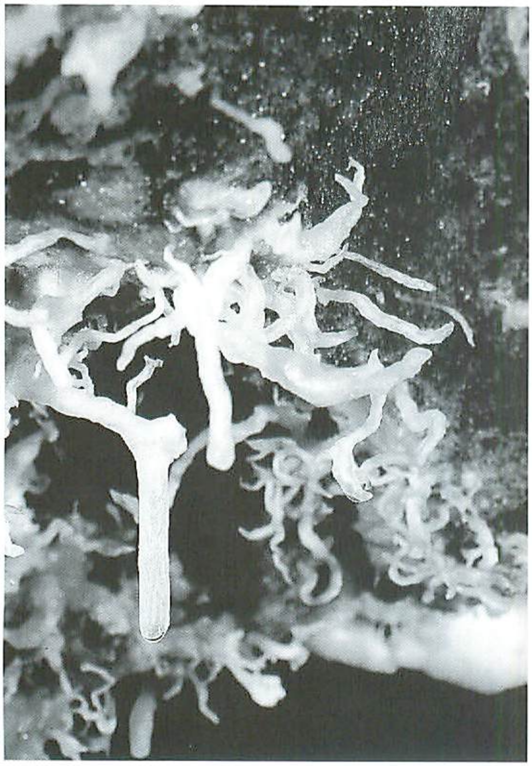

Figure 3. *Helictites converting into soda-straws.*

There are many observations which show the presence of internal feeding for the soda-straws (Hill and Forti, 1997), and the absence of external feeding. This does not contradict the above. These observations are correct, but apply only to long soda-straws, which have been the main object of past observations. The walls of a soda-straw are about 0.5-1.5 mm thick and the carbonates have perfect cleavage. This results in a soda-straw having fractures in its wall. The water column inside the soda-straw creates a strong negative pressure in its upper part, proportional to its length, and which oscillates during dripping. For these reasons water is sucked in through such fractures and for straws of a certain length (10-20 cm) the surface flow can disappear completely. Further evidence for this is the case of long soda-straws having overgrowths on their upper parts, thus demonstrating surface flow, but having no surface flow on their lower parts. So, both the existence of the channel and feeding through it appear not to be reasons for the growth of the soda-straw, but the opposite, consequences of its growth.

The author knows of only one exception in which the feeding of a soda-straw appears to be originally internal. These are soda-straws growing from helictites (Figure 3). This exception still supports the common rule, this is a special case where the favorable dripping point is the feeding channel opening.

Thus it can be seen that soda-straws can be fed either internally or, more frequently, externally and yet the same structure will result.

CONE STALACTITES.

Two theories have been put forward to explain the structure and genesis of cone stalactites (this discussion is limited to varieties which have an internal channel). According to the first (Hill and Forti 1986), they are soda-straws overgrown by a surface crust at a later stage.

According to the second one (Maximovich, 1965; Stepanov, 1971, 1997), the central tube is syngenetic to the crust, and they grow simultaneously. The author believes that the second theory is the right one. Maximovich has statistically proved that soda-straws grow at much lower feeding speeds than cone stalactites. Stepanov showed that crystallization in caves is cyclic and within each cycle the rate of feeding decreases. Thus, in a given cycle soda-straws will appear after cone stalactites, not before. Between cycles there will be a dissolution period, that would leave traces between a soda-straw and its overlying crust and these have not been found. On the contrary, traces of simultaneous growth can be found in each cone stalactite; irregularities in the diameter of the soda-straw caused by distortions of the meniscus by simultaneous growth and the induction surfaces of simultaneous growth.

So, let us discuss the simultaneous growth of the central tube and the crust. To begin with, to simplify the considerations, we will accept the hypothesis that the solutions inside and outside the stalactite are originally the same, having the same source. Variations, of course, exist, but are relatively rare.

