Bulletin of the Mineralogical Society of Southern California

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The 803rd Meeting of The Mineralogical Society of Southern California

" Pseudomorphs: Mendacious Minerals That We Love"

by Si Frazier

Saturday evening, January 22, 2005

To be presented at the Oak Tree Room, 1150 East Colorado Blvd., Arcadia. Happy hour at 5:30 and Dinner at 6:30 to be followed by show awards and program.
Reservations required. See details inside.

Inside this bulletin

Annual Banquet Festivities to Feature Talk on

Pseudomorphs

by Si Frazier

The Annual MSSC Banquet and installation of officers will take place on Saturday evening, January 22, 2005 at the Oak Tree Room (next to Coco's), 1150 East Colorado Blvd., Arcadia at the SE corner of Colorado Blvd. and Michelinda.

Festivities begin at the 5:30 Happy Hour with a no host bar serving wine and beer. Dinner follows at 6:30 with a buffet featuring prime rib, salmon, and chicken with all the trimmings and desert. The cost for the complete meal, tax, and tip is $30. ***Reservations are imperative!*** Make reservations with Walt Margerum ***no later than January 15th*** by phone (310-324-1976) or email. Payment may be made at the door by cash or check, or checks may be mailed in advance to MSSC Treasurer, PO Box 41027, Pasadena, CA 91114-8027.

Our speaker for the evening will be Si Frazier. His topic is ***"Pseudomorphs: Mendacious Minerals That We Love."*** Si has been closely involved in the worlds of geology, mineralogy, and gemstones for more than four decades. He studied geology with an emphasis on mineralogy and petrology at the University of California at Berkeley. He and his wife, Ann, have collected minerals and gems extensively and owned Frazier's Minerals and Lapidary in Berkeley from 1965-1981. After closing the shop, they have divided their time between writing, teaching, traveling for their business, and displaying at gem and mineral shows.

They have written for both rock hound magazines and professional publications. Si has taught geology, mineralogy, petrology, geology of ore deposits, and gemology at San Francisco State University and occasional courses related to gemstones and minerals at San Francisco City College, College of Marin, University of California at Berkeley Extension, the Revere Academy of Jewelry Arts, and Oakland Technical High School.

Si and Ann have long worked as a team, both in teaching and in writing. Their business currently specializes in fine minerals, gems, carvings from Idar-Oberstein, and antiquarian books.

They are now engaged in writing a massive work on the mineral and the gem quartz, the most abundant and prominent mineral species in the Earth's crust. Their article in this bulletin is a supplement to the banquet program.

MSSC Board Meeting to be held on Sunday, January 23

The first board meeting of 2005 will be held at the home of Janet Gordon at 1:00 p.m. on January 23. This meeting is traditionally attended by members of both the incoming and outgoing boards. All society members are welcome to attend, as well. Lunch will be served, so the favor of a reply is requested. Please contact

Janet.

Minutes of the December Meeting

The 802nd meeting of the Mineralogical Society of Southern California was held on Friday, December 11th in the Geology department at Pasadena City College. Vice President James Kusely brought the meeting to order at 7:32pm.

The speaker for December was Dr. Andrea Donnellan. Dr. Donnellan, a geophysicist from JPL, who discussed the use of GPS and InSAR to observe the active deformation of southern California to better predict earthquakes in the future. Earthquake damage is dependant upon the location and size of the earthquake, if the earthquake can be predicted it would aid in the mitigation of the damage. It was a fascinating talk that also included captivating simulations and animations. The subject matter was of great interest to the members, who are residents of the southern California area and of course ‘Earthquake Country’.

After the talk there was a brief reminder regarding the January banquet. The January banquet will be Saturday, January 22nd and the evening’s speaker will be Si Frazier. At 8:40pm the meeting was brought to a close.
Respectfully submitted by Ilia Lyles, Secretary

Dues are Due

Just a reminder that your 2005 dues are due. If you have not yet paid, please send them to me by January 31, 2005, or you will be delinquent. Thank you for your cooperation. The address is in the front of the Bulletin.

Walt Margerum, Treasurer

Richard A. Bideaux

A giant in the mineral community left us when Dick Bideaux passed away on October 21, 2004. The Tucson Gem and Mineral Society is honoring him by initiating the “Richard A. Bideaux Memorial Trophy” for the best Arizona mineral. MSSC members who would like to share memories of Dick Bideaux with others in the Society are invited to submit them to the editor.

Pseudomorphs: An Introduction

©by Si and Ann Frazier December 19, 2004

Introduction

Pseudomorphs are an interesting and important mineral collecting subdivision to which several MSSC members have made important contribution. Long-time member Keith Hershberger is widely known as a pseudomorph collector with a particularly deep knowledge.

Collecting pseudomorphs is fun on several scores. It is not such a cut and dried field as many of the other subdivisions of mineral collecting. For a variety of reasons it is much harder to spend huge sums of money for fine, important specimens than for esthetically pleasing crystals, crystal groups, or for gemstones. Perhaps more important, with a bit of knowledge and a keen eye there is always a possibility of turning up an important specimen on a field trip to the most picked-over site or from the offerings of the most abysmal dealer.

