

October 2005 Mineral of the Month: Gypsum, variety Selenite

"Gypsum is a fine species to collect because of the great variety of crystals and aggregates. Perhaps the most difficult specimens to find are those with clear crystals." –John Sinkankas, *Mineralogy*, 1964

PHYSICAL PROPERTIES

Chemistry: $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ Hydrous Calcium Sulfate (Calcium Sulfate Dihydrate)

Class: Sulfates Subclass: Hydrous Sulfates Group: Gypsum

Crystal System: Monoclinic

Crystal Habits: The varietal name "selenite" is applied to gypsum found as clear, colorless crystals, as explained below. Gypsum crystals occur most commonly as untwinned prismatic or bladed crystals showing rhombic form, and occasionally as arrowhead-shaped twins with beveled edges. Very thin crystals are slightly flexible. Crystals can have warped surfaces, or be bent or twisted. Inclusions are common. Gypsum also forms distinctive, rosette-like, crystalline concretions of sedimentary origin called "desert roses." Other gypsum varieties are granular, fibrous, massive, and earthy.

Color: As an allochromatic (other-colored) mineral, pure gypsum is colorless or white. However, traces of impurities create a wide range of colors including gray, yellow, red, and brown.

Luster: Vitreous to pearly; pearly on cleavage surfaces

Transparency: Translucent to transparent

Streak: White

Cleavage: Perfect in one direction, distinct in two others

Fracture: Conchoidal, splintery, brittle

Hardness: Mohs 2.0

Specific Gravity: 2.3-2.4

Refractive Index: 1.52-1.53

Luminescence: Often reacts to shortwave and longwave ultraviolet light

Distinctive Features and Tests: Flexibility in thin crystals; softness (can be scratched with a fingernail); flat, blade-like crystals.

Dana Classification Number: 29.6.3.1



Figure 1. Gypsum crystal drawing, from Victor Goldschmidt's *Atlas der Krystallformen*.

NAME

The name "gypsum" derives from the Greek *gypsos*, for plaster, a reference to an early use of gypsum. "Selenite" is also of Greek origin, stemming from *selénitēs*, literally "stone of the moon" (from *seléné*, "moon"), an allusion to the moon-like, pearly luster of selenite's cleavage surfaces.

Gypsum's abundance, worldwide occurrence, different forms, and widespread uses have resulted in many other names, including "gypsum rock," "gypsite," "alabaster," "satin spar," "lapis specularis," "oulopholita," "yeso," "gesso," "gypsta," "gypse," "aphroselenon," "acido vitriolo saturata," and "spectacle stone."

COMPOSITION

When we featured gypsum in May 2001, the specimens from Manitoba, Canada we sent to Club members were of a similar gold color to these sent this month, and are usually labeled gypsum rather than selenite, although we have seen them labeled at shows as selenite. Purists in the mineral world would like to abandon the use of the name "selenite" altogether, or at least limit its use to that of a synonym of gypsum, rather than a variety. (Former Smithsonian curator John S. White recently wrote an

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impassioned plea in one of the mineral magazines with the title “Selenite—Die, You Accursed Term.”) However, modern dictionaries continue to define selenite as clear, colorless crystals of gypsum, and it seems certain that the use of this term will continue despite the efforts of Mr. White and others. According to the current dictionary definition, our specimens should be called gypsum—they are clear, they are crystals, but they are not colorless--and the few magazine references we uncovered call these gypsum rather than selenite. Could it be that the name selenite persists because it sound much prettier than gypsum and because its Greek derivation is tied in with the moon?

