December 2004 Mineral of the Month: Azurite

> "The cornflower blue of azurite makes it a favorite among collectors." –Fritz Hofmann, *Rare and Beautiful Minerals*

PHYSICAL PROPERTIES

Chemistry: $Cu^{2+}{}_3(CO_3)_2(OH)_2$ Copper Carbonate Hydroxide (Basic Copper Carbonate)
Class: Carbonates
Subclass: Carbonates with hydroxyl or halogen anions
Group: Azurite
Crystal System: Monoclinic
Crystal Habits: Usually as equidimensional crystals or as tabular or prismatic crystals with dimensions thin in one direction; well-developed crystals rare; crystal faces sometimes faintly wavy or striated; much more common in earthy, massive, stalactitic (as pendant columns), stalagmitic, radiating, fibrous, crusty, and botryoidal forms. More than 45 well-known forms of azurite are described.
Color: Primarily azure blue, also light-to-dark shades of blue
Luster: Vitreous, brilliant
Transparency: Transparent to opaque
Streak: Light blue
Cleavage: Good in two directions, fair in one direction
Fracture: Conchoidal; very brittle
Hardness: Mohs 3.5-4.0
Specific Gravity: 3.77-3.89
Luminescence: None
Refractive Index: 1.730-1.838
Distinctive Features and Tests: Intense, azure-blue color, light-blue streak, and mineral associations, especially with the chemically similar, green copper-carbonate mineral malachite.
Dana Classification Number: 16a.2.1.1

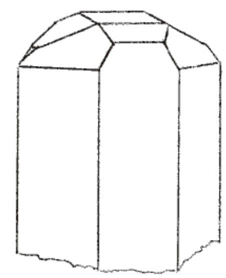

Figure 1. Azurite crystal. From *Mineralogy* by John Sinkankas, used by permission.

NAME

Azurite, pronounced "AZH-ur-ite," is named for its intense azure color. The word "azure" derives from the Persian *lâzhuward*, meaning "heaven," or "blue." This same Persian word is the source of the mineral name lazurite, another blue mineral that is the principal mineral found in the rock lapis lazuli. Azurite has also been known as "azurit," "blue copper," "blue copper ore," "azure copper ore," "blue malachite," "bergblau," "kupfer lazure," and "chessylite," the latter a reference to a famed occurrence in France.

COMPOSITION

We first featured azurite and its vivid color as our eighth featured mineral, back in October 1996. The Deluxe specimens were from the Daye Copper mine, Hubei Province, central China, while our Junior specimens were from Arizona's famous copper mine at Morenci, the second largest open-pit copper mine operating in the United States. Lately, we have been looking for another large lot of Chinese azurite so as to feature it again, but have not found an appropriate lot yet. When we saw the intense color of the Idaho specimens, we decided now would be a great time to again examine this resplendently beautiful mineral, and perhaps in a few more years, we can feature it again, from China. The vigor of the color is one we could return to again and again!

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Azurite's chemical formula, $Cu^{2+}{}_3(CO_3)_2(OH)_2$, identifies this mineral as a basic copper carbonate, or a basic copper hydroxide, containing the elements copper (Cu), carbon ©), oxygen (O), and hydrogen (H). The atomic weight of azurite consists of 55.31 percent copper, 37.14 percent oxygen, 6.97 percent carbon, and 0.58 percent hydrogen. Oxygen is present both in the carbonate $(CO_3)^{2-}$ and hydroxyl $(OH)^{1-}$ anions. Within the azurite molecule, the copper cation consists of cuprous, or divalent, copper (Cu^{2+}). Thus the +6 cationic charge balances the collective -6 anionic charge of the carbonate $(CO_3)^{2-}$ and hydroxyl $(OH)^{1-}$ ions.

Generally, minerals of the carbonate class consist of triangular carbonate ions $(CO_3)^{2-}$ held together by bonds to metal ions. The molecular structure of azurite, because of the presence of hydroxyl ions, is somewhat more complex, consisting of square groups composed of two O^{2-} ions (from the carbonate anions) and two hydroxyl $(OH)^{1-}$ anions attached to a single, central Cu^{2+} ion. The anions are paired laterally or diagonally across one side of the square. These square groups are then linked in chains by triangular carbonate $(CO_3)^{2-}$ anions to form a crystal lattice. Azurite crystallizes in the monoclinic system, in which crystals have three axes of unequal length, two of which are perpendicular to each other. The azurite molecule is held together by both covalent and intermediate covalent-metallic bonds. These bonds vary considerably in strength along certain planes to account for azurite's complex cleavage, which is good in two directions and fair in a third.