Our interest in pseudomorphs is an outgrowth of our interest in quartz. Not surprisingly, it is the most important, or at least the most frequent, if not the most attractive pseudomorphing material.

Below is some of the technical stuff that is really not suitable for inclusion in a lecture taking place after the audience has enjoyed dinner. Over the more than two centuries since they were first recognized and seriously investigated, there have been many definitions, descriptions, and classifications of pseudomorphs.

Definition of Pseudomorph

The term pseudomorph (French = *la pseudomorphose*) was coined by René

Just Haüy (1743-1822) in his epochal *Traité de Mineralogie* (1801, Vol. 1, 140). Haüy did not, however, use it in its present sense. As part of a general discussion about types of concretions he coined the term from the Greek *pseudo* (false) and *morph* (form) for mineral bodies that owed their outward form to circumstances other than their own unique powers of crystallization or formation. Most of the discussion was devoted to fossils, especially fossil shells and petrified wood. He also included at the end of the discussion, the comment "...bodies which have a false and deceitful figure" which "...present in a very remarkable manner foreign or strange forms which they have in some measure obtained from other bodies which had received them from nature (ibid.)." After considerable discussion of what we would now classify as fossils, he adds that, "The mineral kingdom also has its pseudomorphoses. We find some substances of this kingdom under crystalline forms which are only borrowed; and it is probable that, in some cases at least, the new substance has been substituted gradually for that which has ceded its place to it as we suppose takes place with respect to petrified wood (ibid.)."

He ends up by giving us a definition. After defining stalactites and incrustations as the two other forms of concretion, Haüy wrote that "the pseudomorphoses is a concretion endowed with a form foreign to its substance and for which it is indebted to its molocules filling a space formerly occupied by a body of the same form (ibid.)."

Other terms used in former times are *After-Kristalle* (F. J. A. Estner, 1794; Werner, as reported in 1811 by Hoffmann; and Breithaupt 1815) and *Supposititious* crystals (Jameson, 1816). It seems probable that Werner (1749-1817) coined the term *After-Kristalle* and first recognized the phenomenon, even though Estner first used it in print. Estner was both a pupil and great admirer of Werner. *After-Kristalle* obviously has precedence, but by the second half of the 19th century it had been supplanted almost completely by *pseudomorph*.

What is and what is not considered a pseudomorph

George Amadeus Carl Friedrich Naumann (1797-1873), an important pioneer European mineralogist and crystallographer, defined a pseudomorph (1846, 96) as a "crystalline or amorphous body that without itself being a crystal shows the crystal form of another mineral" [*so nennt man nämlich diejenigen krystallinischen oder amorphen Mineralkörper, welche ohne selbst Krystalle zu sein, die Krystallform eines anderen Minerals zeigen*]. That Naumann favored a more restrictive definition than that espoused by some of his colleagues, is shown by his remark (*ibid.)*, "The crystal forms of pseudomorphs are usually quite well preserved [*erhalten*] and easily recognized with sharp, well-formed faces [*DieseKrystallformen der Pseudomorphosen sind meist sehr wohl erhalten und leicht erkennbar, ja zuweilen ganz sharfkantig und glatt*]. (ibid.) In the same work he distinguished 1. *Umhüllung-Pseudomorphosen* 2. *Ausfüllungs-Pseudomorphosen* and 2. *Metasomatische Pseudomorphosen.*

Umhüllungs-Pseudomorphosen: literally wrapping around, enveloping, or encasing type pseudomorphs. It usually refers to the case where a crystal is encrusted by another mineral and then later the first crystal is dissolved away or partially dissolved away. This type of pseudomorph forms commonly as quartz after calcite. Often called perimorph (the new mineral is on the periphery of the first one).

Ausfüllungs-Pseudomorphosen: literally filling in or filling up type pseudomorphs.

Metasomatish-Pseudomorphosen (metasomatic pseudomorph). Metasomatism is a term primarily applied to ore deposits. “It is the process of practically simultaneous capillary solution and deposition by which a new mineral of partly or wholly different composition may grow in the body of an old mineral or mineral aggregate” (Bates and Jackson 1980, 394).

In common with Johann Reinhard Blum (1802-1883, the greatest 19th century expert on pseudomorphs, and other European authorities, Naumann further divided the first category in to *Umhüllings, Ausfüllungs,* and *Verdrängungs* (replacement) pseudomorphs.

Naumann and George Landgrebe (1802-1872) a German chemist and mineralogist who wrote a very influential book on pseudomorphs (1841), divided the second category *metasomatishe* into the following classes of pseudomorphs.

I. Formed by molding (*Abformung*)

A. Molding by being coated e.g., quartz encrusting calcite that then disappears.

B. By having the new mineral totally replace the original one (*Abforming durch Ausfülung*). e.g., the famous talc pseudomorphs after quartz crystals from Göpfersgrun, near Wunsiedel in Bavaria.