Let us now examine what happens with such "mixed" feeding. The solution coming along the central channel can only lose CO_2 at its very end. This is not just a theoretical consideration, otherwise crystallization inside the channel would be seen. The solution on the surface, however, can lose CO_2 at any time and so while it is moving it will deposit the crust. At the end of the stalactite there will be mixing of the two solutions. the internal one is balanced, in CO_2, to the conditions in the feeding fracture, the surface one to the surrounding air conditions. Both are saturated in Calcium relative to CO_2, the internal one oversaturated in CO_2, the surface one about to be balanced in CO_2. As is well known, the $Ca(CO_2)$ saturation function is convex everywhere Palmer (1995) has a good set of graphs which shows this. The mixture of two Calcium saturated solutions is always represented by some point on a chord connecting points which represent source solutions. As all the chords lie completely below the function, every such mixture is undersaturated in Calcium. This causes the well-known effect of "mixing corrosion", that is considered to be one of the main mechanisms for the karstification of limestone. Of course, this mechanism will work only while there is no time for or possibility of additional CO_2 loss. According to Maximovich (1965), dripping rates from cone stalactites are high, much greater than 1 drop/sec. This means that the mixture will have less than 1 second for additional degassing, evidently not enough. In the case of mixed feeding we would therefore see corrosion instead of crystallization. So, we reach a nonsensical position: no mixed feeding is possible until feeding amounts along two "branches" are proportional. One of the flows must be several orders greater than the other and that may then simply be ignored, even if it exists. A comparison between the material deposited by the central tube and on the crust shows that the surface flow is certainly significant, so the internal feeding must be the insignificant "branch". Finally it should be noted, that the situation remains the same if the hypothesis of a common origin for both solutions is ignored as the mixing effects would still be present.

See Figure 4 for an illustration of the above. This shows a formation intermediate between a cone stalactite, and a paragenetic pair of a curtain and a soda-straw (the only difference between them is in plain versus linear surface feeding). The curvity of the monocrystalline tube (soda-straw) in the upper half is seen well and shows clearly that the tube and the curtain are syngenetic and that the tube had external feeding from the curtain at least on its first stage. In the lower part the tube is straight. This straightness, together with the cleanness (without any overgrowths) of a large part of the soda-straw's surface, show that there has been a feeding reconstruction. The original curve is caused by the feeding being both on the surface and

Figure 4. *Soda-straw, curving, aligned to the feeding curtain. A hole, "sucking in" the solution from the surface, is seen near the top.*

uni-directional. This causes the geometry of each drop to be distorted by surface tension, so the dripping point moves against the feeding source, until the length of the stalactite is sufficient to eliminate this force. The lower, soda-straw part is curved and not very smooth, as a further compromise has taken place between the above force and the forces of crystallization. This figure also shows that that the sucking of the solution into the internal channel is not sequential, but goes through an accidental hole, though the process is interactive and the passage of solution may enlarge the hole. This hole may be seen in the upper left corner of the aggregate.

NON-CARBONATE STALACTITES.

In the case of non-carbonate stalactites, oversaturation of the solution may occur for two reasons, neither connected with mechanical agitation. These are: evaporation while the drop hangs static and pressure/temperature condition jumps between the feeding channel and the cave.

The first variant is analogous with the carbonate case: the importance of evaporation grows with the decrease in dripping frequency. So, a carbonate stalactite with very slow dripping will receive some morphological, structural, and textural features from evaporation-controlled formations. As shown by Stepanov (1971), with slow feeding and low humidity, allowing evaporation, stalactites are transformed into corlactites or crystlactites. The two last are formations, significantly controlled by capillarity, intermediate between stalactites and corallites (or crystallictites). Corlactites and crystallictites[2] have the following features: their gravitational control is weakened; capillary film kinetics control is enforced; crystallographic control is enforced; their surface is often faced; a central channel is optional and, if it exists, has irregular geometry, not controlled by the meniscus.

Studies by the author in caves where sulfates are deposited (in all of which oversaturation is caused by evaporation), have shown that their stalactites always have a structure and texture which is more complex than in the carbonate case. In the most simple environments they are similar to carbonate crystlactites (Figures 5 and 6, left), in more complex environments they convert into chandeliers (Figure 6). Corlactites are not found because too high an oversaturation is needed for sulfate crystals to become split. A gypsum "stalactite" (more properly a

[2] See Stepanov, 1997 for these terms.

crystlactite) has an internal channel, which will have irregular geometry, in only about half of the cases; has a faced surface; as a rule is not vertical and is often branched. In localities where the rate of dripping is high enough to suppress these features, no stalactites are found as evaporation is too slow for growth to occur when there is fast feeding.

