

Mineral of the Month Club January 2015

CHRYSOCOLLA

This month we are featuring chrysocolla, a complex, blue-green, copper mineral from Peru. Our write-up discusses chrysocolla's mineralogy and gemology, and explains why mineralogists question its validity as a mineral species.

OVERVIEW

PHYSICAL PROPERTIES

Chemistry: $(\text{Cu,Al})_2\text{H}_2\text{Si}_2\text{O}_5(\text{OH})_4 \cdot n\text{H}_2\text{O}$ Basic Hydrated Copper Aluminum Acid Silicate (This is an ideal formula; actual composition is variable.)

Class: Silicates

Subclass: Phyllosilicates

Group: Chrysocolla

Crystal System: Orthorhombic

Crystal Habits: Often botryoidal; also occurs in massive, stalactitic, stalagmitic, crusty, and earthy forms. Crystals, which are rare, are acicular or fibrous. Chrysocolla usually forms cryptocrystalline or amorphous masses.

Color: Green, greenish-blue, bluish-green, and blue; impurities can create blackish-blue and brownish colors.

Luster: Vitreous to greasy, waxy, earthy, and dull.

Transparency: Translucent to opaque

Streak: White to pale shades of blue or green

Cleavage: None

Fracture: Uneven to subconchoidal; brittle.

Hardness: 2.5-3.5

Specific Gravity: 1.9-2.4

Luminescence: None

Refractive Index: 1.575-1.636

Distinctive Features and Tests: Best field-identification marks are green, greenish-blue, bluish-green, and blue colors; lack of discernible crystals; low density; softness; and occurrence in oxidized, copper-rich environments in association with other green-blue, oxidized copper minerals. Can be confused with turquoise [basic hydrated copper aluminum phosphate, $\text{CuAl}_6(\text{PO}_4)_4(\text{OH})_8 \cdot 4\text{H}_2\text{O}$] and the green-blue variety of smithsonite [zinc carbonate, ZnCO_3].

Dana Classification Number: 74.3.2.1

NAME: The name "chrysocolla," pronounced kriss-uh-KOLL-uh, stems from the Greek words *chrysos*, meaning "gold," and *kolla*, or "glue," alluding to a similar material used in ancient Greece as a flux to solder gold. Chrysocolla has also been known as "chrysocollite," "chrysocole," "chalstakite," "cornuite," "demidovite," "dillenbergitte," "liparite," "copper pitchblende," "somervillite," and "lianca." "Aluminian chrysocolla" is an aluminum-rich variety,

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“cyanochalcite” is a copper-rich variety, and “aluminian ferrian” is an aluminum-rich and iron-rich variety. “Gem silica,” a valuable gemstone, is a silicified form of chrysocolla. “Eilat stone,” or “King Solomon’s stone,” is an intergrowth of chrysocolla, turquoise, azurite, and malachite from Israel; “Abdollah-Giw turquoise” is a chrysocolla variety from Iran. In European literature, chrysocolla appears as *chrysocolle*, *chrysocola*, and *Chrysokoll*.

COMPOSITION & STRUCTURE: Based on its ideal chemical formula, the molecular weight of chrysocolla is made up of 33.86 percent copper, 2.05 percent aluminum, 1.93 percent hydrogen, 17.10 percent silicon, and 45.06 percent oxygen. Actual percentages vary considerably. Chrysocolla is a member of the silicates, a large group of minerals formed when one or more metals combine with silicon and oxygen. Despite its poorly defined crystal structure, chrysocolla is subclassified as a sheet silicate or phyllosilicate. As a secondary copper mineral, chrysocolla forms in the oxidized or altered portions of copper-rich deposits, usually in alkaline chemical environments. It is often associated with azurite, malachite, cuprite, limonite, and quartz. Chrysocolla usually forms crusts, coatings, and fracture fillings, and also occurs as pseudomorphs. Chrysocolla is an idiochromatic or “self-colored” mineral, in which colors are caused by essential elements and/or by the light-absorption properties of the crystal lattice. Chrysocolla’s diagnostic green, greenish-blue, bluish-green, and blue colors are due to the essential element copper, a powerful chromophore (color-causing agent) for the colors blue and green. Chrysocolla is believed to crystallize in the orthorhombic system, which is characterized by three mutually perpendicular axes of different lengths. Mineralogists question chrysocolla’s validity as a mineral species because of its variable chemical composition and poorly defined crystal structure. In a 2005 chemical and structural study of chrysocolla, researchers concluded that it is not compositionally homogenous, but instead consists of several oxidized copper minerals, primarily spertiniite [copper hydroxide, $\text{Cu}(\text{OH})_2$] and other related species that are intergrown with microcrystalline quartz and amorphous-silica materials.

