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A MODEL OF STRUCTURE AND GENESIS FOR THE GYPSUM "NEST", FOUND IN THE GEOPHYSICHESKAYA CAVE (KUGITANGTOU MOUNTAINS, TURKMENISTAN)

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A description, and a possible structure and genetic mechanism for a "gypsum nest", a very rare speleothem consisting of gypsum needles growing from a drying clay massif, are considered. Because of conservation concerns, theoretical modeling is the only acceptable method for studying this complicated and delicate feature. The model suggested considers the "nest" as a screw-dislocated spherocrystal, with its sub-individuals separated by corrosion at some initial stage, and having separate growth at later stages.

EDITORS' NOTE: Some mineralogical terms that are not in common use in the English literature are defined at the end of this paper for the use of the reader.

The speleothem, referred to as a "nest" (Figure 1), is known from only one location in the world, in the Geophysicheskaya Cave, Kugitangtou Mountains, Turkmenistan. All of the main features of the nest are known in other types of speleothems. There are also apparently reports of similar phenomena found in Lechuguilla Cave (Guadalupe Mountains, USA) (D. Davis, pers. comm.). The nest and similar features are not believed to be the result of external physical conditions, but are more likely the result of some mechanism related to crystal growth.

Of course, these speleothems are too rare, too beautiful, and too delicate to be considered for study by direct methods (i.e., collecting). Given this, I offer the following description, along with suggestions (based on theoretical modeling) for the structure and genesis of the nest.

Figure 1. The gypsum "nest" from the Geophyszicheskaya cave. Photo courtesy of Alexander Samoilov.

Description

The "nest" is located on a large flat massif of alluvial clay, that is currently undergoing a drying episode. A part of this massif, tens of square meters in area, where the air circulation is apparently optimum for efflorescence, is entirely covered with various gypsum needles, "hedge-hogs", and "cotton" masses. These are varieties of filamentary crystals and fibrous aggregates, known to crystallize from plastic substrates. The "nest" itself appears as a funnel-shaped mass of thousands of oriented gypsum needles with a hollow interior. The needles are approximately 0.1 - 0.5 mm thick, up to 40 cm long, and twist counter-clockwise around the axis of the "funnel". The diameter of the complete construction is about 30 cm, which makes it stand out from the surrounding gypsum crystal fabrics, that, in turn, are characterized by shorter, thicker, and chaotically oriented needles. The central hole of the nest is also funnel-shaped, and has one needle situated along its central axis. The "nest" grows on a relatively flat floor, and is tilted about 20º relative to the floor.

Possible Structure and Growth Mechanisms

The crystallization mechanism of filamentary crystal crusts, growing from drying clays (Maleev, 1971; Maltsev, 1996; Stepanov, 1971), can have only a spherical symmetry. Other factors, such as local air circulation, humidity, and clay porosity, may cause the formation of aggregates and crusts which are not truly representative of ideal growth of the crystal. So, we must search for the source of the "nest's" symmetry not on the levels of crusts or aggregates, but on the level of individual crystals. Here we deal not with texture symmetry, but with structure symmetry, and it may be controlled not only by mass-transportation factors, but also by crystallization physics.

In a monocrystalline case the most probable reason for such regular twisting is a screw dislocation of the crystallographic framework. Counterclockwise dislocation, as seen in Figure 1, is usual for gypsum (Hill & Forti, 1986). Screw crystals on this clay massif are rare, and so their appearance in such great numbers in one particular spot must be due to some special circumstance.

The hypothesis that is most sound invokes the origin of the nest from a single splitted screw crystal. This explains the two main morphological features of the "nest": (i) regular twisted needles [the screw dislocation is generalized upon the whole splitted crystal], and (ii) the longer crystals that stand out from the surrounding materials [screw crystal growth speed is normally greater than usual crystal growth speed (Grigorgev & Zhabin, 1975; Hill & Forti, 1986; Maleev, 1971)].

Still, several features remain unexplained. For example, filamentary crystals (the base for needles) always grow from their roots outward, and poorly connected spherolite bunches usually grow on their outer heads.

As indicated by other researchers (Casali & Forti, 1969; Maleev, 1971; Maltsev, 1996; Stepanov, 1971), filamentary sulfate crystals growing from drying cave clays have the following properties: a) near the crystal "root", there is a zone of splitted growth, and after it - a zone of skeleton growth, that are controlled by physics; b) when these zones are overlapped, dendritic needles appear in full accordance with the definition of Grigorjev and Zhabin (1975), that a dendrite is a splitted skeletal crystal; c) if the splitting rate is high, needles with properties of spherocrystals appear - with full generalization of the crystallographic network properties upon all the speleothem (Godovikov, et al., 1989; Grigorjev & Zhabin, 1975); d) in places experiencing intense seasonal humidity cycles, the roots of the gypsum needles are usually corroded.