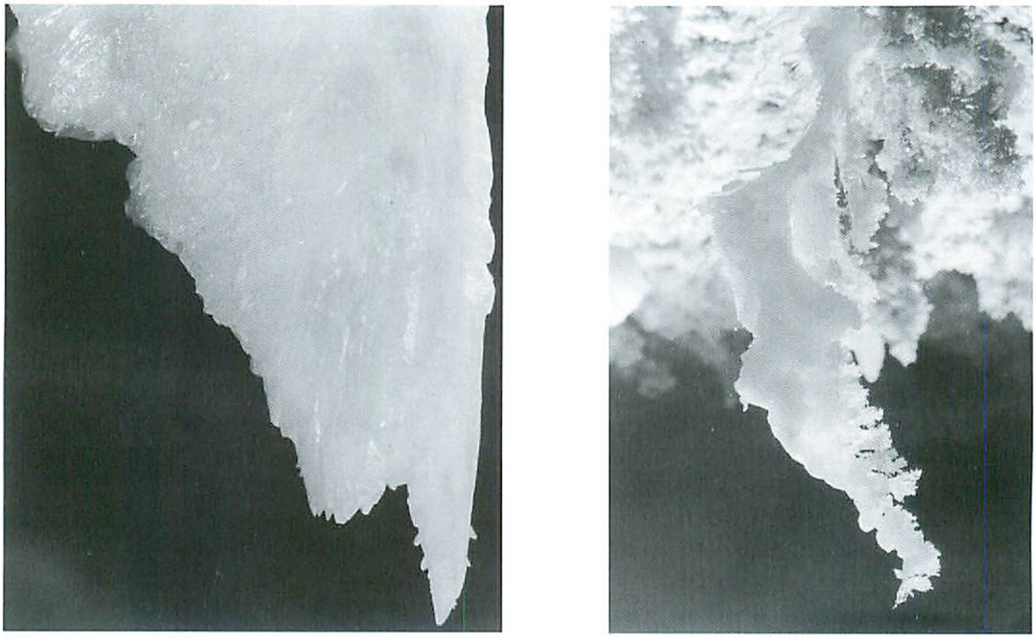

Figure 5. *Calcite (left) and aragonite (right) crystlactites. The tip of the calcite one appears not as a soda-straw, but as a faced crystal without a channel.*

The second variant also has some analogies in the carbonate case. These are spring swells, shields, other formations, generated from rapid degassing on pressure/temperature condition barriers. They appear at the points at which feeding fractures open where there is such a barrier between the cave and the fracture. They may be vertical, and may have a channel. Their structure is granular, up to tufa, no monocrystalline tubes appear, gravitational control is weakened. The channel has irregular geometry. The most "stalactite-like" formations of this kind are tufa tubular stalactites, usually growing in mines within ore deposits (the author has seen them in the Khaidarkan mines), where conditions in feeding fractures and in the growth space (the mine) are strongly disbalanced. They are also characterized by weakened gravitational control, absence of monocrystalline tubes and irregular channel geometry. In Stepanov's classification, they are not stalactites, but tuflactites, tubular variety. All the tubular stalactite-like non-carbonate aggregates, which have their genesis driven by pressure/temperature conditions, both observed by the author and recognizably mentioned in literature (i.e. Plavshudin 1973), have all the characteristics of tubular tuflactites, and never show similar features to soda-straws.

STALACTITES CRYSTALLIZING FROM MELTS.

Now let us look at the products of crystallization from melts, usually of ice or sulfur. Surprisingly, this environment produces aggregates with maximum similarity to the usual carbonate case. Here can be found real stalactites, including monocrystalline soda-straws. The reason for this is simple: when a melt drop hangs in the cold air, its outside layer will be supercooled. Mechanical agitation on the meniscus perimeter during the drop's disconnection (sharp pressure fall) cause this supercooled melt to crystallize in an explosive manner. The physics is almost the same as in the carbonate case, explosive crystallization at the moment of the drop's disconnection, resulting in skeleton crystals and dendrites and subsequent re-crystallization of these dendrites into a monocrystalline tube.