COLLECTING LOCALITIES: Chrysocolla is collected in Peru, Argentina, Mexico, Bolivia, Chile, France, Germany, Canada, Australia, China, Russia, Namibia, Morocco, Democratic Republic of Congo, Zambia, South Africa, Israel, Iran, and the United States (Arizona, Colorado, California, Montana, Nevada, New Mexico, Utah, Idaho, Michigan, Arkansas, Pennsylvania, New Jersey).

HISTORY, USES & LORE: Although used since antiquity as a minor gemstone and smelting flux, chrysocolla has long been confused with such other oxidized copper minerals as azurite, malachite, and turquoise. It was recognized as a distinct mineral species in 1808. Pure chrysocolla is a soft, fragile material with a bright, intense, sky-blue color that only rarely occurs in thicknesses sufficient for gemstone use. Most chrysocolla used in jewelry consists of chalcedony (microcrystalline quartz) or opal that is heavily included with microscopic particles of chrysocolla. Known as “gem silica,” this material has a bright, blue-green color, sufficient hardness to take a fine polish, and durability that suits it for gemstone use. Nicely colored, gem-quality, rough chrysocolla can cost as much as \$100 per ounce. Various forms of chrysocolla are widely misrepresented as turquoise. Also, gray or white chalcedony is often dyed blue and sold as the gem-silica variety of chrysocolla. Because it has been confused with other similarly colored, oxidized copper minerals, chrysocolla has no ancient medicinal uses or lore. But

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modern metaphysical practitioners believe that chrysocolla is a stone of communication, calmness, and peace that aids in verbal and telepathic expression, facilitates the emergence of truth and wisdom, discharges negative energies, and enhances feminine energies.

ABOUT OUR SPECIMENS: Our specimens of chrysocolla were collected at the Acari copper mine in Caraveli Province, Arequipa Department, Peru. Arequipa, one of Peru's 21 departments, is located in southwestern Peru along the Pacific coast, with interior regions extending eastward into the Andes Mountains. The Acari mine complex consists of an underground copper mine and several nearby underground gold mines, all currently inactive. The Acari copper mine produced sporadically in the 1880s and early 1900s; sustained production ceased in 1918. Exploration resumed in the 1970s and continues today. The geology and mineralization at Acari is linked the Andean Orogeny (mountain-building episode) that uplifted the Andes some 60 million years ago. At the site of the Acari copper mine, a system of fractures became filled with copper-rich hydrothermal solutions that precipitated the copper-sulfide minerals chalcopyrite, bornite, and chalcocite. The upper sections of these sulfide veins later become exposed and altered into chrysocolla and other oxidized copper minerals. Mineral specimens from the Acari copper mine first reached international markets in the 1980s. Our chrysocolla specimens were recovered in 2012 by commercial mineral collectors from Lima, Peru, who visit Acari often to search and excavate shallow zones of oxidized copper mineralization. Their recoveries are then transported to Lima and sold to foreign specimen dealers.

COMPREHENSIVE WRITE-UP

COMPOSITION & STRUCTURE

Chrysocolla is formally recognized as a mineral largely because of historical tradition. But due to its poorly defined crystal structure and variable chemical composition, some mineralogists suggest that it should correctly be classified as a mineraloid (a mineral-like material that does not meet the full qualifications of a mineral). For the purposes of this write-up, we are considering chrysocolla to be a valid species and are using its currently accepted orthorhombic crystal structure and ideal chemical formula.

