

December 2008 Mineral of the Month: Azurite

Azurite is renowned for the intensity of its blue color, and malachite for its striking green color. These two popular minerals are often found together and are similar in many ways and quite different in other. Now that we are featuring azurite for the third time, we can use this opportunity to highlight the similarities and differences of these two highly desirable minerals.

PHYSICAL PROPERTIES

Chemistry: $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$ Basic Copper Carbonate (Copper Carbonate Hydroxide)

Class: Carbonates

Subclass: Carbonates with hydroxyl or halogen anions

Group: Azurite

Crystal System: Monoclinic

Crystal Habits: Usually as prismatic crystals in tabular or bladed habit, often thin in one direction; crystal faces sometimes faintly wavy or striated; also in earthy, massive, stalactitic and stalagmitic, radiating, fibrous, crusty, and botryoidal forms.

Color: Azure blue, also light-to-dark blue

Luster: Vitreous, brilliant

Transparency: Transparent and translucent to opaque

Streak: Light blue

Cleavage: Perfect-to-good in one direction, good in a second, fair in a third

Fracture: Conchoidal, brittle

Hardness: Mohs 3.5-4.0

Specific Gravity: 3.7-3.8

Luminescence: None

Refractive Index: 1.730-1.838

Distinctive Features and Tests: Azure-blue color, light-blue streak, and close association with malachite $[\text{Cu}_2(\text{CO}_3)(\text{OH})_2]$. Azurite is softer than the blue minerals lazulite $[\text{MgAl}_2(\text{PO}_4)_2(\text{OH})_2]$ and lazurite [lapis lazuli, $(\text{Na,Ca})_8\text{Si}_6\text{Al}_6\text{O}_{24}[(\text{SO}_4)_2\text{S,Cl}(\text{OH})_2]$]. Can also be confused with bright-blue linarite $[\text{PbCu}(\text{SO}_4)(\text{OH})_2]$, but azurite effervesces in dilute hydrochloric acid, while linarite does not.

Dana Classification Number: 16a.2.1.1.2.1.1

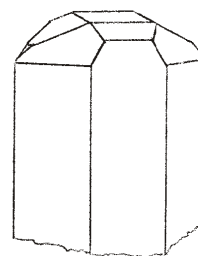


Figure 1. Azurite crystal, from *Mineralogy* by John Sinkankas, used by permission.

NAME

Azurite, correctly pronounced "AZH-ur-ite," is named for its azure color. The word "azure" derives from the Persian *lâzhuward*, meaning "heaven," or "blue." Alternative names for azurite include "azure copper ore," "blue copper," "blue copper ore," "blue malachite," "caeruleum," "bergblau," "kupfer lazure," and "chessylite." As a blue pigment, azurite has been called "mountain blue," "blue bice," and "blue verditer." Italian artists knew azurite pigment as "*azzurro della magna*." In European mineralogical literature, azurite appears as *azurit* and *azurita*.

COMPOSITION

September 1996 was our seventh month of operation, and azurite was the featured mineral. We sent to Deluxe members fine specimens from the Daye Copper Mine (Fengjiashan Mine), Edong Mining District, Daye Co., Huangshi Prefecture, Hubei Province, China. This mine was under government control then, but now is privately owned, and produces specimens only on a limited basis. Unable to get small, inexpensive specimens from Daye, we sent our Junior Club members small azurite rosettes from the Morenci Mine, Copper Mountain District (Clifton-Morenci District), Shannon Mts., Greenlee Co., Arizona,

December 2008 Mineral of the Month: Azurite

the second largest open-pit copper mine operating in the United States. We always want to have an exceptional mineral to feature in December, to give extra incentive to gift-givers, so we featured azurite for the second time in December 2004, sending eager Club members choice pieces of drusy azurite on matrix from the Blue Jay Mine, Leadore District, Lemhi Co., Idaho. Four years later, we're again happy to finish the year by sending you these exceptional specimens from China!