The information presented here applies specifically to gypsum and all its varieties, and we will use the term selenite only to refer to clear, colorless crystals of gypsum, as well as the pieces we sent this month. Gypsum's chemical formula, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, indicates that it is a hydrous calcium sulfate containing the elements calcium (Ca), sulfur (S), oxygen (O), and hydrogen (H). Oxygen is present both in the sulfate anion (SO_{4-2}) and in the attached water (H_2O) molecules. In atomic weight, each molecule of gypsum consists of 23.28 percent calcium, 18.62 percent sulfur, 2.34 percent hydrogen, and 55.76 percent oxygen. Water accounts for 20.93 percent of gypsum's weight. Within the gypsum molecule, the +2 charge of the calcium cation (Ca^{+2}) balances the -2 charge of the sulfate anion (SO_{4-2}). The sulfate class of minerals includes compounds of sulfur and oxygen that are bound together as sulfate anions, which in turn are bound to one or more metals. Of more than 150 sulfate minerals, gypsum is by far the most abundant.

Gypsum's chemical formula tells us that two water molecules are bound to each molecule of calcium sulfate. Because it contains water as a specific number of water molecules, gypsum is classified as a hydrous mineral, or hydrate. Its water, which is referred to as “water of hydration,” is not simply absorbed, but rather is chemically bonded into the atomic structure of the calcium-sulfate lattice. This water is not bonded as separate oxygen and hydrogen ions, but as integral water molecules that retain their characteristic composition and structure. The chemical formulas of all hydrous minerals end with H_2O . By convention, the formulas of hydrous minerals employ a chemical period (·) to separate the parent mineral from its bonded water.

The gypsum molecule is bound together by an unusually complex combination of strong covalent atomic bonds, intermediate ionic bonds, and weak hydrogen bonds. In the sulfate anion (SO_{4-2}), each sulfur atom is covalently bonded to four oxygen atoms that form the corners of a tetrahedron. The double-negative charge of the sulfate ion is evenly distributed over the oxygen atoms. The negatively charged sulfate anion is weakly bound to the positively charged calcium cation by ionic bonds. The crystal lattice consists of repeating, ionically bonded calcium and sulfate atoms, with each sulfur atom surrounded by its four oxygen ions.

The water of hydration is attached by even weaker hydrogen bonds. Water molecules consist of a large oxygen atom covalently bonded to two hydrogen atoms. The hydrogen atoms are not symmetrically opposed, but rather are grouped on one side of the oxygen atom. Although water molecules are neutral, their two closely grouped hydrogen atoms retain a weak positive charge. The opposite side of the water molecule, which is occupied by the large oxygen atom, has a small negative charge. Each individual water molecule therefore behaves as a tiny dipole magnet. Hydrogen bonding, also called polar bonding, forms when the faintly positive poles of the water molecules attract the electrons of other atoms. In gypsum, the positive poles of the water molecules are attracted to the slight negative charge of the oxygen atoms in the sulfate anion. Within the gypsum lattice, calcium-sulfate molecules form layers which “sandwich” the attached water molecules. This is why gypsum has perfect cleavage in one direction: The planes of perfect cleavage are the planes that contain the weakly bound water molecules. These weak hydrogen bonds, together with the weak ionic calcium-sulfate bonds, explain gypsum's softness, its moderate solubility in water, and the flexibility of its thin crystals.

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Because hydrogen bonding is strongest at cold temperatures, gypsum becomes unstable when heated. Heat parts the hydrogen bonds and drives off most of the water. When gypsum is calcined (heated to sub-fusing temperatures to drive off volatile materials), the hydrogen bonds part and exactly three-quarters of the water of hydration is lost. The result is calcined gypsum, a hemihydrated powder with the chemical formula $\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$. In calcium sulfate hemihydrate, one water molecule is attached to every two calcium sulfate molecules. The overall structure of calcined gypsum is identical to that of natural gypsum, except that the lattice sites occupied by water are vacant. When water contacts calcined gypsum, it immediately reoccupies these vacant sites to establish hydrogen bonds and forms a recrystallized, rigid structure exactly like that of natural gypsum. This ability to lose and quickly regain water of hydration gives gypsum many important uses, as we will see.

