

November 2011 Mineral of the Month: Atacamite

This month we are featuring atacamite, a rare, basic copper chloride mineral from Australia. Our write-up details atacamite's mineralogy, its occurrence at Australia's oldest operating mine, and the rich mineral heritage of the "Land Down Under."

OVERVIEW

PHYSICAL PROPERTIES

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

Class: Halides Subclass: Oxyhalides and Hydroxy Halides Group: Atacamite

Crystal System: Orthorhombic

Crystal Habits: Usually as thin, striated, prismatic and tabular crystals; also granular and as fibrous masses and sand particles; twinning common.

Color: Bright-green to dark-emerald-green and blackish-green

Luster: Vitreous to adamantine

Transparency: Transparent to translucent

Streak: Apple-green

Cleavage: Perfect in one direction, good in two others

Fracture: Conchoidal, brittle

Hardness: 3.0-3.5

Specific Gravity: 3.76

Luminescence: None

Refractive Index: 1.831-1.880

Distinctive Features and Tests: Best field marks are occurrence in shallow, oxidized copper deposits in arid environments and association with malachite [$\text{Cu}_2(\text{CO}_3)(\text{OH})_2$] and other oxidized copper minerals. Atacamite dissolves in dilute hydrochloric acid without effervescence; it also fuses easily in a flame, coloring the flame blue.

Dana Classification Number: 10.1.1.1

NAME The name "atacamite," pronounced aht-ah-CAH-mite, is derived from the mineral's type locality in the Atacama Desert region of northern Chile. Alternative names for atacamite include "alacamite," "atakamite," "arsenillo," "halochalcite," "chlorochalcite," "marcylite," "muriate of copper," "remolinite," and "Kuperfersand." In European literature, atacamite appears as *atacamit*, *atacamita*, and *cuivre muriaté*.

COMPOSITION: Atacamite consists of 59.51 percent copper (Cu), 16.60 percent chlorine (Cl), 22.47 percent oxygen (O), and 1.42 percent hydrogen (H). Atacamite is a member of the halides, a class of nearly 200 minerals in which one or more metals combine with a halogen element such as chlorine. The atacamite molecule and lattice are held together by ionic bonding. Because of the unusual strength of copper's ionic bonds, atacamite, at Mohs 3.0-3.5, is harder than most other halides. Because ionic bonding is susceptible to heat, halides form only at low temperatures in surface or shallow mineralogical environments. Atacamite is a basic copper chloride, with the word "basic" referring to the presence of hydroxyl ions (OH^1). Each atacamite molecule contains three hydroxyl ions. Atacamite crystallizes in the orthorhombic system, with three mutually perpendicular axes of different lengths which account for its varying directional cleavage strength. Atacamite is an idiochromatic (self-colored) mineral, meaning its characteristic bright-green to dark-emerald-green and blackish-green colors are caused by the nature of its crystal structure and its essential chemical composition, rather than by trace amounts of accessory elements. Copper, the essential metal in atacamite, is a powerful pigmenting agent for the colors blue and green. Atacamite forms mainly in arid climates where copper sulfide minerals are exposed to atmospheric oxygen in the presence of chlorine ions and limited amounts of water.

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COLLECTING LOCALITIES: The finest atacamite specimens come from Australia, notably from the Cattlegrid Pit at Mt. Gunson, the Wallaroo and Moonta mines, and the Princess Royal, Utica, and Burra Burra mines, all in South Australia. Other localities are found in Chile, Italy, Spain, England, Russia, Democratic Republic of Congo, China, Kazakhstan, and Namibia. In the United States, atacamite occurs in Arizona, Nevada, New Mexico, and Utah.

HISTORY, LORE, & GEMSTONE/TECHNOLOGICAL USES: Atacamite was recognized as a mineral in the 1790s after mineralogists had studied specimens of oxidized copper minerals from the Atacama Desert of northern Chile. Russian ambassador and mineralogist Prince Dmitrii Aleksyevich Golitsyn (also Gallitzen, 1734-1803) assigned the name "atacamite." Basic copper chloride was initially thought to exist as a single mineral until the polymorphic minerals botallackite, paratacamite, and clinoatacamite were discovered later. Atacamite has served as a minor ore of copper. In ancient times, finely powdered atacamite was used as a green pigment for cosmetics, glass, ceramics, and the inks of illuminated manuscripts. Because of its ability to absorb water, powdered atacamite also served as an ink-blotting material before the availability of blotting paper. Atacamite was the model for its own laboratory synthesis. Synthetic atacamite, called "dicopper chloride trihydroxide," is a pigment, a feedstock chemical for the manufacture of other copper compounds, an agricultural fungicide, and a nutritional supplement in animal feeds. Atacamite has no gemstone uses. According to modern metaphysical beliefs, atacamite facilitates self-motivation, enhances self-confidence and enthusiasm, helps to attain independence, and removes energy blocks. It is considered a healing stone that increases fertility and strengthens the nervous system.

