

CAVE MINERALOGY AND THE NSS: PAST, PRESENT, FUTURE

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Abstract: The purpose of this paper is to trace the National Speleological Society's past, present, and future involvement with the science of cave mineralogy, in accordance with the celebration of the NSS's 65th Anniversary. In the NSS's first decade (1940s), a number of articles covering mineralogy topics were published in grotto newsletters, the *NSS News* and *NSS Bulletin*, but it wasn't until the 1950s and 1960s that it published professional scientific papers on this subject. The Society's first huge commitment to this field was in their publication of *Cave Minerals* in 1976, the first book in the world on cave minerals and the first book ever published by the NSS. The book series *Cave Minerals of the World*, the second edition of which was published in 1997, has become the standard reference on the subject. Important fields of future research in cave mineralogy that the NSS may become involved with are those of paleo-environments, microbiology, and minerals ontogeny.

INTRODUCTION

The National Speleological Society (NSS) has been instrumental in promoting the science of cave mineralogy through its publication of the *NSS Bulletin* (now the *Journal of Cave and Karst Studies*), the *NSS News*, and three editions of *Cave Minerals/Cave Minerals of the World*. We will first describe the early years from 1940 (when the first issue of the *NSS Bulletin* came out) to 1976 when the Society published its first book, *Cave Minerals*. Then we will specifically trace the history of the *Cave Minerals* book series involving both of the authors, and finally we will present what we feel are some promising areas for future cave mineralogy work. For a voluminous, descriptive text on cave minerals and speleothems, the reader is referred to the NSS's book *Cave Minerals of the World* (Hill and Forti, 1997). For shorter reviews on the different classes of cave minerals and speleothem types refer to the articles by Hill and Forti (2004a, b) and Forti and Hill (2004) in the *Encyclopedia of Caves and Karst Science*.

PAST

THE EARLY YEARS (1940–1975)

The National Speleological Society's support of cave mineralogy in the early years was mainly through three avenues of publication:

- (1) Grotto publications, where members writing trip reports on caves they had been mapping or exploring also mentioned the minerals and speleothems observed therein. An excellent example of such early grotto publications is the numerous reports by William Halliday in the late 1940s and 1950s in the *California Caver* and *Salt Lake City Grotto Newsletter*.
- (2) *NSS News* publication of short mineral descriptions regarding specific caves.

- (3) *NSS Bulletin* publication of scientific reports related to cave mineralogy.

These reports constituted the most important aspect of the NSS's early involvement with cave mineralogy because they set the foundation for future scientific publications, including the first *Cave Minerals* book.

While it is not within the scope of this paper to include all of the early articles that contributed to this scientific foundation, some of the more important work will be mentioned, both with regard to the recognition of new minerals or speleothem types, and with regard to early NSS attempts to form committees or symposia on the topic of cave mineralogy.

The first published account of cave minerals/speleothems in the *NSS Bulletin* was by Roy Holden in 1940, in the very first issue of the *Bulletin*, where he described the Luray Caverns helictites and offered modes of origin (Holden, 1940). Holden was also the first to report the fluorescence of calcite speleothems in a United States cave in 1944 (Holden, 1944a), and he chaired the first NSS committee on minerals and formations in 1944 (Holden, 1944b). William Foster in 1949 reported on mineralogic data in speleothem work, and he also chaired the NSS committee on formations and mineralogy in 1951 (Foster, 1949, 1951). Henderson (1949) was the first to describe anthodites as a speleothem type from Skyline Caverns, Virginia, and Warwick (1950) was the first to observe and report in the *NSS Bulletin* the occurrence of calcite bubbles, which also became a new speleothem type. While all of these 1940 articles were important first attempts to describe cave minerals and speleothems, overall

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there wasn't much happening in the NSS in cave mineralogy prior to the 1950s.

In 1952, George Moore introduced the term speleothem for any secondary mineral deposit formed in caves (Moore, 1952). Despite some objections to this term over the years, it has stuck and is now the official name in the *Glossary of Geology* for what used to be referred to as a cave formation. Later in the 1950s, Crisman (1956) reported both monocrystalline helictites and stalactites from the Caverns of Sonora, Texas, the first report of monocrystalline speleothems in a United States cave. Davies and Moore (1957) were the first to report a cave occurrence of the minerals endellite and hydromagnesite anywhere in the world, and Good (1957), also working in Carlsbad Cavern at the same time as Davies and Moore, was the first to report a cave occurrence of the mineral montmorillonite anywhere in the world.