II. Formed by alteration (*durch Umwandlung*).

A. Alteration without gain or loss of new components (*Umwandlung ohne Abgabe oder Aufnahme von Stoffen*). e.g., aragonite altered to calcite

B. Alteration with the loss of a component (*Umwandlung mit Verlust von Bestandtheilen*). e.g., laumontites loss of water turning it into a crumbling powdery mess.

C. Alteration with the addition of components (*Umwandlung mit Aufname von Bestandtheilen*) e.g., anhydrite altered to gypsum.

D. Alteration with exchange of components (*Umwandlung mit Austausch* *von Stoffen*) e.g., feldspar altered to cassiterite.

As one can see from the above, the German language's penchant for sticking a number of unrelated words together to make a new jawbreaking noun, makes the original literature of pseudomorphs somewhat daunting, but trying to break them down is worthwhile even if one has no intention of trying to read the original literature. One should remember that in the "good old days," mineralogists writing in English generally had no choice but to try to translate pseudomorph terms from German into English.

Many other definitions, descriptions, and classifications of pseudomorphs have been offered over the years. The vast majority are written in German, a lesser number in French, and very few in English. Those written in English are primarily derived from German authors since during the 19th century particularly, virtually all acknowledged authorities on pseudomorphs wrote in German. Thus, the roots to our English terms applicable to pseudomorphs are derived from German language terms. The most notable exception is the term pseudomorph itself, which is derived from Greek, but first appeared in a French publication. Actually in the era when pseudomorphs were a hot academic topic, academicians of whatever linguistic bent favored trying to show off their knowledge of ancient Greek whenever possible. It was sort of an "in" thing.

Perhaps the best modern classification of pseudomorphs was written by Prof. Dr. Hugo Strunz in the German semi-professional mineralogy and geology journal *Der Aufschluss* (Sept. 1982, 313-342). The classification presented here is based on that of Dr. Strunz with a few additions based on the realities of mineral buying,, selling, and collecting. It is more inclusive than what we are generally encounter. This has the disadvantage that it is not as "bare bones" as we are used to, but it has the advantage that it includes areas and modern concepts that have attracted the attention of modern mineralogists. The collector, of course, is always free to keep or discard whatever parts he or she chooses.

Dr. Strunz recognized four basic types of pseudomorphs, some of which were not even thought of by the old boys.

1. Paramorphs, sometimes called transformation pseudomorphs. e.g., acanthite after argentite. He makes metamict a subcategory.

2. Exsolution pseudomorphs (*Entmischungs-Pseudomorph*) e.g., magnetite and rutile after ilmenite.

3. Replacement (*Verdangungs*) pseudomorphs. Here he has four subcategories.

a. giving up a component e.g., malachite after azurite

b. taking up a component e.g., talc after quartz

c. replacement (*austausch*) of a component e.g., limonite after pyrite or fluorite after calcite

d. exchange of all components e.g., native copper after aragonite

4. Perimorphs e.g., quartz after calcite

Modern Works in English

What is perhaps the most authoritative and recent (!) work on pseudomorphs published in the English language was written by Dr. Clifford Frondel of Harvard University in 1935. Dr. Frondel's remarks are as authoritative on pseudomorphs as any that we know of in English. It was based on an extensive study of pseudomorphs in the collections of the American Museum of Natural History in New York as well as a great familiarity with European works on pseudomorphs, (Frondel 1935, 389-426). The following comments by Prof. Frondel are extracted from this work.

"A pseudomorph is a mineral whose outward crystal form is that of another mineral species; it has developed by alteration, substitution, encrustation, or paramorphism. A pseudomorph is defined as a mineral which has the outward form proper to another species of mineral whose place it has taken through some agency. This precise use of the term would exclude the regular cavities left by the removal of a crystal from its matrix (*molds*), since these are voids and not solids, and would exclude those cases in which organic material has been replaced by quartz or some other mineral because the original substance is not a mineral." (Frondel 1935, 389)

According to Dr. Frondel, general usage does in fact include molds, mineralized fossils, and:

"1. Any mineral change in which the outlines of the original mineral are preserved whether this surface be a euhedral crystal form or the irregular bounding surface of an embedded grain or aggregate.

"2. Any mineral change which has been accomplished without change of volume, as evidenced by the undistorted preservation of an original texture or structure, whether this be the equal volume replacement of a single crystal or of a rock mass on a geologic scale. The condition of no volume change here carries with it a connotation of no change in the dimensions of the surface."

Frondel recommends that the definition of pseudomorph be extended so as to include "...any substance or structure of definite or characteristic form which is represented by another substance to which the form does not properly belong (ibid.)."

Perhaps the most useful recent definition is offered, not surprisingly, by John Sinkankas (1964, 85): "If a crystal changes chemically or structurally, yet keeps the shape of the original, it is called a *pseudomorph* or 'false form'; it looks like a crystal of one species but is composed of another."