Azurite is closely associated with and similar in many ways to bright green malachite which, like azurite, is also a basic copper carbonate. This similarity, apparent in both chemical composition and formulae, is due to copper's two oxidation states. In forming compounds, copper, in its cuprous state (Cu^{2+}), gives up two electrons, while in its cupric state (Cu^{3+}) it gives up three electrons. The chemical formula of azurite, [$Cu^{2+}{}_3(CO_3)_2(OH)_2$], varies only slightly from that of malachite, which is [$Cu^{2+}{}_2(CO_3)(OH)_2$]. The difference reflects the presence of cuprous ions (Cu^{2+}) in azurite, and of cupric ions (Cu^{3+}) in malachite. Even though cupric ions have a higher level of oxidization than cuprous ions, azurite and malachite share similar physical properties and type of occurrence.

The carbonates, which number about 70 species, consist of one of more cationic metallic elements bound to carbonate anions, and sometimes are also bound, as in the case of azurite, to hydroxyl anions. While carbonates are usually colorless or only lightly colored when pure, azurite and malachite are exceptions. Azurite is a deep azure blue, while malachite is a bright green. Both minerals are idiochromatic (self-colored), meaning that essential chemical composition and crystal structure, rather than secondary coloring agents, create their characteristic and diagnostic colors. Copper, the essential metal in both azurite and malachite, is a powerful pigmenting agent for the colors blue and green. In azurite, cuprous ions within the crystal lattice create absorption characteristics that absorb all wavelengths of visible light except for a narrow band of pure blue. The reflectance of this narrow band of blue is the color we perceive in azurite. But in malachite, the presence of more highly oxidized cupric ions alters the light-absorption characteristics of the crystal lattice, resulting in the absorption of only the red and violet ends of the white-light spectrum. The subsequent reflectance of blue, green, and some yellow produce the bright green color we perceive in malachite.

Carbonate minerals generally form in shallow, oxidized mineralogical environments where air can dissolve in water to form carbonic acid (H_2CO_3), which in solution consists of hydrogen ions (H^{1+}) and bicarbonate ions $(HCO_3)^{1-}$. In the proper conditions of temperature, pressure, and chemical concentration, the bicarbonate ions will combine with metal ions to form carbonates. Utilizing this same basic chemistry, azurite can form in two ways, either when carbonic acid reacts with copper-sulfide minerals or when copper solutions react with calcite (calcium carbonate, $CaCO_3$). Depending upon specific conditions, azurite or malachite, or both, can form from this alteration of copper sulfides or calcite. Because of its lower oxidation state, azurite tends to form first in most environments. Malachite, with its higher oxidation state and greater chemical stability, occupies a later stage in the oxidation process. Interestingly, azurite and malachite often occur in the same botryoidal specimens in alternating, concretionary banding patterns. This is caused by alternating oxidation levels in the aqueous solutions from which the azurite and malachite precipitated.

Azurite and malachite usually occur in association with such minerals as cuprite, or cuprous oxide (Cu_2O); chalcopyrite, or copper iron sulfide ($CuFeS_2$); calcite, or calcium carbonate ($CaCO_3$); chalcocite, or copper sulfide (Cu_2S), native copper (Cu); chrysocolla, or hydrous copper silicate $[(Cu,Al)_2H_2SiO_5(OH)_4 \cdot nH_20]$; and linarite, or basic copper lead sulfate $[PbCu(SO_4)(OH)_2]$.

With further oxidation, azurite will alter to malachite, which explains the frequent mineralogical association of these two minerals as well as the greater abundance of malachite. This alteration can also produce pseudomorphs of malachite-after-azurite. Pseudomorphs form when an original mineral crystal is replaced molecule by molecule with a second mineral while retaining the macroscopic crystalline shape of the original mineral. A pseudomorph thus possesses the chemical composition of the new mineral species while preserving the shape of the original, replaced species. Therefore, the color of malachite-after-azurite is malachite green rather than azurite blue.