Gypsum occurs in numerous mineralogical environments, principally in sedimentary rocks of chemical origin where it can form beds more than 30 feet thick. Most gypsum originated as evaporite deposits left behind when ancient seas retreated and forms stratigraphic beds within sedimentary formations of shale, sandstone, limestone, or rock salt (halite, $[\text{NaCl}]$). Gypsum, usually the selenite variety, is also associated with dolomite (calcium magnesium carbonate, $[\text{CaMg}(\text{CO}_3)_2]$) and barite (barium sulfate, $[\text{BaSO}_4]$) in hydrothermal replacement deposits. Another common occurrence is in volcanic formations, where gypsum forms by the action of sulfuric acid (H_2SO_4) on calcium-containing minerals. Gypsum is also a significant component of many clays, where it is formed by the action of sulfuric acid on limestone (a rock consisting primarily calcium carbonate, $[\text{CaCO}_3]$).

Other forms of gypsum include satin spar, a fibrous, silky, white or gray variety, and alabaster, a massive, fine-grained form that is an excellent carving medium. (See our May 2001 gypsum write-up for more on satin spar and alabaster.) Most gypsum, however, occurs as gypsum rock or gypsite. Gypsum rock is an impure, massive form of gypsum containing at least 90 percent hydrous calcium sulfate. Gypsite, an earthy, low-grade source of gypsum, contains about 50 percent hydrous calcium sulfate.

COLLECTING LOCALITIES

Collecting localities for selenite are numerous and found worldwide. In the United States, clusters of bladed, brown crystals occur in Alfalfa County, Oklahoma. Large, colorless crystals are collected in Wayne County, Utah, and Mahoning County, Ohio. In New York, fine crystals occur at Kerhonkson, Ulster County, and in cavity walls in dolomite in Niagara County. Transparent crystals to four inches in length are found at Parsons, Decatur County, Tennessee. Nice crystals have also been recovered at the Gerlach Mine and other sites in the Selenite Range, Pershing County, Nevada.

In Canada, transparent blond selenite crystals are abundant in the Red River Floodway near Winnipeg, Manitoba, which we featured in May 2001. Intermittent saline lakes at Bolton, Victoria, Australia, have yielded quantities of colorless-to-pink selenite crystals. Fine selenite crystals have been recovered from the metal-mining district at Pasto Buena, Peru. The most spectacular selenite occurrences in the world are at Naica, Chihuahua, Mexico, and at Pulpí, Almería, Spain. Both sites have huge subterranean geodes that are lined with transparent, beautifully developed selenite crystals of awesome size.

The finds of enormous selenite crystal at Naica rank among the most awesome sights on the planet. In 1910 at the lead-silver Naica mine, a huge chamber about 70 meters in diameter was found at a distance of 120 meters below the surface. Imagine the miner's awe as they gazed at the huge, translucent selenite crystals shaped like swords filling the chamber! It was quickly named the "Cave of Swords" and the environmentally aware Peñoles mining company has preserved the cave down to this day. Yet, even this incredible find was to be surpassed.

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In April 2000, miners working at a depth of 300 meters encountered a chamber roughly 10 to 20 meters in size, again filled with immense, lustrous selenite crystals. "It was beautiful, like light reflecting off a broken mirror," said one of the miners. Not long after, another even larger chamber was discovered with selenite crystals the size of mature pine trees, as much as 50 feet long and 6 feet in diameter! The simple name "Cave of the Crystals" was given, and the mining company quickly walled off the cave to prevent theft and vandalism, but not before one miner died attempting to remove crystals. The 150° temperature and 100% humidity causes dehydration after just a few moments, and authorized visitors can safely remain only ten minutes or so before becoming disoriented.

JEWELRY & DECORATIVE USES

The great softness (Mohs 2.0) of selenite precludes any use in jewelry. Collectors value selenite crystals for mineralogical and display purposes.

