

January 2005 Mineral of the Month: Glauberite

Glauberite is something of a paradox among minerals, better known for specimens in which it is *not* present, than for those in which it is. In other words, glauberite is one of the Mineral Kingdom's most widely pseudomorphed species, as the write-up will explain. We'll also talk about the former Mineral of the Month Club.

PHYSICAL PROPERTIES

Chemistry: $\text{Na}_2\text{Ca}(\text{SO}_4)_2$ Sodium Calcium Sulfate

Class: Sulfates

Sub-Group: Anhydrous Sulfates

Group: Glauberite

Crystal System: Monoclinic

Crystal Habits: Tabular or prismatic; steeply inclined, wedge-to-tabular-shaped dipyrnidal crystals, sometimes with rounded edges; striated on several faces; pseudomorphic replacement common; also forms epimorphic crystals, in which a second mineral encrusts the original glauberite crystals which then dissolve away to leave hollow, outer shells.

Color: Colorless in unaltered crystals; altered or partially altered crystals yellowish or grayish, often white due to a powdery, efflorescent coating that forms upon prolonged exposure to dry air.

Luster: Vitreous when free of efflorescent coating

Transparency: Transparent to translucent; unaltered crystals usually transparent

Streak: White

Refractive Index: 1.51-1.53

Cleavage: Perfect in one direction

Fracture: Very brittle, producing small conchoidal fragments

Hardness: 2.5-3.0

Specific Gravity: 2.7-2.8

Luminescence: None

Distinctive Features and Tests: Occurrence in evaporate deposits and association with such minerals as halite (sodium chloride, NaCl), calcite (calcium carbonate, CaCO_3), thenardite (sodium sulfate, Na_2SO_4), gypsum (hydrous calcium sulfate, $\text{CaSO}_4 \cdot \text{H}_2\text{O}$). Sometimes confused with halite and calcite, but glauberite lacks halite's pronounced cubic shape and dissolves more slowly in water. Glauberite is also softer than calcite and has a bitter, salty taste.

Dana Classification Number: 28.4.2.1

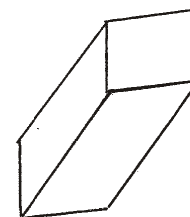


Figure 1. Glauberite crystal.

NAME

Correctly pronounced "GLAU-ber-ite" (the first syllable rhymes with "cow"), this month's mineral is named after German alchemist and chemist Johann Rudolf Glauber (1604-1668). Glauberite has also been called "glauberit" and "white Glauber's salt."

COMPOSITION

From its chemical formula, $[(\text{Na}_2\text{Ca}(\text{SO}_4)_2)]$, it is apparent that glauberite contains the elements sodium (Na), calcium (Ca), sulfur (S), and oxygen (O). Glauberite's molecular weight consists of 16.53 percent sodium, 14.41 percent calcium, 23.05 percent sulfur, and 46.01 percent oxygen. Within the glauberite molecule, the combined 4+ charge of the sodium (Na^{1+}) and calcium (Ca^{2+}) cations balances the 4- charge of the two sulfate (SO_4^{2-}) anions.

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Sulfates are compounds of oxygen and sulfur combined with one or more metals. Most sulfates are complex minerals because of many ways that the sulfate ions can accommodate the metal cations within the crystal lattice. Of the nearly 200 sulfate minerals that have been named, many are rare. Many others are hydrated minerals with attached water molecules. Glauberite is a good example of sulfate complexity, with its double sulfate anion accommodating two sodium atoms and one calcium atom. Sulfate minerals we have featured in the past include anhydrite (June 1998), thenardite (August 1999), jarosite (November 2000), celestite (December 2000), gypsum (May 2001), and barite (January 2002).

In sulfates, oxygen and sulfur combine to form the sulfate ion (SO_4^{2-}), in which four oxygen atoms located at the corners of a tetrahedron surround the sulfur atom. The two excess negative charges are distributed evenly over the oxygen atoms. Although the sulfur and oxygen atoms are held together by strong, electron-sharing covalent bonds, the sulfate ion itself, with its evenly distributed, double-negative charge, functions as an ionic structure that readily forms ionic bonds with positively charged metal ions. Ionic bonds are essentially electrostatic attractions between opposite charges. Not nearly as strong as covalent bonds, they are especially vulnerable to such dipolar solvents as water. Because of its significant solubility in water, glauberite usually exists only in arid climates. Even then, seasonal rainfall and snowmelt often provide enough water to dissolve glauberite into sodium, calcium, and sulfate ions.