The chemical formula $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$ indicates that azurite is a basic copper carbonate or basic copper hydroxide containing the elements copper (Cu), carbon (C), oxygen (O), and hydrogen (H). Azurite's molecular weight consists of 55.31 percent copper, 37.14 percent oxygen, 6.97 percent carbon, and 0.58 percent hydrogen. Like all molecules, azurite's molecules consist of positively charged ions called cations and negatively charged ions called anions. Azurite's simple cation consists of three copper (cupric) ions 3Cu^{2+} with a collective +6 charge. The compound anion contains two radicals (groups of atoms of different elements that act as entities in chemical reactions)—two carbonate radicals $2(\text{CO}_3)^{2-}$ and two hydroxyl radicals $2(\text{OH})^1-$. The collective -4 charge of the two carbonate radicals and the collective -2 charge of the two hydroxyl radicals provide a total anionic charge of -6. This balances the total cationic charge of +6 to provide the azurite molecule with electrical stability.

Azurite is a member of the carbonates, a class of nearly 100 minerals in which metallic elements are combined with the carbonate radical $(\text{CO}_3)^{2-}$. The carbonate radical, the fundamental structural unit of all carbonates, is a flat, triangular structure consisting of a central carbon ion (C^{4+}) covalently bound by shared electrons to three equidistant oxygen ions (3O^{2-}). The +4 charge of the carbon ion and the -6 charge of the three oxygen ions provide the carbonate radical with a collective -2 charge. These negatively charged, triangular carbonate radicals bond ionically to positively charged metal ions to form carbonate minerals.

The azurite crystal lattice is built of repeating square units composed of two oxygen ions (from the carbonate radicals) and two hydroxyl radicals that bond ionically to each copper ion and are positioned laterally or diagonally at the sides of the square. These square units are linked together in three-dimensional structures by covalent bonding between the oxygen ions of adjacent carbonate radicals. Azurite crystallizes in the monoclinic system, which is defined by three axes of unequal length, two of which are perpendicular to each other. Because bonding strength varies along the three lattice planes, azurite's cleavage is perfect-to-good in one direction, good in a second, and fair in a third. The weak ionic bonding between the copper, carbonate, and hydroxyl radicals explains azurite's brittleness and relatively low hardness of 3.5-4.0.

A diagnostic property of azurite and most other carbonates is that they effervesce in contact with hydrochloric acid (HCl). This occurs because the acid's chlorine ions (Cl^1-), which have extremely high chemical reactivity, replace the carbonate radicals in carbonate minerals. In azurite, this effervescence reaction is written as $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2 + 6\text{HCl} = 3\text{CuCl}_2 + 4\text{H}_2\text{O} + 2\text{CO}_2\uparrow$?, which shows quantitatively how azurite and hydrochloric acid react to form copper chloride, water, and gaseous carbon dioxide, the latter producing the diagnostic bubbles of effervescence.

Carbonate minerals are the inorganic salts of carbonic acid (H_2CO_3). Carbonic acid, which consists of hydrogen ions (H^1+) and bicarbonate ions $[(\text{HCO}_3)^1-]$, forms in near-surface conditions when atmospheric carbon dioxide (CO_2) or carbonate ions $(\text{CO}_3)^{2-}$ from carbonate rocks dissolve in water according to the formula $\text{H}_2\text{O} + \text{CO}_2 = \text{H}_2\text{CO}_3$. Under proper conditions of temperature, pressure, and chemistry, free metal ions can then bond ionically with bicarbonate ions to form carbonate minerals.

Azurite is a secondary mineral found in the oxidized portions of copper deposits. It can form either from the reaction of carbonic acid with copper-sulfide minerals or from the reaction of copper-bearing solutions

December 2008 Mineral of the Month: Azurite

with calcite [calcium carbonate, CaCO_3]. Azurite is almost always associated with malachite [basic copper carbonate, $\text{Cu}_2(\text{CO}_3)(\text{OH})_2$], and often with cuprite [cuprous oxide, Cu_2O], chalcopyrite [copper iron sulfide, CuFeS_2], calcite, chalcocite [copper sulfide, Cu_2S], native copper [Cu], chrysocolla [basic hydrous copper aluminum silicate ($\text{Cu,Al})_2\text{H}_2\text{SiO}_5(\text{OH})_4\text{nH}_2\text{O}$], and linarite [basic lead copper sulfate, $\text{PbCu}(\text{SO}_4)(\text{OH})_2$].

Although most carbonates are colorless, white, or only lightly colored, azurite is an exception. Azurite is an idiochromatic (self-colored) mineral, meaning that essential chemical composition and crystal structure, and not secondary coloring agents, create its characteristic and diagnostic azure-blue color. Copper, the essential metal in azurite, is a powerful pigmenting agent for the colors blue and green. Copper ions cause the azurite crystal lattice to absorb all the wavelengths of white light except a narrow band of pure blue, which it reflects as a diagnostic azure-blue color.