HISTORY & LORE

Gypsum has been known since antiquity, first used in crude plasters in Anatolia (present-day Turkey) about 5000 years ago, and soon thereafter in the construction of the great pyramids of Egypt, both as a plaster on interior walls and a binding agent in mortar. The Greek and Romans used stucco, a fine-grained compound composed of gypsum and marble dust as a plaster and as a sculpting and casting material which they worked into ornamental shapes, polished to a marble-like finish, and painted in decorative colors.

During the Renaissance period, gypsum-based plaster served as the substrate of many fresco paintings. White stucco was often used in churches, where it was molded into wall decorations and sculptures, especially figures of angels, while colored, architectural stucco friezes became popular in plazas, gardens, and pavilions. Stucco work reached the peak of its popularity in the 17th and 18th centuries when Baroque and Rococo palaces were decorated with elaborate polychrome stucco in shapes ranging from humanistic figures to twisted columns and festively adorned altars.

By 1800, gypsum plaster was being used to cover household walls in Europe. The plaster was given the familiar name "plaster of Paris" after the gypsum beds in France's Paris Basin, one of the world's largest gypsum deposits. Unfortunately, these original gypsum plasters set almost instantly and were difficult to work with. In 1880, additives were discovered that retarded the setting time, making plaster of Paris an ideal material for interior finishing, artistic and ornamental applications, and even for orthopedic casts.

In 1888, American entrepreneur and inventor Augustine Sackett (1867-1914) found the greatest use ever for gypsum plaster. Sackett poured a half-inch-thick layer of plaster of Paris atop a sheet of thick manila paper, then covered it with a second sheet. The plaster hardened into inexpensive, rigid panels called



Figure 2. Enormous selenite crystals in Cave of the Crystals, Naica Mine, Chihuahua, Mexico. Photo courtesy of The La Venta Exploring Team, Italy.

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“plasterboard” or “Sackett board.” Cheap, durable, fire-resistant, and an excellent thermal insulator, plasterboard proved far superior to traditional wooden or lath-and-plaster walls. By the mid-1950s, plasterboard, now known as “wallboard” or “drywall,” had revolutionized the construction industry and created an unprecedented demand for gypsum.

Gypsum varieties have appeared on the postage stamps of a dozen nations. The selenite variety has appeared on West Germany's 1972 five-pfennige stamp, while selenite in the “desert rose” form has been featured on Algeria's 1983 70-centime stamp, Namibia's 1991 one-cent stamp, and Tunisia's 1997 250-millimes stamp.

Modern metaphysicists believe that selenite, as an emissary of white light, conveys that light to its wearer to calm troubled minds, stabilize emotions, and clarify thoughts.

TECHNOLOGICAL USES

Gypsum, both natural and calcined, has many important applications. Plaster of Paris is used extensively in making ceramic casts, dental plates, metal parts, and surgical splints. Granulated natural gypsum serves as a conditioner for arid, alkaline soils. Gypsum is also used as a bedding material for polishing plate glass, a filler in the manufacture of most paints and papers, and a flux for certain types of reduction smelting. Gypsum, in large quantities, is the preferred setting retardant for Portland cement, enabling the cement to be pre-mixed at central plants, then transported elsewhere for later use.

The greatest use of gypsum, which accounts for three-quarters of all the gypsum mined, is the manufacture of drywall for home, office, and commercial-building construction. More than 28 *billion* square feet of drywall products are manufactured each year in the United States alone—more than enough to cover the entire state of Rhode Island. The wallboard in the average new house built in the United States today contains more than seven tons of gypsum.

Gypsum is obtained from both open-pit and underground mines. Gypsum ore, called “crude gypsum,” consists primarily of gypsite or gypsum rock, along with varying amounts of selenite, alabaster, and satin spar. Crude gypsum is coarsely crushed and, if necessary, concentrated. Because gypsum (S.G. 2.3-2.4) is considerably lighter than common sand and other quartz-based gangue materials (both about S.G. 2.65), it is easily concentrated by hydraulic (washing) methods. The concentrated, crushed, crude gypsum is first passed through gas-fired ovens to remove any surface moisture, producing an intermediate form of gypsum called “land plaster.” The land plaster is then crushed to a powder and calcined in rotating, gas-fired kilns at temperatures of 250°-300° F. The final product is “stucco,” the industrial term for the dry, white powder that is the hemihydrate form of calcium sulfate ($\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$) and the base material for the manufacture of plaster of Paris and all wallboard materials.