This ideal chemical formula $(\text{Cu},\text{Al})_2\text{H}_2\text{Si}_2\text{O}_5(\text{OH})_4 \cdot n\text{H}_2\text{O}$ shows that chrysocolla consists of the elements copper (Cu), aluminum (Al), hydrogen (H), silicon (Si), and oxygen (O). This ideal formula represents a hypothetical chemical model; the actual chemical composition of chrysocolla varies widely. According to this ideal formula, chrysocolla's molecular weight is made up of 33.86 percent copper, 2.05 percent aluminum, 1.93 percent hydrogen, 17.10 percent silicon, and 45.06 percent oxygen.

Like all molecules, those of chrysocolla are made up of an electrically balanced mix of positively charged cations and negatively charged anions. Both cations and anions may be radicals, which are groups of different ions that behave as entities in chemical reactions. The compound cation in the chrysocolla molecule consists of two copper-aluminum radicals $2(\text{Cu},\text{Al})^{2+}$ with a collective +4 charge. In this radical, the comma indicates proportionally variable amounts of

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copper and aluminum. The chrysocolla cation also contains two hydrogen ions 2H^{1+} with a combined +2 charge. Thus, the total cationic charge is +6. The anion consists of the silica radical $(\text{Si}_2\text{O}_5)^{2-}$ and four hydroxyl ions $4(\text{OH})^{1-}$ with a combined -6 charge. The +6 cationic charge balances the -6 anionic charge to provide the chrysocolla molecule with electrical stability.

The “ $\cdot n\text{H}_2\text{O}$ ” in chrysocolla’s chemical formula indicates that it is a hydrous (or hydrated) mineral with a variable number of water molecules (H_2O), called “water of hydration,” attached to each parent molecule. The “n” in its chemical formula denotes a “variable” number of attached water molecules. These attached water molecules are electrically neutral molecules that do not affect the electrical balance of the parent molecule. In the configuration of the water molecule, two hydrogen ions 2H^{1+} are grouped closely together on one side of a large oxygen ion O^{2-} . These grouped hydrogen ions retain a small positive charge, while the opposite side of the molecule, dominated by the large oxygen ion, retains a small negative charge. Because of this polarity, water molecules behave as tiny dipole magnets that can attach themselves to other molecules by a weak attraction called “hydrogen bonding.”

Mineralogists sometimes expressed chrysocolla’s chemical formula as $(\text{Cu}_{2-x},\text{Al}_x)\text{H}_{2-x}\text{Si}_2\text{O}_5(\text{OH})_4 \cdot n\text{H}_2\text{O}$, in which “x” denotes anionic and cationic variables. In this formula, the relative proportions of copper and aluminum vary to significantly that aluminum may not even be present. The resulting change in the electrical charge in the copper-aluminum radical $(\text{Cu}_{2-x},\text{Al}_x)$ is balanced by a quantitative change in the hydrogen ions H_{2-x} . These isolated or “free” hydrogen ions are indicated by the term “acid” in chrysocolla’s chemical name of basic hydrous copper aluminum acid silicate.

Chrysocolla is a member of the silicates, a large group of minerals that form when one or more metals combine with silicon and oxygen. The basic silicate structural unit is the silica tetrahedron $(\text{SiO}_4)^{4-}$, in which a silicon ion is surrounded by four equally spaced oxygen ions positioned at the four corners of a tetrahedron (a four-faced polyhedron). In the silicates, silica anions and metal cations join together in repeating chains to form seven types of structures: independent tetrahedral silicates (nesosilicates); double tetrahedral silicates (sorosilicates); single- and double-chain silicates (inosilicates); ring silicates (cyclosilicates); framework silicates (tectosilicates); and sheet silicates (phyllosilicates).

Despite questions about its structure, chrysocolla is currently classified as a sheet silicate or phyllosilicate, the latter word derived from the Greek *phylon*, or “leaf.” In most sheet silicates, each silica tetrahedron shares three oxygen ions with adjacent tetrahedra to create thin, sheet-type structures that extend indefinitely in two directions. The sheets consist of a checkerboard-like arrangement of alternating “strips” of three tetrahedra each, that are linked together at their corners. In chrysocolla, the tetrahedra within these flat sheets form four- and/or eight-member rings. This arrangement leaves one remaining, negatively charged oxygen ion at each tetrahedral apex that attracts water molecules. Drawn by their dipolar, positive charge, these water molecules fill the spaces between the apices of the silica tetrahedra to partially satisfy the remaining tetrahedral negative charge. The water molecules are attached only by very weak hydrogen bonds that exist between the faintly positive poles of the water molecules and the

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negative charge of each tetrahedral apex. Stacks of these hydrated silica sheets are then bound together by layers of positive metal ions which satisfy their remaining negative charge.