Glauberite is sometimes called a “double salt,” since its molecule can be thought of as two individual salts ionically bound together. These salts are thenardite, or sodium sulfate (Na_2SO_4), formerly known as Glauber’s salt, and anhydrite, or calcium sulfate (CaSO_4). Note that combining these two formulas, Na_2SO_4 and CaSO_4 , produces the glauberite formula $\text{Na}_2\text{Ca}(\text{SO}_4)_2$. The glauberite crystal lattice is formed primarily by ionic bonding of layered, alternating molecules of thenardite and anhydrite, with the sodium and calcium cations ionically bound to adjacent sulfate ions. This bonding arrangement explains glauberite’s physical properties. Weak ionic bonding makes glauberite quite soft (Mohs 2.5-3.0). Also, the inter-layer ionic bonding accounts for glauberite’s one-directional, perfect cleavage. Finally, the dipolar action of water easily breaks glauberite’s ionic bonds to account for its solubility. This solubility is the key to both glauberite’s occurrence and its tendency to form pseudomorphs.

Glauberite is sedimentary in origin and mostly forms as an evaporite mineral in lacustrine (lake bed) deposits and to a lesser extent in marine (seabed) deposits. Lacustrine deposits form when surface water from rain or snowmelt drains into sinks, or intermittent lakes with no outlets. Sinks form only in arid climates where the incoming “feed” water flows on a seasonal cycle. This feed water is often rich in dissolved mineral salts such as sulfates, chlorides, carbonates, and borates. Sink water is lost only through evaporation, a process which concentrates the dissolved salts. When the resulting brines reach a saturation point, the dissolved minerals precipitate out of solution to crystallize on the lake bed. Sinks often evaporate completely during their annual seasonal cycles of replenishment and evaporation, causing complete precipitation and deposition of all dissolved mineral salts. Over repeated cycles and lengthy periods of time, strata of evaporite minerals are often highly concentrated and can attain a thickness of several hundred feet. Glauberite occurs in close association with such minerals as halite, or sodium chloride (NaCl); anhydrite, or calcium sulfate (CaSO_4); thenardite, or sodium sulfate (Na_2SO_4); and gypsum, or hydrous calcium sulfate ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). Although glauberite usually forms crystal clusters, lacustrine environments also promote the growth of “floaters”—well-developed, doubly-terminated, individual crystals that are not attached to any matrix.

Small amounts of glauberite occasionally occur in two other mineralogical environments. One is in low-temperature, low-pressure (epithermal) hydrothermal veins, where it precipitates from sulfate-rich solutions. The other is in basaltic vugs, where it forms when groundwater dissolves sulfur, sodium, and calcium from the mineral matrix. Under proper conditions, glauberite will precipitate out of solution to line basaltic cavities with glauberite crystals.

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Although taste is not often associated with minerals, in some cases it is a characteristic and even diagnostic feature. The sensation of taste is created when soluble compounds disassociate in solution into acidic or alkaline ions which act on the taste buds of the tongue. The most commonly “tasted” mineral is halite, or rock salt (sodium chloride, NaCl). But other minerals, most often of the halite, sulfate, and borate groups, also have distinctive tastes. Glauberite tastes bitter and salty. It is important to realize that “tasting” minerals should be done with caution, as some minerals are poisonous. The proper way to “taste” a mineral is to wet a finger, place the finger on the mineral, then place the tip of the finger briefly on the tongue so as to experience the taste while minimizing ingestion of the mineral itself. Generally, most halite, sulfate, and borate compounds of the alkaline earth elements sodium, potassium calcium, and lithium are nonpoisonous. Their tastes range from sweet-alkaline and alkaline to salty and bitter-salty. Remember that similar compounds of heavier metals, such as chalcantite, or hydrous copper sulfate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$), are poisonous and must never be tasted.

While solubility explains glauberite's occurrence as an evaporite mineral, it also limits its permanence in mineral environments. Solubility also explains why glauberite specimens do not keep well in moist environments. Water easily dissolves glauberite by breaking its ionic bonds, causing it to disassociate into its double-salt components, thenardite (Na_2SO_4) and anhydrite (CaSO_4). Upon disassociation, the anhydrite immediately hydrates, or joins with water molecules, to form gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). Subsequent variations in humidity levels can then cause the gypsum to give up its two water molecules and revert back to anhydrite. This conversion disrupts the surface of the crystal lattice to create a loose, efflorescent (literally “flower-like”) coating of anhydrite—a white powder that dulls the luster of the crystal faces.