The Dana mineral-classification number 16a.2.1.1 first identifies azurite as a carbonate with hydroxyl or halogen anions (16a). The subclassification (2) defines it by the general formula $(\text{AB})_3(\text{XO}_3)2\text{Z}_q$, in which "A" or "B" are divalent metal ions such as copper (Cu^{2+}), "X" is a tetravalent non-metal such as carbon (C^{4+}), "Z" is a hydroxyl or halogen ion, and "q" is a variable quantity. Azurite is then assigned to the azurite group (1) as the first (1) and only member.

COLLECTING LOCALITIES

Azurite is common in oxidized copper deposits worldwide; the following list includes only localities that have yielded notable specimens. Our specimens were collected at the Liufengshan copper mine in the Anqing-Guichi mining district near Guichi in Chizhou Prefecture, Anhui Province, in the People's Republic of China, a locality noted for fine azurite specimens. Other Chinese azurite localities are the Shilu Mine in Yangchun County, Yangjiang Prefecture, Guangdong Province; the Chengmenshan copper-molybdenum-gold deposit at Jiurui, Jiurui Prefecture, Jiangxi Province; and the Jinman copper mines in Lanping County, Nujiang Autonomous Prefecture, Yunnan Province. Russian specimens come from the Dalnegorsk Mine at Primorskiy Kray, Magadianskaya Oblast', in the Far-Eastern Region.

Fine African specimens come from the Tsumeb Mine at Tsumeb, Otjikoto Region and the Kombat Mine at Kombat in the Grootfontein District in the Otjozondjupa Region, both in Namibia. Other African sources are the Toussit mines at Toussit in Oujda-Angad Province in Morocco's Oriental Region; the Shangulowé Mine at Kambove, Katanga Province, Democratic Republic of Congo; the Kabwe (Broken Hill) Mine at Kabwe in Zambia's Central Province; and the Wessels Mine at Hotazel in the Kalahari Manganese Fields in South Africa's North Cape Province.

Australian azurite comes from the Aerial and Silent Sisters mines at Wyloo Homestead in Western Australia, the Burra Burra Mine at Burra in the Mt. Lofty Ranges of South Australia, the Broken Hill district mines at Broken Hill in New South Wales, and the Great Australia Mine in the Cloncurry district of the Mount Isa-Cloncurry region of Queensland. South American specimens are found in Bolivia at the Veta Verde and María Elena mines at Coracora in Pacajes Province, La Paz Department, and at the Llallagua Mine at Llallagua in Bustillos Province in Potosí Department; in Chile at the Manto Cuba Mine at Inca de Oro in Chañaral Province in the Atacama Region; and in Argentina at the Caplitas mines at Andagala in Catamarca. Mexican azurite sources include the Ojuela Mine at Mapimí in Durango, where our May 2008 specimens of azurite were dug, the San Cristóbal and China mines at La Huacana in Michoacán, the San Carlos Mine at Mazapil in Zacatecas, and the Chantuplan mines near Taxco in Guerrero.

Europe's best-known azurite sources are the type locality at Chessy-les-Mines at Chessy, Rhône, Rhône-Alpes, France, and the mines of Bad Lauterberg in the Harz Mountains of Lower Saxony, Germany.

December 2008 Mineral of the Month: Azurite

In the United States, azurite specimens are collected in Arizona at the Warren district mines at Bisbee in the Mule Mountains of Cochise County, the Bluebird Mine at Globe in the Globe-Miami district of Gila County, the open-pit mines at Clifton in the Clifton-Morenci district in the Shannon Mountains of Greenlee County, and the old Verde district mines at Jerome in Yavapai County. Azurite is found in Colorado at the Sherman and Adelaide mines in the Leadville district in Lake County, and the Bandera Mountain mines at Silverton in San Juan County; in California at the Empress and Cerro Gordo mines in the Darwin district in the Argus Range of Inyo County, and the Mohawk Mine in the Clark Mountains of San Bernardino County; in Montana at the Continental Pit at Butte in Silver Bow County; and in Nevada at the Bullfrog Mine at Beatty in Nye County. Specimens are also collected in New Mexico at the Kelly and Graphic mines at Magdalena in Socorro County; in Utah at the Bingham Canyon Mine in the Oquirrh Mountains of Salt Lake County, and the Hidden Treasure Mine in the Ophir district of Tooele County; in Idaho at the Hub and Paymaster mines in the Lava Creek district of Butte County; and in Oklahoma at the Eagle-Picher Mine at Cheta in Jackson County. Moving eastward, azurite is found in Michigan at the Champion Mine at Painesdale in Houghton County, and the Algoman mines at Mass City in Ontonagon County; in Arkansas at the Bellah and Steward mines at Gillham in Sevier County; in Pennsylvania at the French Creek mines at St. Peters in Chester County; in New Jersey at the Schuyler Mine at North Arlington in Bergen County; and in Maryland at the Hunting Hill, Rockville, and Bardon quarries at Rockville in Montgomery County.