Phyllosilicates are subclassified structurally into two-layer or three-layer groups. Chrysocolla appears to exhibit a poorly developed, three-layer or “2:1” structure, with tetrahedral and octahedral layers of metal and hydrogen ions bonded ionically between two hydrated silica sheets. In the chrysocolla structure, the middle layer consists of copper, aluminum, and hydrogen ions “sandwiched” between two tetrahedral silica layers. Within each of these three-layer sheets, a combination of ionic and strong covalent bonding creates cohesive sheet units. But the ionic attraction *between* the three-layer groups is weak. This explains chrysocolla’s low Mohs hardness of 2.5-3.5, which is very soft for a silicate mineral. Even though chrysocolla consists of about one-third copper, loose atomic packing results in a very low specific gravity of 1.9-2.4. Chrysocolla is currently considered to crystallize in the orthorhombic system, which is characterized by three mutually perpendicular axes of different lengths. Minerals that are chemically complex, or that have complex bonding (chrysocolla has both covalent and ionic bonding), often crystallize in the orthorhombic system. Chrysocolla’s poorly developed crystal structure accounts for its lack of cleavage and the fact that it rarely forms visible macrocrystals, which have an acicular or fibrous habit.

The Dana classification number 74.3.2.1 identifies chrysocolla as a phyllosilicate with modulated layers (73). It is subclassified as a phyllosilicate with joined strips in its layered structure (3). Finally, chrysocolla is assigned to the chrysocolla group (2) as the first (1) and only member.

As an idiochromatic or “self-colored” mineral, chrysocolla’s diagnostic green, greenish-blue, bluish-green, and blue colors are caused by the essential element copper, a powerful chromophore (color-causing agent) for the colors blue and green. Because of its highly variable composition, chrysocolla colors vary considerably in wavelength and intensity. Intense, clean, blue colors indicate a high copper content and few impurities. Less intense blues and a shift toward greenish-blue indicate a higher aluminum content, as well as the presence of impurities.

As a secondary copper mineral, chrysocolla forms in the oxidized or altered portions of copper-rich deposits, usually in alkaline chemical environments. It is associated with azurite [basic copper carbonate, $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$], malachite [basic copper carbonate, $\text{Cu}_2(\text{CO}_3)(\text{OH})_2$], cuprite [copper oxide, Cu_2O], limonite (a variable mixture of iron oxides and hydroxides), and quartz [silicon dioxide, SiO_2]. Chrysocolla forms crusts, coatings, and vein and fissure fillings, and also occurs as pseudomorphs that replace earlier secondary minerals.

COLLECTING LOCALITIES

Our chrysocolla specimens were collected at the Acarí copper mine in Caraveli Province, Arequipa Department, Peru. Peruvian chrysocolla also occurs at the Lily Mine at Pisco Umay in Ica Department, and at mines in Cañete Province, Lima Department. Other South American localities are in Bolivia at the Veta Verde and María Elena mines near Coracora in Pacajes Province, La Paz Department, and the Llallagua Mine near Llallagua in Rafael Bustillos

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Province, Potosí Department; in Chile at the Manto Cuba Mine at Inca de Oro in Chañaral Province, Atacama Region; and in Argentina at the Caplitas mines at Andagala, Catamarca. Mexican sources include the Ojuela Mine at Mapimí, Durango; the San Cristóbal Mine at La Huacana, Michoacán; the San Carlos Mine at Mazapíl, Zacatecas; and the Chantuplán mines near Taxco, Guerrero.

Australian localities include the Aerial and Silent Sisters mines at Wyloo Homestead and Ashburton Downs Station at Ashburton Downs in Western Australia; the Burra Burra Mine at Burra in the Mt. Lofty Ranges, South Australia; the Broken Hill district at Broken Hill, New South Wales; the Great Australia Mine in the Cloncurry district, Mount Isa-Cloncurry region, Queensland; and the Wombat Hole Prospect at Benambra, Victoria.