In the early 1950s a young undergraduate chemistry student, who took a special interest in cave mineralogy, emerged from the NSS caver ranks to become one of the leaders in this field for the next five decades: William B. White. White published a number of mineral descriptions in grotto publications in the late 1950s and went on to publish a review of cave mineral studies for 1955–1960 in 1961 (White, 1961), and also to chair the first NSS symposium on cave mineralogy (White, 1962). This symposium was held in December, 1960 at the New York meeting of the American Association for the Advancement of Science, and was one of the first attempts to merge cave mineralogy into mainstream science. This symposium was also the most professional of all the publications done by the NSS on cave mineralogy up to this time.

George Moore continued to write seminal papers in the *NSS Bulletin*, one on the origin of helictites in 1954 (Moore, 1954) and another on the growth of stalactites in 1962 (Moore, 1962), plus he was the first to report dolomite as a cave mineral in 1961 (Moore, 1961). Another NSS member who contributed important scientific papers on cave mineralogy in the *NSS Bulletin* in the 1960s–early 1970s was Rane Curl, who published on the aragonite-calcite problem in 1962 and on the minimum diameter of stalactites and stalagmites in 1971 (Curl, 1962, 1971). Thayer (1967) was the first to propose in the *NSS Bulletin* the name conulite for a new speleothem type that he described as simple drip-drilled mud pits lined with calcite.

Among all of the early (1940–1975) workers in U.S. cave mineralogy who published with the NSS, William (Bill) Halliday, George Moore, and William (Will) White stand out as the three persons who probably contributed the most information to this field.

HISTORY OF THE NATIONAL SPELEOLOGICAL SOCIETY'S BOOK *CAVE MINERALS OF THE WORLD*

1970

It all began on January 18, 1970, when Allan P. Haarr, former NSS Executive Vice President and member of

Elaine Hackerman's Miscellaneous Publications Committee, asked Carol Hill to write a chapter on cave minerals and speleothems for the NSS's *Caver's Handbook*. Al Haarr knew that Carol was interested in cave mineralogy and that she had been collecting a number of articles on the topic. He also knew that because Carol had moved to New Mexico, she had been working on the mineralogy of Carlsbad Cavern and other caves in the Guadalupe Mountains. Thus, Al Haarr asked Carol to contribute an approximately 50 page-long chapter to the *Caver's Handbook*, remarking: "I see this chapter as a fairly complete article on the various speleothems and their theories of formation." What Al Haarr didn't know is that in Carol's view complete really meant complete, and that Carol rarely writes anything short. Thus began the saga of *Cave Minerals of the World*.

1970–1971

For two years Carol Hill gathered together all of the United States cave mineral/speleothem articles she could find, and from this information and her own personal research wrote a chapter on cave mineralogy for the *Caver's Handbook*. However, this manuscript turned out to be much longer than the 50 pages originally intended by the Miscellaneous Publications Committee. Also by this time, a number of photographs had been obtained for the chapter, especially from cave photographer Pete Lindsley. Thus a dilemma arose within the NSS: What to do with this much-longer-than-anticipated manuscript?

1972

To resolve this dilemma, Dave Irving, then on the NSS board of governors (BOG), suggested that the chapter be made into a book to be sold externally to the public as well as to NSS members. This suggestion generated a major controversy within the NSS, the fear being that the book would promote vandalism once the general public found out what treasures actually exist in caves. Al Haarr remarked in his February 8, 1972 letter to Carol Hill that: "I feel your chapter is needed and useful but not worth an internal fight" (within the NSS), and he thus favored publication only to NSS members and geologists, and then only if the book contained a strong conservation message. Other NSS board members disagreed and thought that the publication of a book on cave minerals was an excellent way to educate the public as to cave conservation. Also, sale of the book could be a way of bringing much needed revenue into the NSS. It was finally decided that Carol's book, *Cave Minerals*, would be published, albeit with a strong conservation message and with no cave locations divulged. A Special Publications Committee then emerged from the former Miscellaneous Publications Committee to handle *Cave Minerals* and other potential book manuscripts. In June of 1972, *SpeleoPress* provided the lowest bid out of five, and was awarded the contract to print *Cave Minerals*.

1973

It was the NSS's plan to have *Cave Minerals* printed and available for sale by the 1973 NSS Convention, but by this time the act of publishing the book had turned into a total fiasco, to quote Al Haarr. The problems were two-fold: (1) Carol Hill had never written a book before, and (2) the NSS had never published a book before. There was no person on the Special Publications Committee that actually had the experience to handle such things as dealer quotes, book orders, price fixing, reprint rights, production schedules, interfacing with printers, advertising/marketing, etc., all of which needed to be spelled out and approved by the BOG. In addition, BOG member Dwight Deal felt compelled (or was compelled by the BOG) to take on the daunting task of making sure the book met professional standards and was properly reviewed. So the publication of *Cave Minerals* dragged on and on.

