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THE CLASSIFICATION OF CAVE MINERALS AND SPELEOTHEMS

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ABSTRACT

The classification scheme of Hill and Forti, as used in the second edition of *Cave Minerals of the World*, is presented as a "practical" solution to the classification of cave minerals and speleothems. Classification and naming of cave minerals is by crystal class and follows nomenclature approved by the International Mineralogical Association. Classification of speleothems is based on morphology and whatever is known about origin, with division of speleothems into types, subtypes, and varieties. It is proposed that new speleothem types, subtypes, and names be approved by a UIS Commission of cave mineralogists.

INTRODUCTION

A "cave mineral" is a secondary mineral deposit formed in any natural subterranean cavity, fissure, or tube which is human-sized or larger and which extends past the twilight zone. A "speleothem" is a secondary mineral deposit formed in a cave by a chemical reaction from a primary mineral in bedrock or detritus because of a unique set of conditions therein; i.e., the cave environment has influenced the mineral's deposition (Moore, 1952). A "speleothem" is *not* the same as a "cave mineral." The term "speleothem" refers to the mode of occurrence or shape of a mineral deposit and not to the mineral itself. For example, calcite is a cave mineral, but it is not a speleothem. A calcite stalactite in a cave is a speleothem, as are gypsum stalactites, halite stalactites, or stalactites composed of other minerals. A stalactite in a mine is not a speleothem (although such can grow there by the same mechanism as, and be morphologically identical to, a stalactite in a cave) because a mine is not a natural cave.

Hill and Forti, in their forthcoming second edition of *Cave Minerals of the World*, identify over 200 separate cave mineral species, but only 36 separate speleothem types. This distinction between a "cave mineral" and "speleothem" must be preserved in any viable classification scheme, and thus in the second edition the text is divided into two main parts: speleothems and cave minerals.

CLASSIFICATION OF CAVE MINERALS

Two basic approaches have been taken in the past with regard to the classification of cave minerals: (1) classification by origin, and (2) classification by chemical class

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(carbonates, sulfates, halides, etc.). Minerals in the outside world have always been classified by chemical class (i.e., *Dana's System of Mineralogy*), without regard to origin, while cave minerals have almost always been classified according to origin (e.g., Martini, 1993; Shopov, 1993). This origins approach for the classification of cave minerals has not worked well for two reasons: (1) many minerals have more than one origin, and (2) origin terminology can become so complex as to be confusing to all but the person making up the classification scheme. An example of the first is gypsum. Gypsum is a cave mineral usually derived from rainwater leaching of evaporite/limestone rock, but it can also derive from bat guano, sulfuric acid-derived reactions, or other mechanisms. According to which origin should gypsum then be classified? Dana did not attempt to classify minerals in the outside world by origin because of their genetic complexity, so why should cave minerals be classified by origin when their genesis can be equally as complex? An example of the second is the elaborate "working classification" scheme of Shopov (1993) who, on the basis of origin, classified by type of country rock, main processes, and genetic type. Classes that emerged from this scheme, such as "soil-acid redeposition," "anthropogenic," "osteogenic," and "hypergenic," are more confusing than helpful and certainly do not "work."

CLASSIFICATION OF SPELEOTHEMS

Two basic approaches have also been taken with regard to the classification of speleothems: (1) classification by morphology, and (2) classification by origin. Both of these approaches have their problems.

(1) Classification by Morphology.

The most frequent method of classifying speleothems is by morphology; i.e., by the shapes one sees. This is a "natural" classification scheme in the sense that it is cavers who discover new speleothems and naturally name them for what they look like. However, classification based exclusively on morphology without regard to origin can result in elaborate schemes that add little to the understanding of these speleothems. For example, Halliday (1962) ended up with more morphological classes than there are speleothem types, and DeSaussure et al. (1953) had an "unexplained" category containing more types than any of their other categories. Diaconu (1979) put morphologically-similar speleothems together in the same class (for example, conulites with stalactites), even though the overall origin of these speleothem types is quite different (both are formed by dripping water, but there the similarity in origin ends).