In Europe, chrysocolla occurs at Chessy-les-Mines at Chessy, Rhône, Rhône-Alpes, France; and the Bad Lauterberg mines in the Harz Mountains of Lower Saxony, Germany. Chinese specimens come from the Liu Feng Shan copper mine in the Anqing-Guichi mining district near Guichi, Chizhou Prefecture, Anhui Province; 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 mine in Lanping County, Nujiang Autonomous Prefecture, Yunnan Province. Russian specimens are found at the Dalnegorsk Mine at Primorskiy Kray, Magadianskaya Oblast', Far-Eastern Region. Africa's localities include the Tsumeb Mine at Tsumeb, Otjikoto Region, and the Kombat Mine at Kombat, Grootfontein District, Otjozondjupa Region, both in Namibia; the Toussit mines at Toussit in Oujda-Angad Province in Morocco's Oriental Region; the Shinkolobwe Mine at Kambove in the Katanga Copper Crescent, Katanga Province, Democratic Republic of Congo; the Kabwe (Broken Hill) Mine at Kabwe, Central Province, Zambia; and the Wessels Mine at Hotazel in the Kalahari Manganese Fields, North Cape Province, South Africa. The "Eilat stone" variety of chrysocolla has been found only at the King Solomon Mine in the Timna Valley near Eilat, HaDarom District, Israel. "Abdollah-Giw turquoise" is a chrysocolla variety from Iran.

In Canada, chrysocolla is collected at the Gaspé copper mine at Murdochville, Gaspésie-Îles-de-la-Madeleine, Québec. Chrysocolla localities in the United States include the Warren district near Bisbee in Cochise County; the Bluebird Mine at Globe in Gila County; the Verde district mines at Jerome in Yavapai County; and the Morenci Mine at Morenci in Greenlee County, all in Arizona. Colorado's sources include the Sherman and Adelaide mines in the Leadville district in Lake County, and the Bandera Mountain mines at Silverton in San Juan County. California's localities include 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. Other U.S. sources are the Continental Pit at Butte, Silver Bow County, Montana; the Bullfrog Mine at Beatty, Nye County, Nevada; the Kelly and Graphic mines at Magdalena, Socorro County, New Mexico; the Bingham Canyon Mine in the Oquirrh Mountains in Salt Lake County, and the Hidden Treasure Mine in the Ophir district of Tooele County, both in Utah; the Hub and Paymaster mines in the Lava Creek district, Butte County, Idaho; the Champion Mine at Painesdale, Houghton County, and the Algoman mines at Mass City, Ontonagon County, both in Michigan; the Bellah and Steward mines at Gillham, Sevier County, Arkansas; the French Creek

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mines at St. Peters, Chester County, Pennsylvania; and the Schuyler Mine at North Arlington, Bergen County, New Jersey.

JEWELRY & DECORATIVE USES

Chrysocolla has mixed gemstone qualities. Although pure chrysocolla has a bright, intense, sky-blue color, it is a soft, fragile material that rarely occurs in thicknesses sufficient for gemstone use. Its softness (Mohs 2.5-3.5) makes it difficult to polish and limits its value as a gemstone. Most chrysocolla used in jewelry actually consists of microscopic particles of chrysocolla included within chalcedony [microcrystalline quartz, silicon dioxide, SiO_2] or opal [hydrous silicon dioxide, $\text{SiO}_2 \cdot n\text{H}_2\text{O}$]. Silicification intensifies chrysocolla's color and greatly increases its hardness to create the gemstone known as "gem silica." Chrysocolla gemstones may be uniformly colored or varicolored. Chrysocolla's uniform, bright-blue color rival that of top-quality turquoise. Varicolored chrysocolla is intergrown with azurite, malachite, and other oxidized copper minerals and exhibits a mix of blue and green colors. Nicely colored, gem-quality, rough chrysocolla in pieces large enough to be fashioned into gems cost as much as \$100 per ounce. Top-quality chrysocolla cabochons ready for use in jewelry cost about \$2 per carat, or roughly \$250 per ounce.