1976

By March of 1976, the book had been languishing at *SpeleoPress* for many months and had still not been printed. Therefore, then-NSS Executive Vice President James (Moose) Dawson gave *SpeleoPress* an ultimatum: either have the book printed in time for the Morgantown, West Virginia Convention in June, or the NSS would cancel its contract with *SpeleoPress*. Thus it was that *Cave Minerals* became the first book published by the National Speleological Society for a general audience, and the very first book in the world published on the topic of cave mineralogy (Hill, 1976). *Cave Minerals* was 137 pages long and contained 475 references, which included most of the U.S. cave mineralogy literature and some references from Great Britain and Australia, but which barely touched upon the non-English European literature. The book had a colored cover: The Butterfly from Caverns of Sonora by Pete Lindsley (Fig. 1), but the rest of the photographs were in black and white.

1978

By 1978 the sale of *Cave Minerals* had waned because of the failure of the NSS to advertise the book, even to NSS cavers, who approached Carol Hill asking where they could buy the book. This prompted Carol to write to then-NSS president Charlie Larson and the BOG to ask for an NSS commitment to properly sell the book. However, one important person who was able to buy a copy of *Cave Minerals* was Paolo Forti of the Institute of Speleology in Bologna, Italy. Paolo was perhaps only one of a couple of Europeans who read all of the *NSS News* issues, and in this way he had become aware of the existence of Carol's book. Paolo immediately bought probably the first copy of *Cave Minerals* sold in Europe. Paolo was extremely interested in Carol's book because at that time he was putting together a short booklet of his own on European cave minerals. Paolo sent a copy of this booklet, and many other of his publications, to Carol and a mutual correspondence

flourished. By now Carol realized that the bulk of what had been written on cave minerals resided in Europe, and that *Cave Minerals* had barely scratched the surface of this knowledge base.

1981

Carol Hill met Paolo Forti for the first time at the 8th International Congress of Speleology in Bowling Green, Kentucky in the summer of 1981. Since the NSS had expressed an interest in publishing another edition of *Cave Minerals*, Carol asked Paolo to be co-author of this new edition, now to be entitled *Cave Minerals of the World*. Paolo was very happy and excited to be a co-author, but did not yet realize the tremendous amount of work that this commitment would entail. The ambitious intent of Carol and Paolo was for *Cave Minerals of the World* to include all of the work done in cave mineralogy around the world up to that time, including all of the papers written on speleothems in the very early years of speleology (Fig. 2). Thus, they invited cave historian Trevor Shaw of Great Britain to write a Historical Introduction to the book.

1982–1985

In 1982 the collaboration of Carol and Paolo on the first edition of *Cave Minerals of the World* (CMW1) began, but with the Atlantic Ocean separating them and with no internet available at that time. For two years the authors labored on the manuscript, with Paolo Forti doing the lion's share of the new work because of the enormous amount of European literature on the subject in a variety of languages. Paolo's wife Giovanna complained that she was not able to see much of him during this time because he was always reading and translating cave mineralogy-related articles. In 1984, when the CMW1 manuscript was almost finished, the NSS decided to print the book in Italy because it was envisioned that most of the European sales would occur during the forthcoming International Congress in Barcelona, Spain. So CMW1 was contracted to an Italian printing house for a prescribed amount of Italian lira, which at that time was very weak with respect to the U.S. dollar. In the summer of 1985, Paolo flew to Albuquerque in order to prepare the final manuscript and choose photos with Carol, and after five full days of immersion (with only one hour of walking in the garden during those five days), CMW1 was ready to go to the printers. As a "gift" to Paolo, Carol and her husband Alan took Paolo on a whirlwind trip through Carlsbad Cavern.

1986

The first edition of *Cave Minerals of the World* (CMW1) was published just in time for the 9th International Congress of Speleology in Barcelona, Spain, but not without problems (Hill and Forti, 1986). It turned out that between 1984 and 1986 the exchange rate of dollars to lira had lowered more than 30%, and as a consequence this caused a major disagreement in pricing between the NSS