JEWELRY AND DECORATIVE USES

Relative softness and brittleness limit the use of azurite in jewelry to beads and cabochons for wear in necklaces and pendants. Crystals are occasionally faceted into collectors' gems, but because of the tendency of large azurite crystals or gems to appear black, these are no larger than one carat in size. Massive and banded azurite is an ornamental stone that is fashioned into trinket boxes, ashtrays, figurines, paperweights, and inlay pieces. Intergrowths of azurite with other minerals, especially green malachite, also serve as ornamental stones.

Its vivid blue color, many interesting habits, and ready availability make azurite one of the most popular of all mineral collectibles. Composite specimens of blue azurite intimately associated with green malachite are especially desirable and valuable.

The most famous azurite specimen is the "Newmont Azurite," which is displayed at the American Museum of Natural History in New York City. This 12x12x5-inch cluster of magnificent azurite crystals, some 8 inches long, was recovered from Namibia's Tsumeb Mine in 1952. It was originally traded by a miner to pay off his bar bill, but was quickly reclaimed by the Newmont Mining Company, which then owned the mine. In 1977, this specimen was formally appraised for \$250,000.

HISTORY AND LORE

Bright-blue azurite has served as a pigment and a green pottery glaze since about 3500 B.C. Azurite was one of the first ores of copper in the early Bronze Age, and anthropologists believe that the association of native copper and azurite helped early metalworkers to realize the connection between native metals and metal ores. During the Middle Ages and the later Renaissance, azurite powder was the primary blue pigment used by European artists. Finely ground azurite provided a lighter blue color, while coarser azurite particles produced more intense blues. Italian artists knew azurite pigment as *azzurro della magna*, literally "great blue." Azurite-based paints were used in many classic works of art until the mid-1600s, when artists realized that the blue colors of older artwork were slowly turning green. Centuries later, scientists learned that this was caused by the slow oxidation of azurite (see "Azurite and Malachite: A Close Relationship").

December 2008 Mineral of the Month: Azurite

By the early 1800s, scientists had realized that azurite was a carbonate mineral, but they were still unable to chemically distinguish it from malachite. Because smelting azurite and malachite yielded almost the same amount of metallic copper, azurite was thought to be a color phase of malachite. The two minerals were finally differentiated in 1824 by the French mineralogist and geologist François Sulpice Beudant (1787-1850). Working with specimens collected from the great oxidized-copper deposit at Chessy-les-Mines at Chessy, Rhône, Rhône-Alpes, France, Beudant demonstrated the compositional difference between the two basic copper carbonates and assigned the name "azurite" to the blue mineral. Although azurite had previously been mined from many other localities, Chessy-les-Mines was later designated as the type locality. In 1928, researchers used X-ray diffraction techniques to reveal the subtle differences in the monoclinic structures of both minerals.

Azurite has served for centuries as an indicator mineral for prospectors, who knew that its bright blue color in surface outcrops indicated the presence of oxidized copper and associated precious- and base-metal mineralization. In the late 1800s, prospectors discovered the great copper deposits of the western United States and Australia by investigating the blue stains of azurite (and the green of malachite) in outcrops. Until the early 1900s, azurite and malachite from shallow, oxidized deposits were the primary ores of copper.

Medieval physicians prescribed powdered azurite to alleviate ailments of the throat, spleen, and spine, and suggested wearing azurite necklaces to ease pulmonary and bronchial congestion. To southwestern Native American cultures, azurite was a sacred stone that connected its wearer with spirit guides. According to modern metaphysicists, azurite helps to identify and dispense with unwanted past beliefs and enables the mind to achieve higher levels of consciousness and intellectual receptivity. When worn on the body, azurite is thought to ease rheumatic pain and discomfort, a benefit that some traditional medical practitioners attribute to the mineral's copper content.