A pseudomorph is described as being "after" the mineral whose outer form it has, e.g. quartz after fluorite (Bates, Robert L. and Julia A. Jackson 1980, 506). This convention was introduced by J. R. Blum, who assembled what is probably the world's most extensive pseudomorph collection in the world. It is now preserved in the basement of the Geology building at Yale. It is for the most part not very pretty to look at, but it is very, very important.

The late Dr. William Sanborn colorfully characterized pseudomorphs as "ghosts of crystals past (1976, 60)."

Early Works on Pseudomorphs

The earliest reference to what we would now call a pseudomorph was apparently in a privately printed, very rare descriptive mineralogy by Franz Joseph Anton Estner (1739-1803?), a German born Abbot and mineralogist resident in Vienna. It was "...designed both for the beginner and the lover of minerals" (Schuh, Curtis 1999, Vol. 2, 236). Schuh was able to locate only one copy of this work in a public library (University of Oklahoma). This great, three volume rarity was privately published in 1794 in Vienna by Estner under the title *Versuch einer Mineralogie für Anfänger und Liebhaber nach des Herrn Bergcommissionsraths Werner's Methode.* Estner was a student of and great admirer of Werner.

According to J. R. Blum (1843, 2), Estner in Vol. 1, 143-145 used the term *After-Kristalle*. Estner named crystals that had a different form than what their composition would dictate as "*After-Kristalle*" (Johs, Max 1981, 36-37). The term *After-Kristalle* apparently was used in the present sense of pseudomorph by Werner and taken up by his students, which in that era included a good percentage of the influential mineralogists in Europe. Werner's usage is often cited to 1811 because that is when Christian August Siegfried Hoffmann (1760-1813) started publishing his monumental four volume *Handbuch der Mineralogie.* Hoffmann was a keen student, and Werner was his mentor. Hoffmann "...accepts all of Werner's theories concerning mineral formation and classification" (Schuh, C, 1999, 490). It seems, therefore, fair to credit Werner with the term *After-Kristalle*. Werner had divided crystals into two categories:

1. *Wesentliche* (essential or true)

2. *After-Kristalle*

Johann August Breithaupt (1791-1873) was another famous pupil of Werner. He later had a 40-year career as a full professor of mineralogy at his alma mater, the mining academy at Freiberg. In 1815 he published *Über die Aechtheit der Kristalle* (Concerning the genuineness [*echtheit*] of crystals). This is the first monograph devoted to pseudomorphs.

The earliest systematic treatment of pseudomorphs in English was made by Wilhelm Karl von Haidinger in *Brewster's Edinburgh Journal* in Vols. IX and X (1828). It is not readily available.

In 1841 Dr. Georg Landgrebe (1802-1872) published *Über die Pseudomorphosen im Mineralreiche und verwandte Erscheinungen* in which he described many mineral pseudomorphs, as well as some specimens we would now call fossils.

The extended and exhaustive works of Johann Reinhard Blum (1802-1883), *Die Pseudomorphosen des Mineralireichs* (Stuttgart) appeared in 1843. He issued supplements in 1847, 1852, 1863, and 1879. In 1855 Gustav Georg Winkler (1820-1896) published a small monograph that summarizes the works of Blum, Haidinger, Landgrebe, and others and contains a large descriptive section.

For American collectors, probably the most influential of all classifications is that first proposed by Prof. James D. Dana (1813-1895) in the middle of the last century.

Dana's Classification of Pseudomorphs

For more than a century and a half, Americans have been particularly influenced by the first major scientific work published by a native-born American: *A System of Mineralogy* by James Dwight Dana (1837). In the first edition, he gives very brief treatment of pseudomorphs, but defines a pseudomorph as (41), "A pseudomorphous crystal, is one which possesses a form that is foreign to it, which it has received from some other cause, distinct from its own powers of crystallization." He also makes an observation that may not be appreciated by all pseudomorphs collectors (42), "Pseudomorphs crystals are distinguished, generally by their rounded angles, dull surfaces, destitution of cleavage joints and often granular composition. The surfaces are frequently drusy or covered with minute crystals. Occasionally, however, the resemblance to real [*sic*] crystals is so perfect, that they are distinguished with difficulty." The treatment remained essentially unchanged in the 2nd edition (1844).

In the 3rd edition (1850, 98-103) he summarized the previous descriptive work on pseudomorphs and compiled a list of the 82 pseudomorphs reported to that time. This work seems to be the first important treatment of pseudomorphs by an American author. Dana's work has had great influence on how American collectors and writers conceptualize pseudomorphs. Note that the categories are somewhat different and less inclusive than Dr. Strunz's. In the 4th edition (1854, 223) Dana formalized as follows:

1. **Pseudomorphs by alteration:** Those that formed by the gradual change of composition in a species, e.g., change of augite to steatite, or azurite to malachite.