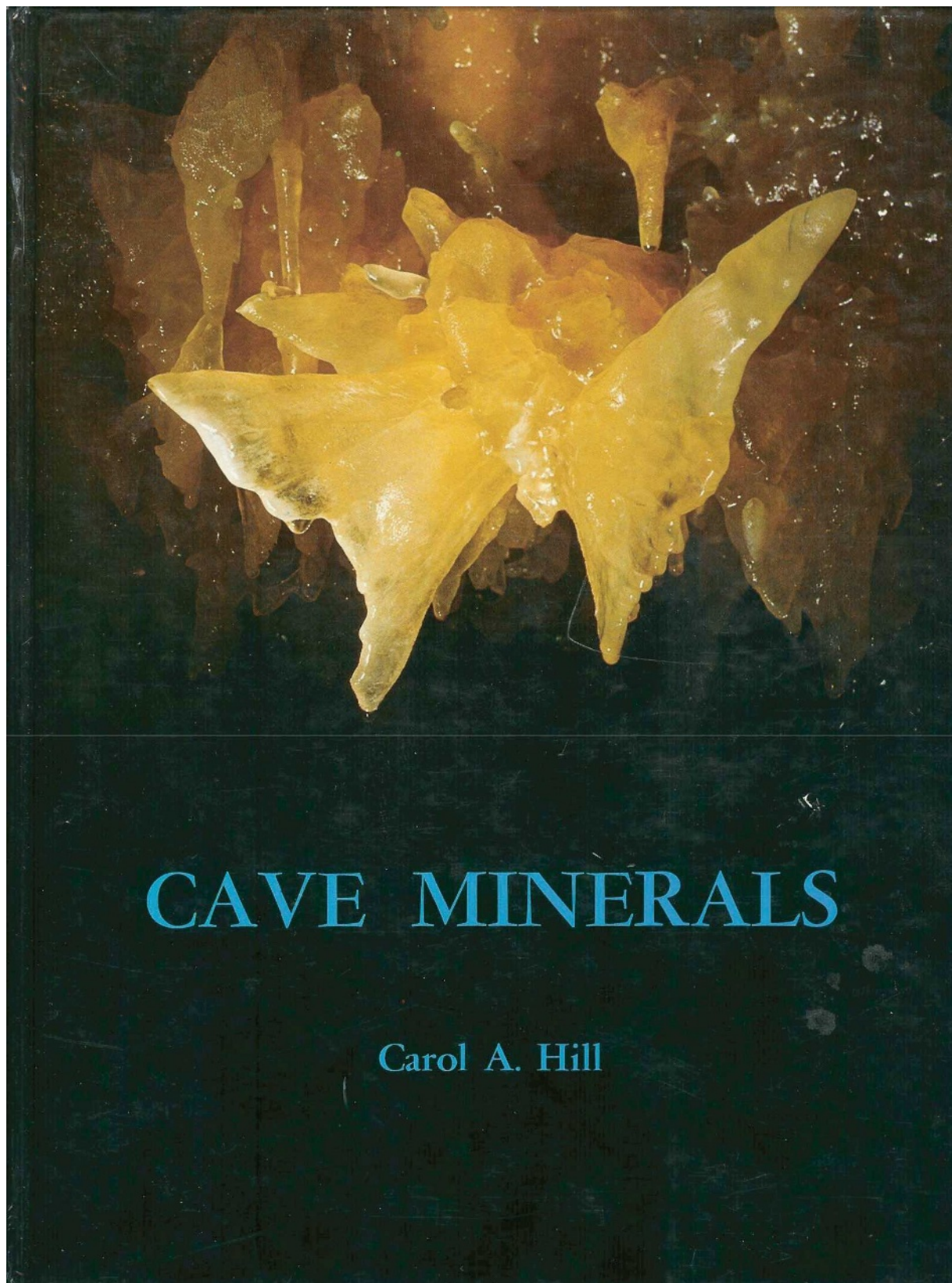


Figure 1. Cover of *Cave Minerals*, published in 1976 by the NSS. This photo by Pete Lindsey of “The Butterfly” in the Caverns of Sonora was the only color photo in the book.