DISCUSSION

With the establishment of the above properties, we can now consider the conditions that could lead to crystallization of a speleothem such as the "nest" (Figure 2). From the above cave conditions and the crystal properties, we can hypothesize the following sequence of events:

1) A splitted gypsum crystal, having properties of a spherocrystal, and not yet extruded from the surface. Because of this, the splitted zone covers its entire length. As shown by Maltsev (1996), the 400%-500% relative oversaturation needed for gypsum crystal twinning (Russo, 1981) is possible. The capillary pressure in the pores of the clay is dozens of atmospheres, and the needle physically blocks the pores, pressing out the solution from between them. When reaching the needle surface, where the pore is enlarged and the capillary pressure is lower, the solution becomes oversaturated due to the

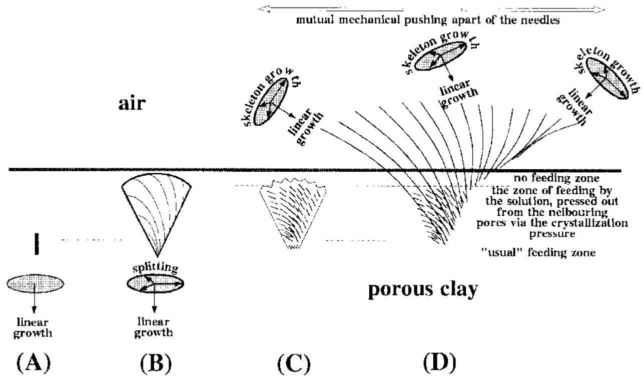

Figure 2. Genetic scheme for crystal aggregates such as the "nest". A. a screw-dislocated filamentary crystal. B. its splitting up to a spherocrystal. C. its partial dissolution with disconnection into acicular relicts. D. their independent growth with mutual mechanical interactions.

pressure change. There are no theoretical restrictions on the existence of such needles with screw dislocations. Moreover, the "antholite-like packets", described by Maltsev (1996) and also known as "gypsum grass" (Hill & Forti, 1986), in reality are splitted needles with screw dislocations, formed in very similar conditions.

2) Flooding, causing 30-50% dissolution of the needle. The corrosion-sculptured forms for spherolites and spherocrystals are widespread and well-known, though not clearly described in the literature. When the spherolite center and its outside surface are equally exposed to the corrosive solutions, the spherolite separates into radial needles - relicts of sub-individuals. The author has studied many such corrosional effects on gypsum spherolites found in caves. These radial needles that are produced by the partial dissolution of the spherolites due to occasional flooding of the clay sediments are formed in place in the clay. The relict needles would be disconnected, but held in place by clay.

3) Restoration of dry conditions, and along with this, reactivation of the needle growth. Given the phenomena above, the relict needle of each packet would serve as an inception point for the new needle growth. And all of them would have the same screw dislocation as the source needle had.

However, there is a difference between the original growth and restored growth. Now we have multiple objects in the feeding zone, suited for one object. With this, the concurrent selection is already impossible - the zone, where the needles could block each other, is already behind. So, the supersaturation of the solution remains, but very strong deficit of solution appears. This leads to limitations in the needles' thickness increase, and to this increase going exclusively through the crystals skeletization, without further splitting.

4) A restricted thickness increase, caused by the above, will change the morphology of the packet. Their divergence angle,

between 5 - 10º originally, will increase, thus converting the packet from having geometry of a cone to having geometry of a hyperboloid of one sheet (akin to an object such as the Eiffel Tower). During this phase, the needles would be mechanically aligned to directions of generatrixes of this hyperboloid.

5) When the needles are extruded through the surface, they retain their orientation from (4) with only one additional change - that caused by curving under their own weight.

In the above I have proposed a genetic and structural model for speleothems such as "nests". Although speculative due to the non-invasive nature of my investigation, this model is realistic and simple enough to be accepted as a working hypotheses. Some other (not screw) bushes of oriented needles, may be also explained through this concept of splitting, dissolution, and growth re-activation.

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DEFINITIONS (OF TERMS NOT IN COMMON USE IN THE ENGLISH LITERATURE)

ANTHOLITE

Somewhat similar to the term "flower". The difference is that "flower" may be applied to separate branches, and "antholite" always refers to the whole aggregate, usually having several branches. When used as "antholite crust" it refers to the all the filamentary efflorescences in a given crystallization episode at a locality.

SKELETON CRYSTALS, SKELETON GROWTH

When the crystallization environment is highly supersaturated, but with weak feeding or weak mixing, the crystallization process becomes unbalanced. The crystals grow rapidly, but the media cannot provide enough space to accommodate massive crystals. This unbalance makes crystal growth concentrate on edges or apexes, barely constructing some edges. The result is a crystal, constructed of needles along edges with nothing between them, or a crystal, having faces, but empty inside, etc. In the English literature these formations are usually referred to either as regular twinning, or as dendrites. Both interpretations are incorrect, because skeleton crystals are true monocrystals, growing from a single nucleus, just in peculiar environments. Skeleton crystals are not mineral aggregates, but mineral individuals - single crystal objects.