COLLECTING LOCALITIES

Fine azurite specimens have been obtained from numerous localities, most of which are copper or multi-metal mines. Azurite has been reported as a common mineral in more than 250 mines in 32 nations! The largest and most spectacular azurite crystals, in lengths up to ten inches, have come from Tsumeb, Namibia, where the mineral occurs in a remarkable variety of forms. Large amounts of azurite have been collected at the mines at Chessy, near Lyon, France. Other prime azurite localities include the ancient silver-copper mines at Laurium, Greece; the tin mines at Cornwall, England; at Burra Burra in South Australia and Broken Hill in New South Wales, Australia; at Touissit, Oujda, Morocco; at the Yang Chweng Mine at Shilu in Guangdong, China; and at the San Carlos Mine at Mazapil, Zacatecas, Mexico.

In the United States, Arizona, with its numerous copper deposits, is the leading source of azurite. Fine specimens were found at the now-closed mines of the Bisbee district in Cochise County, at Ajo in Pinal County, and at Clifton and Morenci in Greenlee County. Azurite also occurs at the Rose Mine in Grant County, New Mexico. Mines in La Salle County, Utah, have produced elongated, tabular crystal clusters of azurite. Our azurite specimens were collected recently in the Lemhi Range, Idaho, as we will discuss.

JEWELRY & DECORATIVE USES

The softness of azurite (Mohs 3.5-4.0) and its good, two-directional cleavage limit its use as a jewelry gemstone to beads for stringing necklaces and cabochons for mounting as pendants. Although azurite takes a high polish, its luster is lost relatively quickly due to wear and scratching. Nevertheless, massive or banded azurite is popular when fashioned into decorative items such as trinket boxes, ashtrays, figurines, paperweights, and inlay-type wall ornamentation. Intergrowths of azurite with other minerals are also valuable as ornamental stones. These include combinations of malachite and reddish cuprite, which is known as “burnite” or “bluebird,” and combinations of azurite and malachite, which is called “azurmalachite.”

The noted mineralogist and author Robert B. Cook describes azurite as “one of the cornerstones of any mineral collection.” Indeed, azurite, with its vivid blue color and myriad forms, has long been an eminently collectible mineral and fine specimens make visually striking displays. Azurite is also occasionally faceted into collector gems. Interestingly, faceted azurite, in all but the smallest gems, takes on a dark, virtually black color. For that reason, azurite collector gems rarely exceed one carat in weight.

HISTORY & LORE

Azurite, easily obtained from vividly colored outcrops, has been known since antiquity. As early as 4000 B.C., azurite and malachite served as ores of copper that were easily reduced to metallic copper in simple charcoal furnaces. The close association of native copper with these two copper carbonates was instrumental in helping early metallurgists to realize the connection between native metals and metal ores.

With its intense blue color, azurite has long been employed as a pigment. The Egyptians favored powdered azurite as a cosmetic eye shadow. During the Middle Ages and the Renaissance, azurite was the most widely used blue paint pigment among European artists. To prepare azurite for pigment use, the pure mineral was simply ground, washed, dried, and sieved. Finely ground azurite provided a lighter blue color, while coarser azurite particles produced more intensely colored and desirable blue paints which, unfortunately, were the most difficult to apply, especially in fine detail. Azurite-based paints are found in such works as the illumination hues of the Gutenberg Bible, printed circa 1450, and the paintings of the Dutch master Jan Vermeer (1632-1675), including *Officer and Laughing Girl* and *Maid Asleep*. (The 2003 film *Girl with a Pearl Earring* has a scene featuring paint-mixing.) The most attractive blue paints of these periods were made from ultramarine, a lazurite pigment extracted from lapis lazuli. These prohibitively expensive lazurite-pigment paints were used only on the finest artwork, often over base coats of inexpensive azurite paints in order to economize on the use of lazurite.

But by the mid-1600s, the use of azurite as a blue pigment in paints ceased abruptly when artists realized that the once-intense blue skies in many older pieces of artwork were slowly turning to green. The reason was that the original particles of blue azurite pigment had, over many years of exposure to heat and humidity, oxidized to green malachite.

The modern name “azurite” was assigned in 1824 by the French mineralogist François Sulpice Beudant. Because it has been known since antiquity, azurite has never been formally assigned a type locality. Mineralogical literature, however, often mentions Chessy, France, and Tsumeb, Namibia, as “informal” type localities.