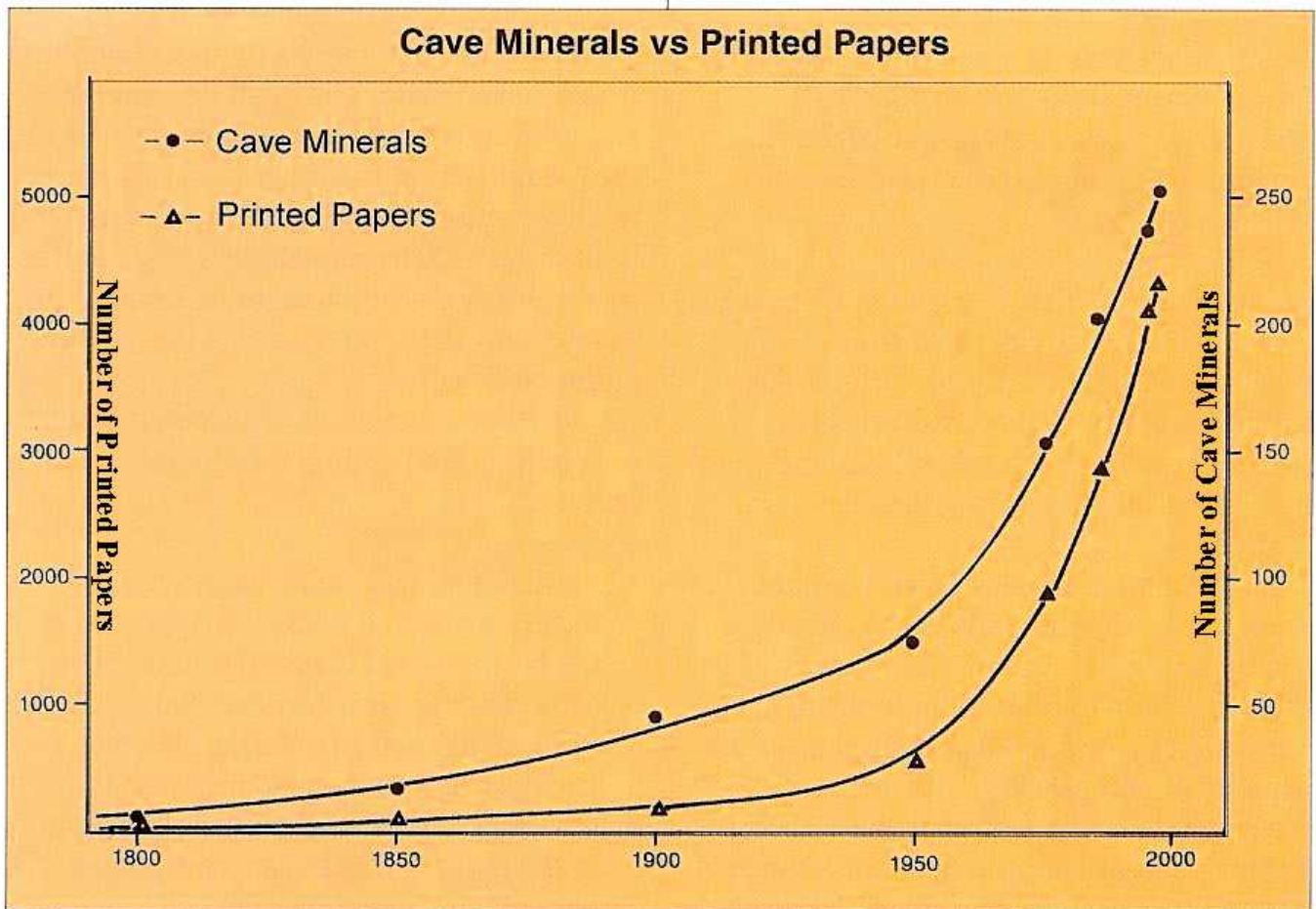


Figure 2. A cumulative graph showing the number of identified cave minerals and printed papers on cave mineralogy from 1800 to the present. Note how this explosion of knowledge has increased almost exponentially with time. From Hill and Forti (1997).

and the Italian printing house. This difficult situation led a very frustrated go-between with Paolo Forti on the European end of things to write to Carol Hill in July of 1986: “I am a University Professor, not a clerk of the NSS.” However, CMW1 did make it to Barcelona on time and sold well at the Congress. The prime objectives of this first CMW1 edition were to: (1) set a classification standard for the field of cave mineralogy, and (2) cover cave minerals and speleothems worldwide. The first edition, CMW1, contained over 3,000 references and was 238 pages long. It had a front (Fig. 3) and back colored cover and an insert section of 33 color plates. However, this endeavor so exhausted Carol and Paolo that neither of them planned to write another edition.

1994

In 1994 Paolo Forti, who was by now rested from writing CMW1, became convinced that there needed to be yet another edition of *Cave Minerals of the World* that would: (1) bring CMW1 up-to-date since 1986, (2) provide

a new format (reorganization) of the book, which would be more professional and easier to use, and (3) include the finest and most complete set of photographs of cave minerals/speleothems ever assembled. So Paolo, during the Workshop, Breakthroughs in Karst Geomicrobiology and Redox Geochemistry, held in Colorado Springs, Colorado in February of 1994, convinced a reluctant Carol that another edition was needed.