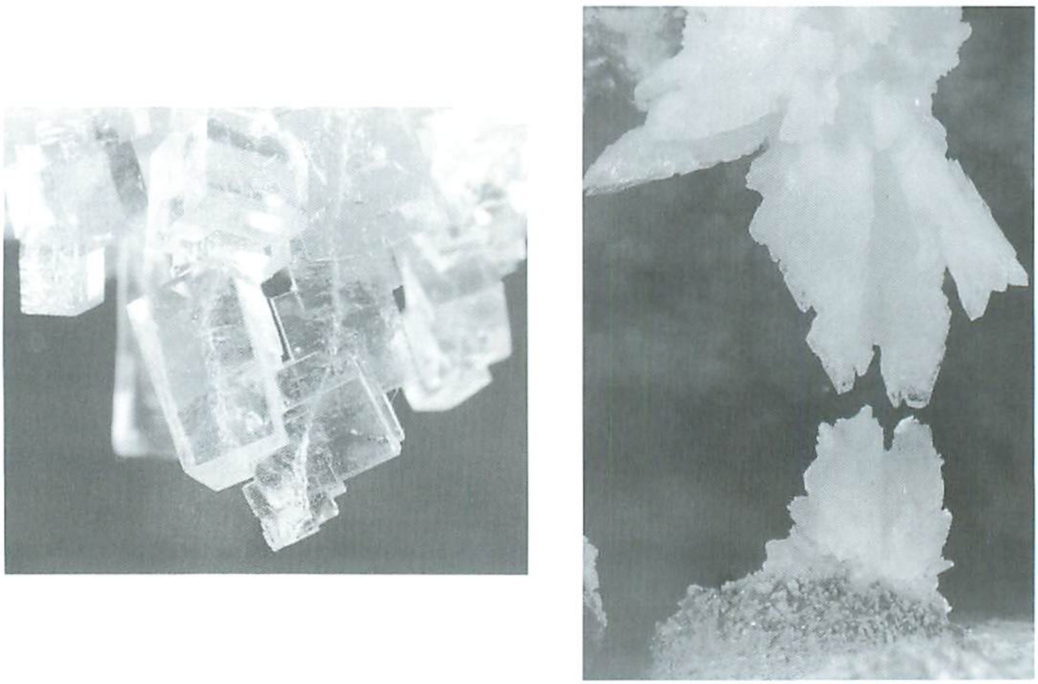

Figure 6. *Crystlactites with combined (internal plus external) feeding: halite crystlactite on the left and gypsum chandelier on the right.*

The ice case is even more illustrative than the carbonate one. Icicles, growing outside caves and more than 1 day old cannot have an active feeding channel, in the night the melt inside will be frozen, and there is no mechanism which will open the channel again. The following day the icicle continues growing with undeniable surface feeding and again grows as a soda-straw. Yet again, the channel which is always present (Makkonen, 1988) appears to be not a cause of growth, but a consequence.

CONCLUSIONS

The classification of stalactites by their feeding mechanisms does not correspond to considerations of their structure and texture and in the most common cases is simply wrong.

Real stalactites, appearing as a result of the degassing of bicarbonate solutions, or the freezing of melts, have a central channel not by reason of their tubularity, but as a consequence of their crystallization physics. The occasional appearance of internal feeding in these stalactites is a secondary effect.

Tubular tuflactites are mostly characteristic of crystallization, driven by pressure/temperature condition barriers. These aggregates, significantly differing from stalactites in their structure and texture, may form from any sufficiently soluble minerals. These are the only stalactite-like aggregates with a real feeding role for the central channel.

Corlactites and crystlactites, appearing within prevailing role of evaporation, also may be formed from any sufficiently soluble minerals. They also have strong differences from stalactites in their structure and texture. A central channel is optional, but if it exists it is a real feeding channel. Its existence or absence has an influence upon the aggregate's texture, but not its structure.

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