Too strict of a classification scheme according to morphology alone can also be troublesome because speleothemic forms often mimic each other, even when origin differs. For example, an antler helictite outwardly resembles a quill anthodite, yet a helictite is formed by capillary solutions oozing through a tiny central canal whereas an anthodite is believed to form by solutions moving primarily along its outer surface. Also, morphological classifications can get "hung up" on what White (1976) called "style" or what we call "variety;" that is, variant shapes based on different flow or depositional rates, crystal composition, or other factors. For example, a "soda straw" does not look exactly like an ordinary stalactite, having straight, thin-walled sides rather than a carrot-like shape, but it forms like other stalactites (by dripping water) and, in fact, all stalactites begin their growth as soda straws. Based strictly on morphology, then, soda straws and stalactites could be classified as two separate speleothems, but based on origin, soda

straws should be classified as a monocrystalline variety of stalactite. Another example is a spathite, an aragonite soda straw with regularly flaring and receding sides. The origin of aragonite spathites and calcite soda straws is essentially the same, only the crystal form of aragonite shapes the spathite differently so that it exhibits undulating, rather than straight, sides. All three (stalactites, soda straws, and spathites) belong to the same speleothem type, but show a variant morphology.

(2) Classification by origin.

A rigorous classification scheme for speleothems based exclusively on origin is almost purposeless, because, as for cave minerals, this origin can (and usually does) involve many mechanisms. Again taking the common stalactite as an example: growth occurs primarily by material precipitated from dripping water, but the stalactite is also enlarged by material precipitated from water flowing down along its sides. According to which mode of origin should this speleothem be classified then: by dripping water or by flowing water? Also, the origin of some speleothem types is unknown, and this can be a major problem for classifiers (including us). Gams (1968) was one investigator who based the classification of speleothems on genesis. Gams' classification scheme worked as far as it went, but could only encompass the common stalactite, stalagmite, shield, and helictite speleothems. Another "universal classification" scheme was that of Andreichouck (1992) who divided speleothems into taxons such as "water-chemogenic," "water-kriogenic," etc. Such schemes, no matter how well-intentioned, end up being fruitless exercises in terminology.

CLASSIFICATION SCHEME, *CAVE MINERALS OF THE WORLD*

The classification scheme of Hill and Forti, as presented in the second edition of *Cave Minerals of the World, is* a practical one based on a compromise between the three factors of chemical class, morphology, and origin. Cave minerals are exclusively classified according to chemical class, after the manner of *Dana's System of Mineralogy*, starting with the native elements, sulfides, and oxides-hydroxides (Dana's v. I), and then proceeding to the other chemical classes (Dana's v. II and III), but in alphabetical order. Specific cave minerals within each represented chemical class are also listed in alphabetical order. Cave minerals are *not* classified partly by origin as was done in the first edition (e.g., into "ore-related minerals" or "miscellaneous minerals" categories): this old scheme (like all mineral schemes based on origin) proved to be complicated, cumbersome, and repetitious, where the "miscellaneous" category became as large, or larger, than some of the other mineral categories. Classification by origin (even partial origin) simply doesn't work!

The classification of speleothems in *Cave Minerals of the World*, second edition, basically follows that of the first edition: i.e., it is based on morphology tempered by what is known of origin (Hill and Forti, 1986). In addition, an attempt is made in the second edition to define the criteria by which speleothem types, subtypes, and varieties can be recognized, with types and subtypes being considered "official" and with varieties being considered "unofficial" morphological variations of types and subtypes.

(1) Type.