The job of doing *Cave Minerals of the World*, second edition (CMW2) turned out to be much easier than CMW1 due to the fact that the internet and e-mail now allowed us to work together in real time. Because of the time shift between Italy and New Mexico, Paolo’s updates could reach Carol by early afternoon, while Carol’s material could then reach Paolo by early the next morning, his time. This advancement in computer exchange of information also allowed Carol to more quickly edit Paolo’s “Fortian” writing (a hybrid of English-Italian) into standard English. This time around the most difficult task was to obtain full information on cave mineral research in Eastern European

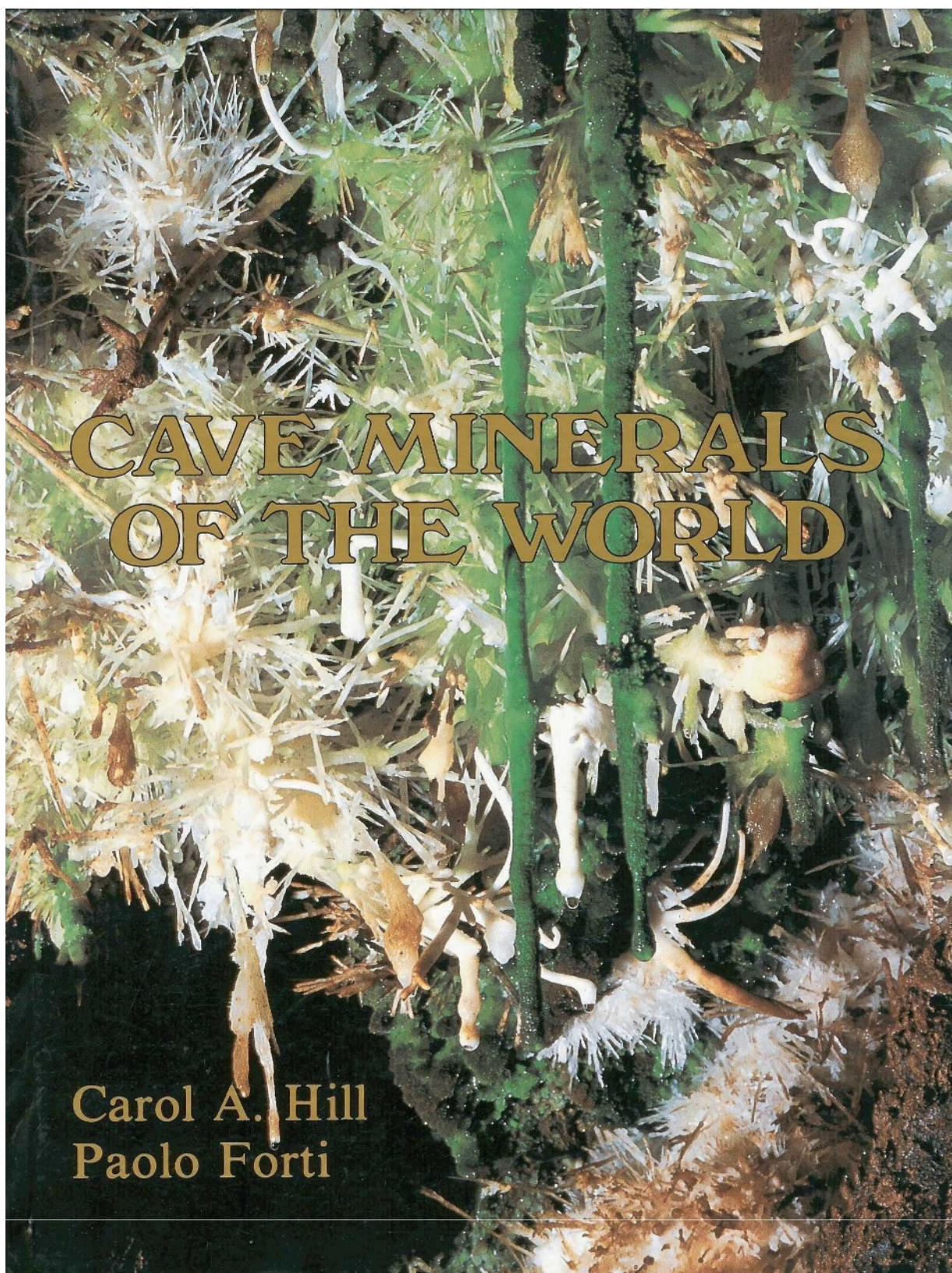


Figure 3. Front cover of *Cave Minerals of the World*, first edition, published by the NSS in 1986. This first edition of CMW1 had color front and back covers and an inset series of 33 color plates.

countries, which had been under-represented in CMW1 because of the adverse political conditions there in the early 1980s. Over a two-year time period, Paolo was obliged to fly to Russia (three times), Bulgaria (two times), Romania, Slovenia, and the Czech Republic besides traveling to Spain, France, Switzerland, and Austria. During these trips over 10,000 slides were selected and over 200 hours of discussion were spent by Paolo with local cavers and scientists. Truly, this book had now become *Cave Minerals of the World*.