In the American Southwest, such Native American cultures as the Zunis of New Mexico carved fetishes from massive azurite. In the latter decades of the 19^{th} century, prospectors discovered enormous outcrops of nearly pure blue azurite and green malachite at Bingham Canyon, Utah; Butte, Montana; and at numerous sites in southern Arizona. Azurite, and to a lesser extent malachite, were actually the ores that started the copper-mining industry in the American West. Azurite was a direct-smelting ore, that is, an ore so rich that it required no prior concentration or other preparation prior to smelting. Miners exploited the outcrops from the surface, then hand-cobbed, or separated, the azurite from gangue rock solely on the basis of color. Azurite, which contained more than 50 percent copper by weight, was easily smelted, or chemically reduced, to copper metal with nothing more than a medium-temperature furnace and a cheap reducing agent such as charcoal. But miners exhausted these direct-smelting ores in just a decade. Still, these azurite outcrops had another importance—they often marked deeper and far more massive deposits of lower-grade copper-sulfide ores that are the mainstays of today’s copper-mining industry.

In medieval times, physicians used azurite to treat problems of the throat, spleen, and spine, and placed pieces of azurite on the body to alleviate congestion. In Native American tradition, azurite was a sacred stone that connected its wearer with spirit guides. According to modern metaphysicists, the energy of

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azurite helps identify and dispense with unwanted past beliefs and enables the mind to achieve higher levels of consciousness and intellectual receptivity. Metaphysicists also believe that azurite worn on the body eases rheumatic pain and discomfort, a benefit that some attribute to the mineral's copper content.

Azurite has appeared on the postage stamps of at least six nations, including Zimbabwe's 77-cent stamp of 1993, Kazakhstan's 20-tenge stamp of 1997, Switzerland's 30-centime stamp of 1960, Namibia's 10-cent stamp of 1991, Chile's 150-peso stamp of 1996, and the United States' 29-cent stamp of 1992.

TECHNOLOGICAL USES

Azurite served as major ore of copper from antiquity until about 1900, when a newly mechanized mining industry gained access to deeper copper-sulfide ore bodies. Azurite still has limited use as a pigment for specialized applications.

ABOUT OUR SPECIMENS

This is now the second mineral we have featured from Idaho, after heulandite-CA in November 2002, from a new find south of Challis, Idaho. This month's specimens come from the long abandoned Blue Jay Mine, in the Lemhi Mountains of southeastern Idaho, west of Leadore and the Montana border. It is described in a U.S. Geological Survey this way:

"The Blue Jay mine is on the glaciated south wall of the canyon of Big Eightmile Creek, and explores a deposit of chalcopyrite and secondary copper minerals disseminated in the Big Eightmile stock. The deposit, first reported in mining periodicals about 1910, was explored underground by a south-trending adit about 1,000 ft long in 1920-1921. The New Departure Copper Mining Company also constructed an aerial tram at this time, reaching from deeply oxidized outcrops of brecciated, copper-stained gossan, at an altitude of about 8,400 ft. to the valley floor. The copper deposit has been prospected repeatedly since 1921, and since 1960 has been further explored by drilling, apparently with discouraging results. Only the southern part of the potentially mineralized area has been explored. The northern part of the stock is largely concealed beneath glacial deposits, and the extent of copper mineralization remains unknown. The production from the Blue Jay mine is unknown."

This mine was known for producing good specimens of azurite, malachite, and chrysocolla, and no doubt local collectors had from time to time obtained pieces for their collections. This latest find took place when a mineral collector got bored on a fishing trip to the nearby Big Eightmile Creek. Since he just happened to have a topographic map with him, a handy item for collectors to have at all times, he took it out and noticed a mine symbol, prompting a desire for further investigation. He traveled up the creek to where a road was supposed to have a bridge across the creek. Finding it had been washed out for many years, he used a crowbar to dislodge some big rocks and make his own bridge! An arduous drive to the 8400 foot level was next. He describes what he found there:

Figure 2. View from Blue Jay mine, looking west, over the old mine dumps.

"The original adit (horizontal passage from the surface into the mine) is now gone, with several east-west bulldozer trenches dug as exploration trenches cutting the old adit, and burying its entrance. A loading chute (inclined channel or passage) is still present, with mine car railroad tracks trending north, that are buried at their north end under bulldozer debris.

Figure 3. View of the old ore bin at the Blue Jay mine.

"There are 3 open cuts trending east-west into the hillside on the lower side of the Blue Jay at about 8,400 feet. Higher up the mountain are other bulldozer scrapings and trenches. Some of them appear to date from the 1920's, and these are heavily overgrown. More recent scrapings appear to have been done in the past 20-30 years. Traces of azurite and especially malachite are widespread.