A speleothem type is herein defined as a group or category of speleothems sharing a

common morphology and origin different from other speleothem types. Speleothem type morphology is controlled by one or more known hydrologic mechanisms: dripping, flowing, pool, geyser, capillary, condensation, and aerosol water. A speleothem type can be shaped by one of these mechanisms or by a combination of these mechanisms. For example, stalactites and stalagmites are speleothem types formed primarily by dripping water, elongated in the vertical direction of dripping. Flowstone forms, layer upon layer, from water flowing over cave walls or floors. Coralloids and frostwork grow from thin films of splashing or seeping water where the water is controlled by capillary forces on outside surfaces. Helictites twist in every direction because they grow by capillary water seeping through tiny internal canals, and fibrous speleothems are controlled by capillary forces within the pore spaces of bedrock. Cave rafts are flat planar speleothems because they form on the surfaces of pools, while spar can form in pool water beneath the surface. Geysermites form from the action of thermal "geyser" water upwelling from below. Rims are deposits which line bedrock or other speleothems in places where water condenses due to changes in temperature and/or humidity, and aerosol "sinter" crusts form where an aerosol mist causes very small, solid particles to coat cave walls. Where two or more of these basic hydrologic mechanisms are at work, other speleothem types can result. For example, a drapery speleothem is created when a drop of water flows down an inclined ceiling and then drips to the floor. Cave pearls form where water drips into a shallow pool. And so on.

A speleothem type has an origin different from all other speleothem types. However, this does not necessarily mean that there is only one origin for each type. The origin of a type can involve the above hydrologic mechanisms or, in addition, it can involve other factors or mechanisms. For example, cave crusts can originate from seeping or aerosol water or, in addition, a common-ion effect (incongruent dissolution) can be involved in their formation. Cave powder and moonmilk are speleothems which can originate in many ways. For example, moonmilk variously forms due to: (1) the freezing of limestone by water ice, (2) the life cycle of microorganisms, (3) the disintegration of bedrock or speleothems, and/or (4) crystallinity factors related to the mineral making up the moonmilk. Morphology takes precedent over origin when it comes to classifying and naming speleothems because, again, that's what people see (i.e, a cave powder will be called "powder" no matter what its origin is). However, the concept of a different origin (or origins) for *different* speleothem types is important because morphology reflects origin. It is also important because some speleothem types morphologically mimic each other, even when their origin differs. For example, a geysermite resembles a stalagmite in that both are convex-upwards floor deposits, but stalagmites form from water dripping downward due to gravitational forces, whereas geysermites form from water upwelling due to artesian forces. In such cases speleothems can be classified as separate types based on origin rather than morphology.

The morphological and genetic boundaries between different speleothem types may be clear or they may be arbitrary. For example, the boundaries between the speleothem types frostwork-anthodites-helictites seem to be transitional in nature: frostwork is formed by capillary water seeping along the outsides of crystals, helictites are formed by capillary water seeping through a central canal, but anthodites (intermediate between the two) may be formed by *both* (or either) processes, thus alternating in shape between frostwork and helictites. Moreover, the boundaries between speleothem types may be arbitrary when origin is unknown. For example, "pool fingers" are a new speleothem type where a number of subaqueous pool deposits, of similar morphology but uncertain origin, have been "lumped" together until origin can be determined.

(2) Subtype.

A speleothem **subtype** is herein defined as a group or category of speleothems containing structural components identical to the type, but having a composite form deviating from the type. Often the deviant morphology is produced by a hydrologic mechanism which occurs *in addition* to the mechanism(s) which form the type, or it can also involve other factors. Using the cave raft as an example: if cave rafts forming on the surface of a cave pool or body of water are sunk at a consistent drip point, then these rafts can pile up on the floor of the pool into cone-shaped masses called cave cones. Cave cones are a subtype of cave raft because, not only are the structural components identical to normal cave rafts (i.e., planar deposits formed on a water surface), but, in addition, a dripping-water hydrologic mechanism sinks the rafts so as to produce a deviant morphology (cones). Using a similar logic, lotus rimstone and crescent shelfstone are subtypes of rimstone and shelfstone, respectively, because of an additional dripping water mechanism. Examples of subtypes caused by other factors are septaria and reticulated fins, both subtypes of boxwork. Septaria are crystalline fins formed in clastic floor material, while reticulated fins form in cracked speleothems—materials different from bedrock in which boxwork usually forms. Examples of subtypes caused by significant differences in bedrock porosity are gypsum balls (a subtype of blister); starburst gypsum (a subtype of crust); and hair, cotton, and rope (subtypes of fibrous speleothems).