PSEUDOMORPHS

Glauberite is something of a paradox among minerals, because it is better known for specimens in which it is *not* present, than in those in which it is present. In other words, glauberite is one of the Mineral Kingdom's most widely pseudomorphed species. Although glauberite is now somewhat rare, it was once much more common as evidenced by the abundance of pseudomorphic forms in localities where little or no glauberite now exists.

Pseudomorphs form when a different mineral replaces, alters, or coats a previously deposited mineral in a manner that precisely retains the original mineral's crystal shape. Derived from the Greek words *pseudēs*, meaning “false,” and *morphē*, or “form,” “pseudomorph” literally means “false form.” Our January minerals are classic pseudomorphs that are correctly described as gypsum-after-glauberite. Also found at this same locality is calcite and aragonite after glauberite. At other locations, quartz (silicon dioxide, SiO_2) and even opal (a hydrous, non-crystalline form of silica) also replace glauberite in pseudomorphs.

Mineral replacement which maintains original crystal shape occurs through both **paramorphism** and **pseudomorphism**. Paramorphism, the simpler manner of forming pseudomorphs, does not involve chemical change. Paramorphism occurs when a mineral changes its internal crystal structure, but retains both its original chemical composition and its external crystal shape. An example is calcite-after-aragonite. Both minerals are calcium carbonate (CaCO_3), but calcite crystallizes in the trigonal system, while aragonite crystallizes in the orthorhombic system. The resulting calcite-after-aragonite paramorph consists of calcite in the orthorhombic crystal shape of aragonite.

Pseudomorphism, on the other hand, involves chemical change in which an original mineral is removed and replaced by a second mineral of a different chemical composition. Pseudomorphism can occur by substitution, alteration, or incrustation. **Pseudomorphism by substitution** occurs when a new mineral completely replaces the original mineral, changing both the chemistry and the internal crystal structure.

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The original mineral is removed very gradually and simultaneously replaced by the new mineral, literally on a molecule-by-molecule basis. Our January minerals, gypsum-after-glauberite, is an example of pseudomorphism by substitution.

Pseudomorphism by alteration occurs when a new mineral replaces some portion of the original mineral to change at least part of both the chemistry and the internal crystal structure. An example is malachite-after-azurite, specimens of which usually contain both species. While both minerals are copper carbonates, the oxidation state of the copper changes, as does the quantitative chemical composition. Also, malachite $[\text{Cu}_2(\text{CO}_3)(\text{OH})_2]$ crystallizes in the monoclinic system, as does azurite $[\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2]$.

Pseudomorphism by incrustation occurs when a new mineral coats an original mineral with a thin film in the precise shape of the original crystal. A common example is chalcocite (copper sulfide, Cu_2S) coating pyrite (iron disulfide, FeS_2) to produce steel-gray pyrite cubes and pyritohedrons. The incrusting minerals are called **epimorphs**, or “outer forms.” The enclosed minerals are known as **endomorphs**, or “inner forms.” Should endomorphs dissolve away to leave hollow cavities (casts or “negative molds”), the cavities themselves are correctly known as **perimorphs**, or “enclosed forms.”

While our January minerals are examples of pseudomorphism by substitution, glauberite pseudomorphs can also form by alteration as well as by incrustation. In alteration, glauberite disassociates into thenardite and anhydrite, while retaining its original, external crystal shape. In incrustation, glauberite, especially in basaltic environments, is cast by several minerals, notably quartz (silicon dioxide, SiO_2) and prehnite (calcium aluminum silicate, $\text{Ca}_2\text{Al}_2\text{Si}_3\text{O}_{10}$). These new silicate minerals overgrow the original glauberite crystals as epimorphs. Later, the endomorph glauberite dissolves away, leaving perfect hollow casts—perimorphs—in the exact shape of the original crystals.

COLLECTING LOCALITIES

Glauberite is found in many lacustrine and marine salt-bed deposits in arid climates worldwide, although in many localities only pseudomorphic forms remain. Glauberite is still collected at mines near its type locality at Villarrubia de Santiago, Ocaña, Castile-La Mancha, Spain. Nice specimens have come from Australia at salt beds in northern Victoria and from salt mines at Lake Bumbunga in South Australia. At White Cliffs, New South Wales, Australia, high quality gem opal is found as a pseudomorph of glauberite crystals with the shape of fossilized pineapples and animal bones! Ancient salt beds at Salzburg, Austria, Strassfurt, Germany, and the southern Italian island of Sicily have also provided nice glauberite specimens. Other specimens have been collected at the numerous dry salt lakes of Chile's Atacama Desert.