"Eilat stone," also known as "King Solomon's stone," is the national stone of Israel. It is an intergrowth of chrysocolla with turquoise, azurite, and malachite, and is found only near Eilat, Israel's southernmost city. The source of "Eilat stone" is now closed. But because it was a popular souvenir from Israel for many decades, imported imitations from the copper mines of Africa and Arizona are often misrepresented as "Eilat stone" and are widely sold to tourists.

Chrysocolla gems and jewelry are classic examples of "caveat emptor." Various forms of chrysocolla are often mislabeled as turquoise, while large amounts of gray chalcedony are dyed blue and sold as the costly, gem-silica variety of chrysocolla.

Collectors value chrysocolla for its bright colors and association with other oxidized copper minerals. Especially popular are specimens of "drusy chrysocolla," which is chrysocolla covered with a delicate, drusy coating of transparent, colorless, terminated crystals of macrocrystalline quartz.

HISTORY & LORE

The name "chrysocolla" was first used in 315 B.C. by the ancient Greek philosopher and naturalist Theophrastus (ca 372-ca 287 B.C.). The word stems from the Greek *chrysos*, meaning "gold," and *kolla*, or "glue," and alludes to a chrysocolla-like material that the Greeks used as a flux for soldering gold. Despite serving as a minor gemstone for several millennia, chrysocolla has long been confused with azurite, malachite, turquoise, and other oxidized copper minerals. French mineralogist and geologist André-Jean François Marie Brochant de Villiers (1772-1840) recognized chrysocolla as a mineral species in 1808 and revived the ancient Greek name.

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Brochant de Villiers, for whom the mineral brochantite [hydrous copper sulfate, $\text{Cu}_4(\text{SO}_4)(\text{OH})_6$] is named, conducted much of the early investigative work that differentiated the oxidized copper minerals.

Chrysocolla has appeared on the 100,000-new zaire postage stamp of Zaire (now the Democratic Republic of Congo) in 1996; the 1,350-congolese franc stamp of the Democratic Republic of Congo in 2011; and the 700-rupiah stamp of Indonesia in 1997. Because of its confusion with other similarly colored, oxidized copper minerals, chrysocolla has no specific ancient medicinal uses or lore. But according to modern metaphysical practitioners, chrysocolla is a stone of communication and calmness that aids in verbal and telepathic expression, facilitates the emergence of truth and wisdom, discharges negative energies, and enhances feminine energies.

Because of its variable chemical composition and poorly developed crystal structure of chrysocolla, many mineralogists question its current status as a recognized mineral species. In 2005, a joint French-American research effort used infrared spectroscopy, scanning X-ray transmission microscopy, and X-ray diffraction methods to determine that chrysocolla is not a compositionally homogenous mineral as traditionally assumed. Instead, it appears to consist of several oxidized copper minerals, primarily spertiniite [copper hydroxide, $\text{Cu}(\text{OH})_2$] and other similar species that are intergrown with small amounts of chalcedony [microcrystalline quartz, silicon dioxide, SiO_2] and amorphous silica materials such as opal [hydrous silicon dioxide, $\text{SiO}_2 \cdot n\text{H}_2\text{O}$]. The study also noted that the supposed orthorhombic structure of chrysocolla is likely based on spertiniite's orthorhombic structure, rather than on any definable structure of chrysocolla itself. Accordingly, the study concluded that chrysocolla's recognition as a unique mineral species should be reconsidered. To date, the International Mineralogical Association, the organization of mineralogists that is responsible for recognizing and naming mineral species, has not acted on this proposal to discredit chrysocolla as a mineral species.

MINING AND MINERAL SPECIMENS

The majority of the minerals available on specimen markets today were collected at localities that are currently being mined or that have been mined in the past. Mines are prolific sources of mineral specimens because the mining process involves breaking large quantities of rock in areas that are heavily mineralized. Mines that yield mineral specimens fall into two general categories:

1/ Active mines that currently produce mineral commodities: These are mines in which mineral specimens are an authorized or unauthorized by-product of mining operations. An example is Colorado's Henderson molybdenum mine, the source of the creedite specimens that we featured last month. At Henderson, mineral specimens are an unauthorized by-product of the production of molybdenite [molybdenum disulfide, MoS_2] ore, the primary source of molybdenum.