Dendrites are somewhat similar formations to skeleton crystals. They also require the same unbalance in the environment, but also need some splitting factor. Dendrites are characterized by permanent splitting of skeleton crystals during growth, and/or additional nucleation.

SPHERICAL SYMMETRY, SPHEROCRYSTALS, SPHEROLITES

In the onthogeny of minerals the concept of characteristic symmetry of mineral bodies is of central importance. The idea of the characteristic symmetry of some natural phenomena, defined as maximum possible symmetry, consistent with the existence of these phenomena, was first suggested by Curie, then was carried into mineralogy by Lemmlein. Another concept used is dissymmetry, defined as a single symmetry element, missing or possible raising the characteristic symmetry of an object to the next level.

This concept is very useful. It can be applied to irregular objects, that MAY be regular, and tend to be regular. We cannot see characteristic symmetry completely (like crystallographic symmetry), but we always can see its traces. Here appears the first use for this concept - it can be applied not only to trivial objects and phenomena, but also to higher organized objects-not only to crystals, but also to aggregates, crusts, etc.

The main use of this concept comes from the Curie symmetry principle. If some mechanism or process has some consequence, then the consequence's characteristic symmetry or dissymmetry is some projection of the mechanism or process's symmetry (dissymmetry). Characteristic symmetry may be found not only in material objects, but also in properties of environments. Knowing this, we can find connections between the mass-transportation symmetries and dissymmetries of the crystallization environments, and structure and texture symmetries and dissymmetries of the crystallization products. The last can be also used in reverse, for identifying crystallization environment properties required for growth of a given mineral body.

The characteristic symmetry is usually referred to in terms of a geometric shape having a particular needed symmetry, such as cylinders, cones, or spheres. This is easier than operating with mathematical descriptions. For example, spherical symmetry for a mineral aggregate means that individual crystals have no preferential growth directions, unless if caused by mechanical obstacles.

SPLITTING, SPLITTED GROWTH

Mineral bodies, starting as a single crystal, and then converting into a "packet" of "crystals", bending apart one from another, are well-known, and may be seen in any museum. In Western mineralogical thought they are usually taken as "crystal groups" or something like that.

In reality they are single crystals with a single nucleus and contiguous growth, but a splitted crystallographic network. If we take a splitted crystal of quartz, we will see that all of the sub-individuals are left, or all are right-never mixed. This is because they are not separate crystals, but separate heads of one crystal.

Crystal splitting may occur for several reasons and may go to several splitting grades. The most common reasons for splitting are:

a) Microscopic mechanical inclusions (also possible from the same mineral). They leave "shadow holes" in the crystallization front, allowing the crystallization forces to push apart separate zones of crystal, thus bending the crystallographic network.

b) Extra molecules appearing in some layers of the crystallographic network. This usually comes from solutions that are highly supersaturated, but not so oversaturated as to cause spatial nucleation.

c) Structural admixtures of an ion with different radius than the main one. In reality this leads to the (b) case, because the larger or smaller ion does not lead to regular increase of the molecular quantity from layer to layer, but provides "weak places" for inserting additional ions even without high supersaturation. For example, admixture of Mg or Sr in calcite makes splitting much easier.

Some minerals are hard to split, some easy. Under usual cave conditions it is almost impossible to find splitted gypsum, or to find unsplitted aragonite. But in unusual conditions it may be the opposite.

Mechanical splitting (a) may produce only objects of low splitting grade, where sub-individuals are separated and have faced heads-clusters, sheaves, etc. Typical cases of rough splitting, that can be seen in any museum-stilbite sheafs, or kyanite clusters. The other two mechanisms (b,c) may provide higher grades of splitting (as well as low grade).

When the sub-individuals are seen only as fibers, and have no faced heads, we speak of spherolites (straight fibers), or spheroidolites (bent fibers). Both are distinctly different from radial-fibrous aggregates. The latter have an internal core and multiple mineral individuals around them (usual or splitted), aligned through geometrical selection. The most common example of spherolites are globular chalcedony formations.

When splitting reaches the highest grade, all boundaries between fibers disappear-splitting goes on almost at the molecular level. The crystallographic network totally generalizes upon the entire object, together with all of its properties. If with rough splitting the faces of crystal heads are straight, the cleavage is usual, etc., in the high grade case, we can see curved crystal faces, spherical cleavage, etc. Such formations are called spherocrystals. The most typical example is malachite spherocrystals, widely found in ore deposits.

All splitted crystals, as with skeleton crystals and usual crystals, are not mineral aggregates, but mineral individuals - single crystal objects.

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