Azurite has appeared on 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.

AZURITE AND MALACHITE: A CLOSE RELATIONSHIP

Our specimens are composites of blue azurite and green malachite, both basic copper carbonates that crystallize in the monoclinic system, have similar origins, occur in the same mineralogical environments, and share many chemical and physical properties. Specimens of azurite almost always contain some malachite, and vice versa. The contrast between the vivid blue and rich green colors makes azurite-malachite one of the most collectible and attractive of all composite-mineral specimens. Yet despite their many similarities, azurite and malachite also have important differences that are explained by comparing their chemistry and structure.

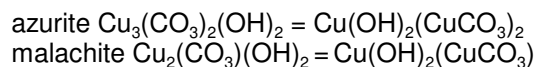
Turning first to the chemistry, we see that azurite and malachite have similar chemical formulas and compositions:

	% copper	% oxygen	% carbon	% hydrogen
Azurite $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$	55.31	37.14	6.97	0.58
Malachite $\text{Cu}_2(\text{CO}_3)(\text{OH})_2$	57.48	36.16	5.43	0.91

Because of its somewhat lower copper content, azurite is slightly less dense (specific gravity 3.7-3.8) than malachite (specific gravity 3.9-4.0).

December 2008 Mineral of the Month: Azurite

When rewritten, the formulas of these two minerals show that malachite is more oxidized than azurite:



In the rewritten formulas, we see that azurite has a $\text{Cu}(\text{OH})_2:(\text{CuCO}_3)$ ratio of 1:1, while malachite has a ratio of 2:1. Since $\text{Cu}(\text{OH})_2$ is less oxidized than CuCO_3 , azurite, with its 1:1 ratio, is the less oxidized mineral and thus occupies an earlier stage than malachite in the oxidation process. Both azurite and malachite crystallize directly from aqueous solutions. Because azurite requires less oxidation energy to form in an aqueous mineralogical environment, it usually precipitates out of solution before malachite. However, when greater amounts of oxidation energy are available, malachite can crystallize before azurite. Changes in levels of available oxidation energy within the aqueous solutions can cause alternating precipitation of azurite and malachite that forms the alternating, well-defined layers of blue azurite and green malachite seen in many of our specimens.

One major difference between the two is that because azurite is less oxidized than malachite, it is also less chemically stable. When exposed to water (H_2O), azurite will slowly oxidize into malachite according to the formula $2[\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2] + \text{H}_2\text{O} \rightarrow 3[\text{Cu}_2(\text{CO}_3)(\text{OH})_2] + \text{CO}_2$. In this reaction, two molecules of azurite and one molecule of water combine to yield three molecules of malachite and one molecule of carbon dioxide. The oxidation of azurite into malachite is a very slow, gradual process that is often reflected in color gradations between blue and green. In your specimen, see if you can find intermediate blue-green colors that indicate where azurite is slowly oxidizing into malachite. Azurite's chemical instability and its tendency to oxidize over time into malachite explain why malachite is the much more abundant mineral.

Although both azurite and malachite crystallize in the monoclinic system, their lattice structures are not identical. As previously explained (see "Composition"), azurite's atomic structure consists of square units composed of two oxygen ions (from the carbonate radicals) and two hydroxyl radicals that are ionically bound to each copper ion and positioned laterally or diagonally at the sides of the square. Covalent bonding between adjacent carbonate radicals links these square units together in three-dimensional structures to form the crystal lattice. But in malachite, the copper ions are bound ionically to surrounding structures alternately composed of four oxygen ions and two hydroxyl radicals or four hydroxyl radicals and two oxygen ions. These structures are, in turn, linked together by covalent bonding between adjacent carbonate radicals to form the crystal lattice.