"The best appearance for azurite was found in the central east-west cut, on the north side. About 8 foot up from the bottom of the trench was a small patch of weathered azurite about 18" across. Trenching into this area proved that the azurite showing was the top of a breccia zone that extended downward an unknown distance. (Breccia, acceptably pronounced as "BRECK-ke-a" or "BRET-she-a", is a coarse-grained rock composed of angular broken rock fragments held together by a naturally occurring mineral cement or a fine-grained matrix.)

Figure 4. Collecting azurite in the breccia zone.

"The matrix rock is a highly silicified (silica [SiO_2] enriched), fine-grained pod of tactite (a rock of complex mineralogical composition, formed by contact metamorphism and metasomatism of carbonate rocks, also known as skarn). Visible sulfide minerals are chalcopyrite and sphalerite, as small grains scattered through the siliceous matrix; biotite, pyroxene and minor feldspar made up the rest of the matrix, all as small crystals less than 1-2mm across. This skarn pod (an ore body of an elongate or lenticular shape) was highly brecciated, with individual fragments up to about 24" across, grading down to small pebble-sized fragments. Most breccia fragments are coated with varying amounts of azurite and malachite. In the original outcrop area of the trench, at the top of the exposure, azurite was the dominant mineral, with no malachite. Breccia fragments up to 24 inches across were sometimes entirely coated with bright blue, drusy, microcrystalline azurite. As I worked downward in the breccia zone, malachite became more common, initially as the typical malachite green, which gradually became lighter green with depth. By the time the bottom of the pod was found, where it was in sharp contact with the Big Eightmile Creek stock, the malachite was grading into what appears to be rosasite of a pretty, almost turquoise blue color. Some chrysocolla is also present in this lowermost area of the deposit. It appears that the malachite became increasingly rich in zinc towards the bottom of the pod, which would account for the lighter color, in a downward direction, until the zinc became dominant and the malachite changed to rosasite (the rosasite has been sight identified only, and has not been x-rayed for verification.)

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“The initial azurite at the top of the pod was primarily botryoidal (having the form of a bunch of grapes), which gradually changed to drusy azurite from the middle of the pod to the base of the pod. The color of the azurite became lighter and brighter blue with depth. From near the center of the breccia pod to the bottom of the pod, the malachite became more common, and in some areas the breccia fragments are all botryoidal malachite with no azurite.

“The total size of the breccia pod is approximately 10 feet from top to bottom and about 8 feet wide, and extended about 8 feet into the side of the cut. The sides and bottom of the breccia pod were in sharp contact with diorite of the Big Eightmile Creek stock. (Diorite is a group of plutonic [formed at considerable depth by the crystallization of magma and/or by chemical alteration] rocks intermediate in composition between acidic and basic, characteristically composed of hornblende, oligoclase or andesine, pyroxene, and sometimes a little quartz.) The entire pod was removed during my collecting efforts. The copper mineralization extends a short distance into the stock along these edges only as light green stains of malachite.

“This appears to be a single occurrence of azurite and malachite. Minor azurite and malachite showings are present in several areas of the open cuts, but exploration trenching into these showed no collector quality mineralization.”

It takes only a quick glance to be blown away by the intense color of this month’s mineral, and close inspection with a lens reveals azurite as small spheres, also in its botryoidal form, and as minute crystals that make up the druse. Some pieces have bright green malachite in similar forms. Some of the malachite is a lighter shade of green than normal, caused by the presence of zinc in its crystal structure, as noted above. And a few pieces show some light blue chrysocolla, and some, what is perhaps the similarly blue-colored but much rarer carbonate group mineral, rosasite. As you can see by its formula of $(Cu^{2+},Zn)_2(CO_3)(OH)_2$, it is quite similar chemically to azurite and malachite, with the addition of zinc (Zn). However, the identification of rosasite is based only on the crystal form and association, and cannot be made certain unless further testing is done.

We’ve made several references to the intense blue color of azurite, described mainly as azure, or sky blue, or as cornflower blue, a deep brilliant blue color with a tinge of purple. This latter color reference comes from the cornflower, a favorite garden flower originally native to the Mediterranean, cultivated and also naturalized in North America, that has showy heads of blue, purple, pink, or white flowers. Its official name is *centaurea cyanus*, of the composite family, and it is also known as Bachelor’s-button and Bluebottle. Large crystals of azurite from Tsumeb and other places are occasionally seen on display that have this deep intense blue color with a tinge of purple, a color that can have an emotional effect on a person. We’re already looking forward to featuring azurite again!

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