2/ Inactive mines that no longer produce mineral commodities and are reopened or searched specifically for mineral specimens: In recent decades, such mines have become increasingly important sources of mineral specimens. A prime example is the Ojuela Mine at

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Mapimí, Durango, Mexico. Ojuela yielded silver, lead, and gold for hundreds of years until regular production ceased after World War II. Sections of the Ojuela Mine are now leased specifically to specimen miners for the collection of mineral specimens.

The relationship between mines and mining and the supply of mineral specimens evolved well over a century ago. As late as the 1870s, no collector market for mineral specimens existed. Mineral specimens and crystals, no matter how brightly colored or beautifully developed, were either discarded into mine dumps as gangue (waste rock) or sent to the crushers to be processed as ore. Museum curators today lament the fact that countless thousands of spectacular mineral specimens were lost in the frontier-era mining process. But when the mining industry in the western states grew rapidly in the 1880s, a number of underground gold mines, mainly in Colorado and California, began recovering spectacular specimens of crystallized gold. More often than not, miners “high-graded” or pocketed this gold, not because of its beauty and rarity, but simply for its bullion or “melt-down” value. Miners justified this theft by considering it well-earned compensation for their poor wages and terrible working conditions.

But these miners soon learned that the novelty value of a high-graded, crystallized gold specimen sometimes substantially exceeded its bullion value. Mine owners did everything possible to acquire the fine specimens for themselves. In the process, some owners amassed spectacular collections of crystallized gold, which they displayed in eastern cities to help raise mine-development capital. These displays attracted great attention among both museum curators and the general public. A market for gold specimens quickly became established with specimen prices soaring well above actual bullion value.

Collector interest then soon spread beyond gold to other minerals and crystals. As both prices and demand increased steadily, catalogue companies, such as Philadelphia’s Foote Mineral Company, sent professional collectors to western mines to gather specimens themselves and also to purchase specimens from miners. This gave often-needy miners secondary source of income, while providing the growing numbers of collectors with a steady supply of specimens.

As interest in mineral collecting and demand for mineral specimens boomed in the United States and Europe during the 1950s and 1960s, active mines and working miners continued to provide most specimens. During this period, mining companies were not concerned with miners collecting mineral specimens, as long as their ore-production quotas were not compromised. Many companies also allowed mineral collectors to search mine dumps for specimens and sometimes even to visit underground workings to collect specimens themselves.

But the relationship between the mining industry and specimen collecting changed dramatically during the 1970s. Now concerned with liability and safety issues, mining companies closed their properties to mineral collectors. And to reduce operating costs and increase production, most companies also barred miners from collecting specimens. This resulted, first, in a decrease in the availability of specimens, then in the appearance commercial specimen-collecting companies that specialize in collecting mineral specimens both from active and inactive mines. Today, commercial collectors, who are specialists in everything from specimen extraction to specimen marketing, contract with mining companies for permission to collect on mine properties in ways

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that do not interfere with regular production. They also lease and reopen inactive mines specifically to collect specimens. Yet while commercial collectors provide most of today's mineral specimens, our previous Mineral of the Month—creedite from Colorado's Henderson Mine—also shows that the traditional miners' practice of high-grading continues.

TECHNOLOGICAL USES

Chrysocolla has no technological uses. It has in the past occasionally served as a minor ore of copper and as a flux for soldering processes.

ABOUT OUR SPECIMENS

Our specimens of chrysocolla were collected at the Acarí copper mine in Caraveli Province, Arequipa Department, Peru. Arequipa, one of Peru's 21 departments (political divisions comparable to American states), is located in southwestern Peru along the Pacific coast, with its interior regions extending eastward into the high Andes. Caraveli Province, one of Arequipa's eight provinces (the equivalent of American counties), is located in northwestern Arequipa. Caraveli Province is sparsely populated, with just 40,000 residents living in an area of 5,000 square miles. Caraveli's coastal region has an agricultural economy; inland sections rise quickly into the Andean foothills, where the economy is based on herding and mining. The Acarí copper mine is located in northern Caraveli Province about 30 miles from the Pacific coast and the same distance southeast of the city of Nazca in neighboring Ica Department. The Acari region, at an elevation of 3,500 feet in the Andean foothills, is 250 miles southeast of the national capital of Lima.