Because of these differences in unit structure, malachite, unlike azurite, has one atomic plane dominated solely by weak ionic bonding that creates perfect, one-directional cleavage. Structural differences between azurite and malachite also explain their different crystal habits. Azurite often forms bladed and tabular crystals, while malachite rarely forms visible crystals, occurring instead primarily in the massive and botryoidal forms. In your specimen, note that azurite occurs as well-formed, bladed and tabular crystals, while malachite assumes mostly massive, botryoidal, and incrusting forms. Any green, tabular crystals are almost certainly pseudomorphs of malachite-after-azurite. Pseudomorphs form when an original mineral crystal is replaced molecule-by-molecule by a second mineral, while retaining the shape of the original mineral. Pseudomorphs thus possess the chemical composition of the new mineral, but the shape of the original mineral. In malachite-after-azurite pseudomorphs, the original azurite crystals have oxidized into malachite. The resulting pseudomorphs have malachite's chemistry, crystal structure, and green color, but retain the outward crystal form of the original, bladed azurite crystals.

Color is the most obvious physical difference between azurite and malachite. As idiochromatic or self-colored minerals, both azurite and malachite owe their respective blue and green colors to differences in

December 2008 Mineral of the Month: Azurite

their crystal lattices. The copper (cupric, Cu^{2+}) ion is a powerful chromophore or coloring agent. As noted, copper ions within the azurite lattice absorb all wavelengths of white light except for a narrow band of blue, which is reflected as the diagnostic, vivid blue color. But in malachite's structure, different positions and energy levels of the copper ions cause the lattice to reflect the blue, green, and yellow wavelengths of white light that we perceive as its diagnostic, rich green color.

TECHNOLOGICAL USES

Until 1910, azurite was a major ore of copper; it still occasionally serves as a minor ore. Azurite now has limited use as a pigment for specialized applications.

ABOUT OUR SPECIMENS

As noted, our azurite specimens were collected at the Liufengshan Mine in the Anqing-Guichi mining district near Guichi in Chizhou Prefecture, Anhui Province, in the People's Republic of China. Located in east-central China, Anhui Province is bisected by the Yangtze River. Chizhou Prefecture is in the southern part of Anhui Province and south of the Yangtze River. The Liufengshan (which translates loosely to "Six Mountaintops") Mine is located near Guichi, population 100,000, which is 270 miles west of the major port city of Shanghai. A city of historical and cultural importance, Guichi gained prominence during the Tang Dynasty (A.D. 618-907) and is known for its poets' contributions to Chinese literature. Located at the foothill juncture of the Huangshan and Jiuhua mountain ranges, Guichi has a subtropical climate that favors the production of rice, bamboo, and tea.

Guichi is located within the Huangshaping Polymetallic District, a belt of geologically related lead, zinc, silver, tungsten, copper, molybdenum, and iron deposits. The origin of this mineralization began when the tectonic collision of the South China and North China cratons (stable sections of continental crust) and the westward subduction of the Paleo-Pacific Plate produced massive crustal deformation and three mountain-building episodes: the Indosinian Orogeny 220 million years ago, the Yanshanian Orogeny 160 million years ago, and the Himalayan Orogeny just 40 million years ago. These tectonic stresses uplifted and fractured great sections of basement rock, enabling magma and associated hydrothermal solutions to surge upward into older, carbonate sedimentary rocks, where they created both skarn and hydrothermal mineral deposits. Skarns form from metasomatism (the introduction of new elements into rock) during contact metamorphism. Hydrothermal deposits form when mineral-rich, superheated solutions associated with magma are forced into faults and fissures in the surrounding country rock to form vein- and replacement-type structures rich in metal sulfides. The 150-mile-long Huangshaping Polymetallic District has a succession of both skarn and hydrothermal mineral deposits.

The Liufengshan copper-iron deposit was emplaced when acidic, copper- and iron-rich, hydrothermal solutions rose upward into formations of fractured limestone, a marine sedimentary rock rich in calcite. The acidic solutions dissolved parts of the limestone to create voids. As contact with the carbonates decreased their acidity, these solutions precipitated metal sulfides that filled the voids. The resulting mineralization consists largely of chalcocite [copper sulfide, Cu_2S], pyrite [iron disulfide, FeS], and chalcopyrite [copper iron sulfide, CuFeS_2] emplaced in a complex system of veins and pods. Although the mineralization was emplaced at depth, subsequent surface erosion has exposed the upper part of the deposit to water and atmospheric oxygen and initiated the process of oxidation. Contact with both atmospheric carbon dioxide and the carbonate host rock converted circulating groundwater to weak carbonic acid which reacted with the sulfides to form azurite, malachite, and the iron-oxide minerals goethite [basic iron oxide, $\text{FeO}(\text{OH})$], hematite [iron oxide, Fe_2O_3], and limonite (a variable mixture of iron oxides and hydroxides).