In the United States, the prime source of glauberite specimens and pseudomorphs are the salt beds of the Verde Valley in Yavapai County, Arizona, explained in detail in *About Our Specimens*. Glauberite has been collected and mined in California at the Saline Valley in Inyo County and at Searles Lake in San Bernadino County. Glauberite also occurs in the seasonal shoreline crystallization of Utah's Great Salt Lake. Specimens and pseudomorphs of glauberite have also been collected from both basaltic and sedimentary (sandstone) environments at Paterson and Great Notch, New Jersey.

JEWELRY & DECORATIVE USES

Although glauberite's softness, solubility in water, and tendency to effloresce (to become covered with a powdery deposit in dry air) precludes any gemstone use, the mineral is popular among collectors for its variety of crystal shapes and pseudomorphic forms.

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HISTORY & LORE

Because of its occurrence in surface or near-surface salt beds, glauberite and associated sodium and calcium sulfates have been known since antiquity and have long served as cathartic medicines. The mineralogical relationships between glauberite, thenardite, and mirabilite (hydrous sodium sulfate, $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$) remained confused until 1808. That year, the French mineralogist and naturalist Alexandre Brongniart (1770-1848), studying specimens from the type locality at the El Castellar Mine, Villarrubia de Santiago, Ocaña, Castile-La Mancha, Spain, identified sodium calcium sulfate as a distinct mineral species. Because sodium calcium sulfate is a double salt, one salt of which is sodium sulfate (Na_2SO_4), formerly called "Glauber's salt" (now thenardite), Brongniart named the new mineral in honor of German alchemist and chemist Johann Rudolf Glauber (1604-1668).

As a source of sodium sulfate, glauberite and associated lacustrine salts have long been mined worldwide. This month's specimens actually come from a prehistoric mine site. The Verde Valley salt beds in Yavapai County, Arizona, were first mined as early as 1360 A.D. by the southern Sinagua culture. This date was determined by researchers from the State University of New York at Binghamton based on radiocarbon (carbon 14) dating of pick handles, juniper bark torches, and other wooden artifacts found at the site. Evidence shows that Native Americans traveled more than fifty miles to Verde Valley to collect one of the minerals essential to human and animal life, halite [NaCl , sodium chloride, better known as rock salt or table salt]. During historic times, glauberite and related minerals were mined and sold to local ranchers for use in salting livestock. During the 1920s, anthropologists recovered many pre-Columbian mining artifacts which are now in the collections of the American Museum of Natural History in New York City and the Arizona State Museum in Phoenix. That same decade demand for sodium sulfate for paper and glass manufacturing soared and the Sodium Products Corporation established the United Verde Salt Mine which continued open-pit and underground mining operations at the Verde Valley lacustrine salt beds until the 1950s.

TECHNOLOGICAL USES

Glauberite is commercially valuable as an ore of sodium sulfate, a compound used to process paper pulp and manufacture paper, glass, and detergents. Some 2.5 million tonnes (metric tons) of sodium-sulfate-containing mineral salts, including glauberite, are now mined worldwide each year. The United States produces about 350,000 tonnes of sodium-sulfate-containing salts with a value of \$3 million annually. Glauberite is recovered both by open-pit mining and solution mining, the latter a technique which forces superheated water through injection wells into underground salt beds to produce brine, which is pumped to the surface.

ABOUT OUR SPECIMENS

Our specimens from this month come from the now-closed Camp Verde salt mine, located about two miles west of the town of Camp Verde, southeast of Clarkdale, on the west side of the Verde River, in Yavapai County, Arizona, about ninety miles north and slightly east of Phoenix and sixty miles south of Flagstaff, on Highway 17. Over the years, Camp Verde gained a reputation as a source of well-formed, easily found crystals, with easy access to collectors, as noted in a 1983 featured article "Camp Verde Evaporites" in the *Mineralogical Record*. Now the area is fenced off in an effort to keep collectors out. In addition to gypsum, other minerals found here as pseudomorphs after glauberite are calcite [CaCO_3] and aragonite [CaCO_3], polymorphs of calcium carbonate. Unaltered glauberite crystals are also found, as are crystals of thenardite and blue halite, sometimes with blue or purple phantoms. These minerals are also found at Copper Canyon, about a mile to the west.