Gypsum mining and calcining, along with the manufacturing of prefabricated gypsum products, are a multi-billion-dollar industry. Worldwide, more than 100 million metric tons (one metric ton equals about 1.2 standard tons) of crude gypsum are mined each year. Most is used in the manufacture of 60 billion square feet (more than 2,000 square miles) of wallboard. The United States is the world's leading source of gypsum, mining 16 million metric tons each year from 50 mines in 17 states. But to meet domestic demand, the United States must import an additional 16 million metric tons. Crude gypsum currently sells for \$6.90 per metric ton, and calcined gypsum for \$20 per metric ton. The United States also produces about three million metric tons of synthetic gypsum each year as a by-product of flue-gas desulfurization systems that reduce sulfur-dioxide (SO_2) emissions from coal-fired power plants. Synthetic gypsum is chemically identical to natural gypsum and has the same uses.

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ABOUT OUR SPECIMENS

Normally, we are able to get detailed locality information, including photos, to share with you, but this month is an exception. Our source was in contact with his Peruvian sources and could not provide even a photo of the mine! The 2003 *Mineralogical Record* update on Peruvian minerals provides this information: "The Las Salinas halite mine near Otume village south of Pisco has produced very aesthetic clusters of golden gypsum crystals during the last two years. The crystals reach about 7 cm and are commonly twinned on {100}. The only associated mineral is halite in colorless cubes to about 5 cm. The most recently found gypsum specimens are among the most beautiful known."



Figure 3. Twinned gypsum crystal drawing, from Victor Goldschmidt's *Atlas der Krystallformen*.

Our specimens are certainly aesthetic, with some of the larger pieces on a matrix of massive halite, sometimes with a few halite crystals. The most common crystals forms we observed are like the drawings in Figures 1 and 3, and twinned crystals like the one depicted in Figure 3 are common. Such are called "spear head twins" or "swallowtail twins" due to their appearance. (See our September 2004 write-up on Japan-Law Twinned Quartz for a detailed explanation of twinning in minerals.)

The MR cited above mentions that the twinning occurs on {100}. This designation belongs to the crystallography method known as Miller indices, devised and published in 1839 by W. H. Miller of Cambridge, England. This system is used to describe the position of crystal faces with regard to crystal axes. In this case, {100} indicates the crystal face parallel to the b-axis, which runs across, and the c-axis, which runs up and down.

Our specimens fluoresce a ghostly yellow color and phosphoresce for a few seconds in both short and long wave ultraviolet light, as those with a UV lamp will observe. Another interesting property of gypsum is that it will slowly dissolve under sustained water pressure, along the layers described in *Composition*. This method is used by some collectors, who place large single selenite crystals in a river for a few days, to remove the mineral-encrusted outer layers and reveal the pearly luster underneath. This would not work with our specimens, as the water would be absorbed by the matrix and the specimen would remain wet for a long time. Our source tells us that a moist Q-tip can be used to clean and enhance some of our specimens, if you wish to try it at home, but be careful. Gypsum is the standard for hardness degree 2 on the Mohs hardness scale, which means it can be easily scratched with a fingernail, which one of the best field indicators for gypsum. This is partly why undamaged gypsum specimens are hard to come by, and also calls for extra care in handling your specimen, as one good knock can damage a crystal.

Without a doubt, this month's mineral, call it gypsum, selenite or gypsum variety selenite, is as intriguing and important as it is attractive, especially in the Cave of the Crystals as one of Earth's greatest natural wonders. We are already looking forward to featuring it in another crystal form in the future!

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