December 2008 Mineral of the Month: Azurite

The Liufengshan deposit was discovered about 1900, but it was not mined until 1970, and then only as part of a government economic-development program. Owned and operated by the Tongling Nonferrous Metals Company, the deposit was first mined with open pit methods to exploit the shallow, oxidized ores. Then in the early 1990s, miners sank three shafts to access deeper mixed-sulfide and oxidized ores from underground workings. The open pit ceased operations in 1999, but underground production continued until 2006 when the mine finally closed.

Since 2003, the underground workings have yielded many fine specimens of azurite-malachite. These workings penetrate a heavily faulted zone of breccia (rock fragments embedded in a fine-grained matrix) characterized by a reddish clay rich in hematite in which mining is difficult and dangerous. Sections of this zone consist of more stable clays richer in limonite and goethite that contain numerous vugs ranging in size from a few inches to two feet. The walls of many of these vugs are lined with thick layers of azurite-malachite.

Azurite-malachite specimens from the Liufengshan Mine are typically layered and intergrown, suggesting that the oxidation chemistry has changed repeatedly during crystallization, thus enabling azurite and malachite to crystallize individually in alternating stages. After crystallization was complete, some of the azurite oxidized into malachite. Many of our specimens clearly show the original azurite-malachite layers as well as light crusts of green malachite atop blue azurite, where azurite has oxidized into malachite. With a loupe or magnifying glass, observe the excellent development of the small, bladed and tabular, azure-blue to blackish-blue azurite crystals that line small vugs. Azurite-malachite specimens from the Liufengshan Mine compare favorably with classic specimens from the mines at Bisbee, Arizona.

Although copper production at the Liufengshan Mine ended in 2006, independent miners have continued to work the dangerous underground drifts in the fault zone for azurite-malachite specimens to sell to visiting dealers. But specimen production was halted in 2007 when the Chinese government ordered the mine stripped of all steel and timbers, including the ground support and shaft-hoisting equipment. Our specimens are thus among the last to come from the Liufengshan Mine.

Since azurite is a fairly abundant mineral, we may tend to take it for granted, until a particularly striking specimen catches our eye and mesmerizes us! This happens to us at shows when we have occasion to see some of the world's most extraordinary azurite, and also occurred as we were examining our specimens prior to sending them to you. Azurite's best feature must be the intensity of its blue color, which evokes an emotional response in many people. Composite specimens of intense blue azurite and bright green malachite are especially pleasing to the sense of sight, the complimentary colors stirring in some of us a feeling of intense peace. And after absorbing this write-up, we will have a greater appreciation for these two minerals, so similar yet so different, but both so desirable!

References: *Dana's New Mineralogy*, Eighth Edition; *Encyclopedia of Minerals*, Second Edition, Roberts, et al, Van Nostrand Reinhold Company; *2004 Glossary of Mineralogical Species*, J. A. Mandarino; *Mineralogy*, John Sinkankas, Van Nostrand Reinhold Company; *Gemstone and Mineral Data Book*, John Sinkankas, Geoscience Press; *The Complete Guide to Rocks & Minerals*, John Farndon, Hermes House, 2007; *Gemstones of the World*, Walter Schumann, Sterling Publishing Company; *Studies in Ancient Technology: Metallurgy in Antiquity*, R. J. Forbes, Brill Academic Publications; "Connoisseur's Choice: Azurite: Tsumeb, Namibia, and Toussit, Oujda, Morocco," Robert B. Cook, *Rocks & Minerals*, January-February 2002; "Some Thoughts About Azurite," Paul E. Desautels, *Rocks & Minerals*, January-February 1991; "Famous Mineral Localities: Bisbee, Arizona," R.W. Graeme, *The Mineralogical Record*, September-October 1981; "Abstracts of the FM-TGMS-MSA Symposium on Azurite and Other Copper Carbonates," K. Wenrich, *The Mineralogical Record*, January-February 1991; "Azurite, Malachite, and the Copper Age," Steve Voynick, *Rock & Gem*, September 2000; "Azurite," Bob Jones, *Rock & Gem*, November 1977; "Minerals in Depth: Azurite," Bob Jones, *Rock & Gem*, March 1991; "Azurite and Malachite," *Geology Today*, R. J. King, July-August 2001; "The Frugal Collector: Azurite and Malachite," Bob Jones, *Rock & Gem*, November 2003.