The Acari mine complex consists of an underground copper mine and several nearby underground gold mines, all currently inactive. The Acari copper mine was developed in 1877, shortly after Peru legalized foreign mine ownership in an effort to attract foreign development capital. Although the mine shut down within three years, it reopened in 1884 only to close again in 1887. Following a modernization program, Acari resumed operations in 1907, this time producing until metal prices collapsed in 1918 following World War I. Modern mine-exploration activities commenced in the 1980s and continue today.

The geology and mineralization at Acari is linked to the Andean Orogeny (mountain-building episode) that created the Andes Mountains some 60 million years ago. This uplifting of dioritic and granitic basement rock was accompanied by volcanic activity that emplaced such volcanic rocks as andesite and dacite. Associated mineral-rich, hydrothermal solutions surged through the fractured dioritic and granitic rock to precipitate various metallic and semimetallic minerals in erratic vein systems. At Acari, fractures were filled with chalcopyrite [copper iron sulfide, CuFeS_2], bornite [copper iron sulfide, Cu_5FeS_4], and chalcocite [copper sulfide, Cu_2S]. Erosion subsequently reduced the surface to expose the upper sections of these vein systems, enabling the chemical action of atmospheric oxygen and groundwater to oxidize the copper-sulfide minerals into chrysocolla, atacamite [basic copper chloride, $\text{Cu}_2\text{Cl}(\text{OH})_3$], cuprite [copper oxide, Cu_2O],

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azurite [basic copper carbonate, $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$], and malachite [basic copper carbonate, $\text{Cu}_2(\text{CO}_3)(\text{OH})_2$].

After rising prices for silver, gold, copper, lead, and zinc revived Peru's mining industry in the 1970s, Peruvian mines became major sources of mineral specimens. The first important mineral was pyrite, [iron disulfide, FeS_2]. With many mines in operation, waste dumps filled with large quantities of beautifully developed pyrite crystals, what at the time had no value. After a Peruvian entrepreneur began selling pyrite specimens to foreign visitors and middle-class Peruvian citizens in the Lima markets, dozen of competitors, called *piriteros*, followed his lead. After world-class rhodochrosite [manganese carbonate, MnCO_3 ,] specimens were found at a number of Peruvian mines in 1980 and attracted attention on international markets, collectors and dealers descended on Peru. Peruvian miners then regularly began collecting mineral specimens as sources of secondary income. Within a decade, Peru had become noted for fine specimens of pyrite, rhodochrosite, quartz, barite [barium sulfate, BaSO_4], galena [lead sulfide, PbS], and sphalerite [zinc sulfide, ZnS].

Varied mineralization makes the Acari copper mine a significant specimen source. Acari's gangue minerals include pyrite, actinolite [basic calcium magnesium iron silicate, $\text{Ca}_2(\text{Mg,Fe})_5\text{Si}_8\text{O}_{22}(\text{OH})_2$], calcite [calcium carbonate, CaCO_3], hematite [iron oxide, Fe_2O_3], and quartz. The oxidized copper minerals are chrysocolla, atacamite, bornite, chalcocite, cuprite, malachite, and azurite. The primary sulfide ore mineral is chalcopyrite. Acari specimens first reached international markets in the early 1980s. Since then, the mine has been a steady source of mineral specimens. Commercial mineral collectors from Lima collected your chrysocolla specimen from thin, erratic veins in the near-surface, oxidized portion of the Acari copper deposit in 2012.

Acari has also yielded a blue-green, opal-chalcedony material that takes its color from included, microscopic particles of chrysocolla. This material, which is marketed as a gemstone under the names "gem silica," "blue chrysocolla chalcedony," "chrysopal," and "Peruvian blue opal," has a soft translucency, a bright, blue-green color, fine grain, and a superior hardness that enable it to take a fine polish.

As you examine your specimen, note that the greenish-blue chrysocolla has the very fine grain and uniform, intense color of gem-quality material. The chrysocolla occurs in a matrix of colorless and white massive quartz. The small areas of dark, brownish-red are cuprite [copper oxide, Cu_2O]. Your chrysocolla specimen is a fine example of oxidized copper mineralization and, because chrysocolla may eventually be discredited as a mineral species, a reminder that mineralogy is a continuously changing science.

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