2. **Pseudomorphs by substitution:** Those that formed by the replacement of a mineral which has been removed or is gradually undergoing removal, e.g., petrifaction of wood.

3. **Pseudomorphs by encrustation:** Those formed through the encrustation of a crystal which may have subsequently dissolved away; often the cavity afterwards is filled [or partially filled] by infiltration; e.g., change of fluorite to quartz [for a wonderful photograph of a pseudomorph of this type see page 166 of Peter Bancroft's *The World's Finest Minerals* (1973)].

4. **Pseudomorphs by paramorphism:** Those formed when a mineral passes from one [dimorphous] state to another e.g., change of aragonite to calcite or [beta quartz to alpha quartz].

5. **Perimorph:** Not to be confused with paramorph. A perimorph is a special type of pseudomorph which is formed when one mineral is encrusted by another, and then the original mineral is leached out leaving a hollow shell in the form of the original mineral. Epimorphs are a special case of a perimorph. L.P. Gratacap in his *Popular Guide to Minerals* (1912, 63) defines an epimorph as "a pseudomorph formed by encrustation as when quartz coats calcite, concealing the covered mineral completely though assuming the crystalline form of the calcite. Such phases of pseudomorphism are called epimorphs.

Some authors specify that an epimorph is a *thin* coating as when a pyrite crystal is altered on the surface to limonite. Some authorities quite rightly object to the term perimorph because it phonetically is too close to paramorph and, heavens knows, the whole subject of pseudomorphs is confusing enough as it is.

Dana in the 4th edition (1854, 222-240) has a detailed discussion of pseudomorphs and how they form. He gives a classification and an exhaustive (86!) list of pseudomorphs known at that time. For some reason this valuable section was dropped from later editions.

Modern Works on Pseudomorphs

The most extensive modern work on pseudomorphs, from a collector's point of view, is the November, 1981, issue of the German mineral collectors magazine *Lapis*. The entire issue was devoted to pseudomorphs with articles by various European authorities. This is now a sought after collector's item. A delightful short chapter on pseudomorphs appeared in the late Dr. William Sanborn's popular book *Oddities of the Mineral World* (1976, 60-70).

Unfortunately for American readers, the study of pseudomorphs has been most strongly pursued by authors who wrote in German, and the literature reflects that fact. The best modern discussion and classification of pseudomorphs is a long article by Prof. Dr. Hugo Strunz (1982, 313-343). The classification scheme presented in this paper is based on Strunz's article.

Classification of Pseudomorphs

Different authors at different times and in different languages have offered not only many different definitions and descriptions but also many schemes of classification. A classificatory system can be very helpful not just for organizing a collection of specimens but for appreciating relationships among them. Unfortunately there is no single, well agreed upon, classificatory scheme for pseudomorphs although the one by Dana has been particularly influential among American authors. To our minds the best, most modern, most inclusive, and useful is the one published by Prof. Hugo Strunz in 1982. In the opinion of many, this is the best general paper on pseudomorphs published in post W.W.II times. We believe that this classificatory scheme is particularly well suited to the modern collector.

We offer here an outline of nine categories into which pseudomorphs might be divided. These categories are basically those of Prof. Strunz, with a few additions. Included are, in the interest of comprehensiveness, certain mineralogical phenomena which are included in only a few of the many classifications of pseudomorphs published over the years. In any classificatory endeavor whether it be natural history subjects, great baseball players, postage stamps, or any other attempt to bring order to a diverse group or collection, there is a natural tension between “lumpers” and “splitters.” Some collectors and some scientists may be inclined to broader and others to more restricted categories. We have tried to make our categories cover as broad a range as possible, working under the premise that the curator, collector, or scientist can always discard any that he or she feels do not belong or do not fit their purposes. We have tried to arrange our categories from simple to more complex.

Additions, corrections, and suggestions would be very welcome. This list was initially compiled to organize the information about quartz pseudomorphs to be included in a book on quartz. Various classifications previously proposed have much to recommend them, but we like the one proposed by Dr. Strunz, one of Europe’s most distinguished mineralogists, because it has the advantage of proceeding in logical steps from simple to more complex. In considering quartz pseudomorphs (by far the most abundant and diverse ones) it seems to work quite well. Some pseudomorph fans may be thrown a bit by the inclusion of categories which do not often appear in more traditional classifications. The inclusion of metamict, patina, *Narben*, epimorphs, and polyhedroids are particularly likely to raise some eyebrows, but they are included in the interest of comprehensiveness.

Categories I through VIII are, with the exception of Category VII, based on the paper on pseudomorphs by Prof. Strunz. Category IX is our own invention based on the cynicism generated by being in the mineral business for a half century. Category VII is also added to Professor Strunz’s in the interest of completeness and in acknowledgment of the fact that the term pseudomorph, coined in 1801 by the Abbé René Just Haüy, referred mainly to fossils, more importantly to plant and animal fossils than to pseudomorphs *sensu strictu* as we now use the term.