In the summer of 1996, another rush trip was made by Paolo to the Hill house in Albuquerque (on this visit, the time was so short that not even a walk in the garden was permitted) in order to select all of the photographs for CMW2 and to finalize the manuscript. From Albuquerque, Paolo and Carol drove by car to the NSS Convention in Salida, Colorado, where all of the material for CMW2 was given to David McClurg, chair of the Special Publications Committee. This time CMW2 would be printed in the United States under David's direct scrutiny.

1997

The second edition of *Cave Minerals of the World* (CMW2) arrived at the 1997 11th International Congress of Speleology in La Chaux de Fonds, Switzerland on time, due mainly to the Herculean effort of David McClurg. At the Swiss Congress CMW2 won the UIS award for Best Cave Book for the previous four years (since the Hungarian Congress). The second edition of *Cave Minerals of the World* is 463 pages long and has 28 co-authors of the Special Topic and Top Ten Caves sections, over and above the contributions of authors Hill and Forti and again-co-author Trevor Shaw (Fig. 4). CMW2 was published by the NSS in *full* color, including the back and front covers (Fig. 5) and 333 color photos and figures. It also includes more than 5,000 references, which essentially did in both Carol and Paolo. The authors now consider their work to finally be *complete* and anticipate writing no further editions. And, as a positive assurance of that, after publication of CMW2, Carol Hill mailed all of her *Cave Minerals of the World* material to Paolo Forti at his Institute of Speleology in Bologna, where it now resides for all to access.

PRESENT

In the decade since CMW2 was published by the NSS, the book has had a great impact among cavers and scientists, as testified by the fact that it is the speleological book which has obtained the highest number of citations in both speleological and non-speleological papers. The names and related properties of the main speleothem types and subtypes have been definitively standardized. The book has also been important in increasing the number of scientists involved in cave mineral research all over the world, whereas before this time such research was limited

to a dozen or so persons working in relatively few countries. As a consequence of the NSS publishing this series of three books, new minerogenetic processes are now understood and new minerals for science have been described. And happily, the fear of the NSS in the early 1970s, that the book would promote vandalism, has not been realized. Rather, the publication of the *Cave Mineral* book series has helped to educate the public as to the importance of conserving cave minerals and speleothems. Finally, the book has been essential in making all people aware of the beauty and fragility of the cave environment and its need for protection.

FUTURE

The authors recognize that CMW2 is not the final word in cave mineralogy, but that this science will evolve and be carried on by a new generation of speleologists. As a way of promoting that future, the authors will attempt to identify three areas of future research that they feel are promising for advancing the field of cave mineralogy.

PALEO-ENVIRONMENTS/PALEOCLIMATOLOGY

One of the most important future areas of research in cave mineralogy is the study of paleoclimate and paleo-environment as it relates to the current concern over global warming. An excellent overview paper concerning the dating of calcite speleothems and its application to paleo-environments is by Derek Ford (1997), who has been one of the pioneers and leaders in this field for the last three decades. However, while up to the present calcite and aragonite speleothems have been used almost exclusively for such analyses, in the last few years other cave minerals have begun to be used to determine paleo-environments, minerals such as elemental sulfur as an indicator of high hydrogen sulfide concentration, or opal substituting for calcite as an indicator of rainfall increase over time. An explosion of interest is expected toward the hundreds of different cave minerals whose deposition in caves is controlled by boundary conditions, which in turn are related to the environment or paleo-environment.

The application of speleothems to paleoclimate studies not only involves dating. It also involves determining stable isotope, trace-element, color-banding, and luminescent analyses and profiles of these speleothems (White, 2007). Especially important to the problem of global warming are paleoclimate studies done on Holocene-age speleothems, such as was done by Polyak et al. (2001), who depicted changes in climate over the last 3,200 years from studying mites preserved in stalagmites from Hidden Cave, New Mexico. The presence of these mites, encased in travertine that was dated by the uranium-series method, implies that a wetter and cooler climate existed 3,200 years ago than is present today in the Guadalupe Mountains.



Figure 4. Paolo Forti and Carol Hill autographing copies of their updated second edition of *Cave Minerals of the World*, which made its debut at the International Congress of Speleology in La Chaux de Fonds, Switzerland, in the summer of 1997. Many of the 28 co-authors of CMW2 were at the Congress and formed a long line of book autographers along side of Carol and Paolo.