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Over the years, we have made mention of the first Mineral of the Month Club, operated through the 1970's and 1980's by Russ and Alexandra Filer of Filer's Minerals, Yucaipa, California. We had the opportunity to obtain a couple of their mineral "fact sheets" pertaining to Camp Verde, written by Alexandra Filer. It seems they featured gypsum after glauberite from Camp Verde as their Mineral of the Month in January 1974 (while we were still in High School), and then in June through September 1979 they featured glauberite and the three pseudomorphs previously mentioned, all from Camp Verde. Interestingly, the specimens they sent were comparable to our Junior-size specimens, and the price was not much less than what we charge now for our Junior membership, some twenty years later.

We thought it might be fun to highlight a few points about Camp Verde from their fact sheet, copyright 1979 by Alexandra T. Filer: *"What interests us right now are those crowded-together low hills between the flood plain and the bluff. They also appear to be stratified . . . There is much fine-grained clay (hardened silt) throughout the entire hills. Ah ha! There is our first surprise. Do those objects in the talus at the foot of the slope have crystal form? We pick several of them. They certainly do. We speculate that they probably are one of the salts which were crystallized out of solution at the time that some of these strata were deposited. This would be during one of those intermittent periods when the ancient lake was shallow and its waters brine-like. The waters were so supersaturated with chemical salts that they no longer could stay in solution . . .*

"While glauberite crystals were crystallizing out of solution, silt also was being deposited which eventually hardened to clay. All of the accumulation of hardened sediments subsequently was subjected to the action of percolating groundwater. Now groundwater can eventually dissolve even slightly soluble minerals . . . So far as each glauberite crystal was concerned its sodium calcium sulfate was dissolved and carried off, leaving an opening in the clay—a clay mold. A clay mold with the shape of a glauberite crystal, with its various faces, angles, edges, and intergrowth crystals (if any . . .) The waters of subsequent percolating groundwater could have been highly charged with still other chemicals which went about different chemical activity. According to the chemical content and fractions of chemicals, either gypsum, or calcite, or aragonite was crystallized out of solution. Since though, this crystallization took place within a mold, like metal or glass or plastic which have been poured into a mold, the final shape was that of the shape of the walls of the mold. The final shape was not the one which was natural for that particular mineral, but that of the geometric form of the glauberite crystal." Well said!

We tested several of our specimens under shortwave ultraviolet light, and they gave off a very slight white color, with a fleeting hint of phosphorescence, as might be expected in gypsum. You might enjoy inspecting your piece with a UV lamp. Let's close with a final quote from 1979 by Alexandra Filer: *"We think you would agree that with its glauberite crystals, and the afterkristalls of gypsum, calcite, and aragonite (and with their variants of form and intergrowth), along with archaeological evidence of early man, the Verde Valley of central Arizona is a valley of surprises!"*

References: *Dana's New Mineralogy*, Eighth Edition; *2004 Fleischer's Glossary of Mineral Species*, J. A. Mandarino and M. E. Back; *Encyclopedia of Minerals*, Second Edition, Roberts, et al, Van Nostrand Reinhold Company; *Manual of Mineralogy*, 21st Edition, Cornelia Klein and Cornelius S. Hurlbut, Jr., John Wiley & Sons; *Sodium Sulfate: Handbook of Deposits, Processing, and Use*, Donald E. Garrett, Academic Press; "Sodium Sulfate," *1997 Minerals Yearbook, United States Geological Survey*; "Using the Proper 'Morph'-Let's Get it Right," John S. White, *Rocks & Minerals*, September-October 2003; *Back From the Salt Mines: Reinterpreting the Verde Salt Mine Site*, Nancy Jo Chabot, Master's Thesis, State University of New York, Binghamton, New York; "An Aboriginal Salt Mine at Camp Verde, Arizona," Earl Morris, *Anthropological Papers of the American Museum of Natural History*, New York, 1928; *Mineralogy of Arizona*, Third Edition, J. W. Anthony, Arizona Bureau of Mines, 1995; "Verde Valley Salt Mines," Gerry Blair, *Rock & Gem*, December 1990; Camp Verde Evaporites, J. Robert Thompson, *Mineralogical Record*, March-April 1983; "Verde Valley, Arizona—A Valley of Surprises," Alexandra T. Filer, 1979

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