Categories of Pseudomorphs

I. Paramorphs.

A. Enantiotropic (reversible) e.g., alpha to beta quartz.

B. Monotropic (irreversible) e.g., diamond to graphite.

II. Metamict.

III. Exsolution pseudomorphs.

IV. Alteration pseudomorphs. (processes involving chemical reactions). Note that these are very similar to those used by Landgrebe, Blum and other European authors a century and a half ago.

A. Loss of a constituent.

B. Gain of a constituent.

C. Partial exchange of constituents.

D. Patinas and other surface alterations primarily of artifacts.

V. Replacement pseudomorphs. The process involves complete or partial solution and chemical precipitation of a new substance.

A. Replacement of petrified wood.

B. Infiltration (partial replacement).

VI. Encrustation pseudomorphs (Perimorphs).

A. Epimorphs.
B. Perimorphs *sensu strictu,* e.g., hydrocerussite on WWI lead bullets.
C. *Narben* -scars left by now vanished crystals on the surfaces of host crystals e.g., the scars left by now vanished fluorite crystals on some smoky quartz crystals from the Alps.
D. Molds.

VII. Fossils.

A. Petrifactions.
B. Molds (of animals or plants).
C. Casts.

VIII. Complex combinations of the above.

There is very little in the natural world that is actually totally simple and straight forward. This category is for those more interesting cases where more than one process is involved.

IX. Unknown, obscure, fake, and/or highly controversial.

A. Selling: Geochemical reality is often strained, stretched, or completely ruptured in the process of trying to sell a rock.
B. Buying: Credulity can be a deadly sin from the point of view of your economic well-being.

Types of pseudomorphs

The terminology of different types of pesudomorphs presents many problems. Since the vast majority of the important scientific work on pseudomorphs has been done by Germans, the literature is full of long, unwieldy nouns. The result is bad enough in German, but when different authors have translated them into English, the result often borders on chaos. We have attempted to collect and describe the most important of these terms and to sort out the synonyms.

I. Paramorphs

Paramorphs are the result of polymorphism. Polymorphism is the existence of a chemical compound or element in two or more crystal structures. Carbon as diamond or graphite, and now, as “bucky balls”, (see *Scientific American*, October, 1991, 54-63), is a familiar example. A mineral material called cliftonite found in certain meteorites is graphite pseudomorphing diamond, Alpha (low temperature) quartz pseudomorphs (paramorphs) after beta (high temperature) quartz are well known.

If two forms are possible, they are dimorphs. If there are three forms they are trimorphs and so on. Rutile, anatase and brookite are trimorphs of titanium dioxide Ti02 and kyanite, sillimanite, and andalusite are trimorphs of aluminum silicate (Al2Si05).

Paramorphs have also been called transformation pseudomorphs (H. Strunz, 1982, 315), inversion pseudomorphs (W. Wise p.c. Feb., 1983) and *Umlagerungspseudomorphosen* (R. Metz, 1964, 113). H. Strunz (ibid.) rejects this latter usage.

There are two broad categories of paramorphs:

A. Enantiotropic (reversible) e.g. alpha quartz after beta quartz. If alpha quartz is heated to over 573^{o}C. then it inverts to beta quartz; when cooled below 573^{o} it reverts back into alpha quartz.

B. Monotropic (irreversible) e.g. graphite after diamond or low (alpha) quartz after stishovite, coesite, or tridymite. DeBeers would be most upset if the diamond to graphite inversion was found to be enantiotropic!

The first (A) involves only minor changes in the crystal lattice. The second (B) is characterized by substantial reorganization of the constituent atoms. Therefore, the first is reversible and the second is essentially irreversible.

II. Metamict, e.g., low zircon after high zircon

Metamict crystals are not traditionally classified among pseudomorphs, but some authors do include them including H. Strunz (l982, 315).

A metamict mineral is one that, although originally crystalline, has had its crystal structure damaged by the type of radiation known as alpha particles. Alpha particles consist of two protons and two neutrons making them identical to the nucleus of a helium atom. They do not have much penetrating power, but like a 300 pound tackle they can do a lot of damage in the short distance they travel. They can turn a crystal which was originally crystalline with the properties characteristic of its crystal structure and composition, into an opaque amorphous mass with much lower properties such as refractive index and specific gravity than possessed by the original crystal. Even a small amount of structural damage by alpha particles can change the physical and optical properties of the host crystal. There are at least 50 minerals known to occur in a metamict state.

The best known example is the gem mineral zircon, a tetragonal zirconium silicate that sometimes incorporates small amounts of uranium and/or thorium into its structure. The gem trade refers to clear sparkly zircon gems with a high index of refraction and significant double refraction as “high” zircon. Faceted gems of colorless “high” zircon have so much sparkle and dispersion that they have often been misrepresented to the ignorant or unwary as diamond. Zircons with some radiation damage are not clear and have lower refractive indices and dispersion. The radiation damage to the crystal lattice can often be repaired with careful heating. This was discovered long ago by “primitive” natives in Sri Lanka and on the Burma-Thailand border long before European scientists unraveled the differences between “low” and “high” zircon. The natives became highly proficient in improving zircon gems by use of their cooking stoves.