MICROBIOLOGY

Another field where it is anticipated that research will develop substantially is the inter-relationship between microbiology and cave mineralogy. Microorganisms (mainly bacteria) are responsible for many, if not most, of the low enthalpy processes leading to the deposition of cave minerals (Forti, 2002; Contos, 2001). Such studies, most of which are only a few decades or less old, also have economic importance because they reflect the same mechanisms that cause the mobilization and/or re-deposition of ore bodies in chemoautotrophic environments (Onac et al., 2001). Biominerals, such as form in caves, may also have application to industry and medicine.

One of the most important areas of future research with respect to microbiology-cave mineralogy is that of proving biogenicity, that is, catching microbes in the act of forming minerals. This proves to be a very difficult task, as the products of microbial precipitation often mimic those formed during inorganic processes (Barton et al., 2001;

Jones, 2001). And just because fossilized microbes exist in speleothems does not necessarily mean that they played active roles in the precipitation of that speleothem. Even when dealing with living microbes, proving biogenicity is difficult because biogenic mineral production cannot be verified with culturing techniques alone. As discussed by Northup (2006), a process called molecular phylogeny must be used whereby extracting and analyzing DNA provides a genetic tree that can help identify the role that microorganisms play in the creation of mineral deposits. These results can then guide microbial culturing efforts to more closely study the actual mineral production by microorganisms. Such studies are on the forefront of knowledge in understanding the dual organic-inorganic reactions involving the precipitation of cave minerals and speleothems.

MINERALS ONTOGENY

Cave Minerals of the World, like Dana's classic *Manual of Mineralogy*, is mainly a *descriptive* work, one that



Figure 5. Front cover of *Cave Minerals of the World*, second edition, published by the NSS in 1997. This second edition was in full color, containing 333 color photographs and figures as well as color front and back covers.

describes what a speleothem or cave mineral looks like. One of the most important futures of cave mineralogy lies in the subject of minerals ontogeny, which studies the growth of speleothems and cave minerals from a *genetic* perspective rather than from a descriptive perspective. Ontogeny of cave minerals as a scientific study has been developed in Russia, but is poorly understood in the West. As a first step in bringing this subject to the general attention of speleologists and cavers, Charles Self and Carol Hill published an introduction to minerals ontogeny in the August, 2003 issue of the NSS's *Journal of Caves and Karst Studies* (Self and Hill, 2003). This paper introduced the basic principles of minerals ontogeny and explained a hierarchy scheme whereby mineral bodies can be studied as crystal *individuals*, *aggregates* of individuals, associations of aggregates (termed *koras* by the Russians), and as sequences of koras (*ensembles*). However, ontogeny is not simply a new classification system for minerals. It is a method by which past crystallization environments can be deciphered from the mineral bodies themselves. (For example, needles in frostwork-type speleothems never touch each other because of the type of selection encountered within a capillary film environment.) The structure and texture of mineral bodies can be directly related to environmental factors, and speleothems in caves prove to be ideal subjects for this type of study.

In September, 2005, at the Athens-Kalamos, Greece, International Congress of Speleology, the UIS Commission on Cave Mineralogy formed a sub-committee composed of Charles Self (chair) of Great Britain, Bogdan Onac of Romania, Kyung Sik Woo of Korea, and William White and Carol Hill of the United States, to further investigate and promote the subject of minerals ontogeny. As of this writing, Will White is composing a paper for publication entitled: "Speleothem microstructure/speleothem ontogeny: A comparison of crystal growth concepts between Western and Russian conceptual frameworks and between mineralogy, ceramics, metallurgy, and semiconductor technology." Perhaps these endeavors in minerals ontogeny will turn into the subject of another cave mineralogy-related book that the NSS will publish sometime in the future.

CONCLUSION

The National Speleological Society is to be commended on its 65 years of protecting the cave environment, and specifically the speleothems and cave minerals within that environment. The authors especially thank the NSS for disseminating the wonderful and beautiful world of cave minerals to cavers and the public alike through their books *Cave Minerals* and *Cave Minerals of the World*.

ACKNOWLEDGMENTS

The authors thank Will White for his contributions to the past history and paleo-environment sections, and

Penny Boston and Diana Northup for their contribution to the microbiology section. The authors would also like to thank these photographers for the cover photographs: Pete Lindsley (Fig. 1), Philippe Crochet (Figure 3), Dave Bunnell (Figure 4), and Patrick Cabrol (Figure 5).

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