(3) Variety.

A speleothem "variety" is herein defined as a group or category of speleothems which vary in morphology from a type or subtype due to slight variations in water flow or to variations in mineral composition, color, crystallinity, or other factors. A speleothem "variety" differs from a speleothem **subtype** in that its basic morphology and origin is similar to the type, whereas a subtype has a morphology and/or origin deviant from the type. For example, a "parachute" shield is a variety of shield where a slight excess of water has flowed evenly out from the medial crack, causing dripstone and flowstone to form on the shield's bottom plate so that it resembles a parachute. Another example is a spathite soda-straw stalactite, which has flaring, rather than straight, sides because the crystal system of aragonite causes growth at an angle to the straw side. "Bacon" is a variety of drapery which is multicolored due to impurities in solution; tabular gypsum is a variety of cave crust where crystals are macroscopic rather than microscopic; and pyramids are a monocrystalline variety of cave cups.

Speleothem varieties exist for both types and subtypes. For example, a "snowflake" is a very thin, white, cave raft—a variety of the type speleothem, raft, while a "volcano cone" is a variety of a cave cone (subtype of the type raft) where the same dripping water that sunk the rafts under subaqueous conditions has produced a drip hole in the apex of the cone under later, subaerial conditions. Clastic canopies, bell canopies, and baldacchino canopies are all varieties of canopy flowstone (a subtype of flowstone), where somewhat different mechanisms have caused the lateral development of flowstone to be pronounced over the vertical development.

NOMENCLATURE

The naming of cave minerals and speolethems has been a subject of confusion due to non-standardization of terms around the world and also due to the lack of guiding

principles based on a practical classification scheme. Cave mineral names should correspond to minerals approved by the Commission on New Minerals and Mineral Names of the International Mineralogical Association, such as are listed in the *Glossary of Mineral Species* (Fleischer and Mandarino, 1995).

Names of speleothem types usually follow morphology (e.g., cave pearls), but in some cases they may follow origin (e.g., geysermites). The same applies to subtypes; e.g., starburst gypsum (a subtype of crust) is named for its star-like shape, while gypsum-alteration calcite crusts (another subtype of crust) refers to the mechanism (common-ion effect) by which calcite replaces gypsum and in the process forms crusts. Names of speleothem varieties usually follow morphology and consist of colloquial terms such as "witches fingers," "waterfalls," "fried eggs," "bacon," etc. Rarely, variety names may reflect origin (e.g., elastic canopies).

A "good" speleothem name reflects its morphology and/or origin, whereas a "bad" speleothem name reflects neither. An example of a good name is "helictite" because the Greek root "helikos" means to spiral, which is exactly what a helictite does. The names stalactite and stalagmite mean to "ooze out in drops" and "that which drops," respectively, which names reflect the origin of these two speleothem types. However, a name like "skullite" (a variety of cave pearl found in, and named for, Skull Cave, New York), is not satisfactory because it gives no information on what the speleothem looks like or its origin. Also, names that can be confused with speleogens (e.g., fins, scallops), detritus (e.g., sand, pebbles), or other material found in caves (e.g., fossils, shells) should *not* be used for speleothem types and subtypes.

It is proposed that a "Working Group" of international cave mineralogists study the problem of classification and naming of speleothems at the 1997 UIS/IC meeting in Switzerland. The authors believe that the field of cave mineralogy has progressed far enough over the last 20 years so as to attempt standardization of terms and names.

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