III. Exsolution pseudomorphs

Also called *Entmischung-Pseudomorphosen.* These were not known to the early giants of the study of pseudomorphs such as Blum, Scheerer, Landgrebe, etc. The first exsolution pseudomorph was described by A. Pelikan in 1902. He discovered that some “ilmenite” crystals were actually rutile (titanium oxide) and magnetite (iron oxide) that had separated out of homogeneous ilmenite (iron titanium oxide) which had formed at higher temperatures. The crystals became unstable and separated into laths of rutile and magnetite as the crystal slowly cooled. The study of exsolution pseudomorphs has become very important in recent years in the study of ore deposits.

IV. Alteration pseudomorphs (processes involving chemical reactions). These are the classical pseudomorphs after which collectors hunger.

A. Loss of a constituent, e.g. copper after cuprite or azurite
B. Gain of a constituent, e.g. malachite after cuprite, gypsum after anhydrite
C. Partial exchange of constituents, e.g. goethite after pyrite, galena after pyromorphite
D. Total replacement, e.g. quartz after calcite, barite, or fluorite
E. Patinas and other alterations of artifacts. e.g. the Statue of Liberty whose mineralogy has been carefully studied by Dr. Kurt Nassau, and found to be a complex mixture of mostly rare secondary copper minerals.

V. Replacement pseudomorphs (replacement without chemical reaction- process involves only solution, then precipitation)

A. Infiltration, e.g. silicified wood such as the huge petrified logs in the Petrified Forest in Arizona. The silicification of wood has traditionally been described as a process where silica replaces the substance of the wood. Recently a young German scientist, Michael Landmesser has convincingly demonstrated that the silica does **not replace** the woody substance but only infills all of the pore space. His ideas are summarized in English in an article in the *Lapidary Journal* (Frazier, Si and Ann Frazier, 1996). The original work was published in an *Extra Lapis* in 1994 that was devoted to petrified wood.
B. Replacement, e.g. native copper after aragonite from Corocoro, Bolivia

VI. Encrustation pseudomorphs (perimorphs) and (epimorphs)

A. "Pseudomorphs, epimorphs, perimorphs. Molecules of a crystal can be replaced by molecules of another material without altering the form of the crystal. Thus, a crystal of pyrite may be changed to limonite. If the change is more or less complete, a pseudomorph of one mineral has been formed on the original mineral; if the change is superficial, as for example, when only the periphery of the pyrite crystal has been change to limonite, an *epimorph* of limonite has been formed on the pyrite. If a crystal of one mineral is encrusted by another, and the original mineral is later leached out, a *perimorph* is formed" (Cissarz, Arnold and William R. Jones 1931, 111). There is much confusion in the literature and even on museum labels between epimorphs and perimorphs.
B. Perimorphs *sensu strictu*: where an original mineral is encrusted by a second and then the first mineral is leached away leaving a hollow shell in the form of the original mineral. They have also been called encrustation pseudomorphs or *Umhullungspseudomorphosen.*
C. *Narben:* In German *die Narbe* means scar. Swiss mineralogists use the term for the scars or impressions left by a now vanished minerals on the

faces of another crystal. The most famous examples are smoky quartz crystals from Switzerland that show the impressions of now vanished fluorite crystals.

D. Molds and casts including polyhedroids. Polyhedroids (also called box quartz, *rectanulos* (Port.), lattice quartz, *Polygonachat* (Ger.), quartz interstices, *Polyedrische Quarz Drusen* (Ger.), *Pseudoachat* (Ger.), *Phantomachat* (Ger.), radiate bladed quartz, geometric geodes, box geodes, triangular agate, *polygonal umgrentzte Achate* (Ger.), pegmatite agates, quasi-crystals, angle-plated quartz, *Zwickelfülling* (Ger.) (*Zwickel* is a German term for space between crystals), *Catazeiras* (Port.), Paraiba agate, *Poly-Quarz* (Ger.), and *Poly-Hydrolite-Achat* (Ger.) have also been erroneously described as pseudomorphs after feldspar or calcite. Polyhedroid is the preferred term. They actually are silica infillings between now vanished, thin, flat plates of calcite that intersected at random angles. Dr. Fred Pough has suggested, perhaps with tongue-in- cheek, that they be called pseudo-pseudomorphs.

VII. Fossils

In 1801 Haüy coined the term pseudomorph to apply specifically to mineral replacements of plants and animals. Just how and when the term came to be used in its present sense is something we have not been able to discover. Suffice it to say that by the middle of the century before the last century, Haüy's term had been changed to essentially the modern sense.

VIII. Complex combinations of the above

Especially in ore deposits, the sequence of events can be quite complex. but unraveling that sequence can be quite valuable in understanding a particular deposit or prospecting for a new one.

IX. Unknown, obscure, fake and/or highly controversial

A cynic might suggest that how these are looked at is often influenced by whether one is selling or buying.

A. Unknown. Most pseudomorph labels should probably read "pseudomorph after undetermined mineral, possibly..."
B. Obscure. Another degree of A
C. Fake. A well-known recent example is the case of the lovely green pseudomorphs of an undetermined copper mineral after calcite pseudomorphs after glauberite from Camp Verde, Arizona. Well known mineral dealer Dave Shannon became suspicious of these and discovered that they are easily made by throwing one of the abundant calcite pseudos after glauberite from Camp Verde, Arizona into a bucket of copper sulfate solution. Unfortunately a number of these specimens changed hands for

significant sums before Dave blew the whistle. There are still certain dealers and collectors who refuse to recognize reality, however. Three years after Dave revealed this scam to the mineral world at Tucson, these attractive fakes were still changing hands for significant sums of money. Now some collectors regard them as collectibles being particularly fine examples of the art of fakery.

Recently some “calcite crystals replaced by chalcanthite” from France appeared at the booth of a prominent American mineral dealer. It appeared that the same process as that deciphered by Dave Shannon had been used. The bright green micro crystals coating the surfaces of the low quality calcite crystals were definitely not chalcanthite, but chalcanthite or commercial copper sulfate had possibly been used to make them.

D. Highly Controversial. Perhaps this is what makes pseudomorphs such fun. Identifying the present composition of a pseudomorph is pretty straight-forward. Identifying what the now vanished mineral(s) was (were) is deductive which is always fun and more often than not leads to more than one possibility.

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2005 Calendar of Events

Jan. 12, 2005 Bay Area Mineralogists will host an evening devoted to the Champion Mine, White Mountains, California. Mr. Bob Wallace, of ASM International (formerly American Society of Metals) will discuss his efforts leading to ASM designation of the Champion Mine as a historic site in 1995. We be treated to rare 8 mm color footage taken when the mine was in operation, along with the classic movie "Story of a Sparkplug" (US Bureau of Mines),and a videotape of some of the early volunteers recounting their experiences restoring the mine buildings. On display will be mineral specimens collected by BAM members at the Champion Mine over the years. It is rumored that some spectacular woodhouseite and rutile will be making an appearance. Meeting is at 8:00 pm in Geology Room (P-24), Foothill College, Los Altos Hills, CA.

Jan. 22, **MSSC Banquet!** At the Oak Tree Room, 1150 East Colorado Blvd., Arcadia., Happy hour at 5:30 and Dinner at 6:30 to be followed by show awards and a program. by Si Frazier. Reservations required.

Jan. 29-30,Redlands, Southern California Micro-Mineralogists, 39th Annual Pacific Micromount Conference, San Bernardino County Museum, 2024 Orange Tree, Museum Hours: Sat. 9 - 10; Sun. 9 - 1, Beverly Moreau (714) 577-8038.

Jan. 29-Feb. 12, Arizona Mineral & Fossil Show, Tucson, AZ at InnSuites Hotel, 475 N. Granada Ave.; Ramada Ltd., 665 N. Freeway; Clarion Hotel-Randolph Park, 102 N. Alverton; Smuggler's Inn, 6350 E. Speedway; Mineral & Fossil Marketplace, 1333 N. Oracle; www.mzexpos.com.

Feb. 10-13, The 51st Annual Tucson Gem and Mineral Show, Tucson Convention Center, Arizona.

Feb. 18-27, Indio, San Gorgonio Mineral & Gem Soc., Date Festival - Gem & Mineral Bldg #1, Riverside County Fair & Date Festival, 46-350 Arabia St.., Hours: !0:00 am - 10:00 pm, Bert Grisham (951) 849-1674.

April 22-23 Desert Symposium, Theme: Mining History of the Eastern Mojave Desert, Desert Studies Center, Zzyzx, CA, with field trip April 24-26. Dr. William Presch, CSU Fullerton, 714-278-2215.

Sept. 10-13, The weekend before the Denver Gem and Mineral Show, a mineral symposium on **"Agate and Other Forms of Cryptocrystalline Quartz"** will be held at the Colorado School of Mines campus in Golden, Colorado. The symposium will be, Sept. 10-11, with optional field trips on Sept. 12 and 13. The symposium is cosponsored by the Colorado Chapter of Friends of Mineralogy, the Colorado School of Mines Geology Museum, and the U.S. Geological Survey. It will include two days of talks on the mineralogy, origin, and worldwide occurrence of agate and other forms of cryptocrystalline quartz, a welcoming reception and tour of the Colorado School of Mines Geology Museum; a Saturday evening banquet; and information about self-guided field trips to Colorado mineral localities. Registration will be $40; Contact Friends of Mineralogy, Colorado Chapter, P.O. Box 5276, Golden CO, 80401-5276, to register or to be put on a mailing list for further information.