ABOUT OUR SPECIMENS: Our atacamite specimens were collected at the Cattlegrid Pit at Mt. Gunson in the Stuart Shelf area of the Andamooka Ranges-Lake Torrens region of South Australia, Australia. The state of South Australia is in the south-central part of the Australian continent. Mt. Gunson is located in semiarid, sparsely vegetated desert country 240 miles north-northeast of the state capital of Adelaide. Copper ore was discovered at Mt. Gunson in 1875; production began in 1899 from an open pit called the Main Open Cut. Production increased sharply during World War II to help satisfy the critical Allied demand for copper. Mt. Gunson shut down after the war as ore grades and metal prices declined. The mine reopened in 1970 on a larger scale with a new flotation-separation concentrator to treat lower-grade ores. In 1974, the Cattlegrid Deposit, the source of our specimens, opened adjacent to the Main Open Cut. By the time the Cattlegrid Pit shut down in 1986, it had produced 7.2 million metric tons of ore grading 1.9 percent copper that yielded 127,000 metric tons of copper and 62 metric tons (more than 1.9 million troy ounces) of silver. The Mt. Gunson copper deposit lies within a rift valley and is part of South Australia's Stuart Shelf-Adelaide Geosyncline Copper Province. These copper deposits formed early in the Proterozoic Eon some 1.5 *billion* years ago when copper-rich hydrothermal solutions surged upward from basement rock into an overlying formation of layered sediments that is now known as the Stuart Shelf. Atacamite formed when shallow deposits of copper-sulfide minerals oxidized in the presence of chlorine ions from saline lake-bed evaporite minerals. Current geological exploration has revealed a massive ore body grading almost three percent copper along with lesser amounts of silver, lead, zinc, and bismuth. Full-scale mining at Mt. Gunson will resume in 2014.

10 YEARS AGO IN OUR CLUB: Vanadinite, ACF Mine, Mibladen, Khenifra Province, Morocco, the first time we featured it. Our write-up began with this wonderful quote: "The hyacinth red of crocoite, the butterscotch yellow of wulfenite, the fine red of vanadinite . . . are among the choicest treasures of the Mineral Kingdom. It is specimens such as these— and a hundred more like them— that, even more than the gems, make mineralogy a study of deeply satisfying aesthetic pleasure." — Richard M. Pearl, *1001 Questions Answered About the Mineral Kingdom*, 1959. One memory we have of shopping in Denver in the days after 9/11 occurred was the tremendous amount of exquisite vanadinite being offered by several Moroccan dealers there. Now, you hardly see any available—2001 was the right time to feature vanadinite!

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COMPREHENSIVE WRITE-UP

COMPOSITION

Atacamite, chemical formula $\text{Cu}_2\text{Cl}(\text{OH})_3$, contains the elements copper (Cu), chlorine (Cl), oxygen (O), and hydrogen (H). Its molecular weight consists of 59.51 percent copper, 16.60 percent chlorine, 22.47 percent oxygen, and 1.42 percent hydrogen. The atacamite molecule is made up of a simple cation (positively charged ion) and a compound anion (negatively charged ion). Atacamite's cation consists of two divalent copper (cuprous) ions 2Cu^{2+} with a total cationic charge of +4. The compound anion has a single chlorine ion Cl^- and three hydroxyl ions $3(\text{OH})^-$ which produce a total anionic charge of -4. This -4 anionic charge balances the +4 cationic charge to provide the atacamite molecule with electrical stability.

Atacamite is a member of the halides, a class of nearly 200 minerals in which one or more metals combine with a halogen element such as fluorine, chlorine, bromine, or iodine. In halides, the bonding is primarily ionic and forms when the positive charge of a metal cation attracts the negative charge of a halogen ion. Because ionic bonding is liable to the action of water, halides are among the most soluble of all minerals. The strength of the ionic bonding in halides, and thus their solubility, varies greatly. Ionic bonding is strongest when the cationic metal exhibits strong metallic properties and weakest when the metal is less metallic. Copper has exceptional metallic properties and, in atacamite, forms strong ionic bonds with chlorine. Thus, atacamite is one of the least soluble of the halides. In comparison, halite [sodium chloride, NaCl] is highly soluble because sodium, with its poor metallic properties, bonds weakly with chlorine. Because ionic bonding is generally weak and susceptible to mechanical stress, halides are quite soft. With its unusually strong ionic bonding, atacamite, at Mohs 3.0-3.5, is harder than most other halides. Because ionic bonding is susceptible to heat, halides form only at low temperatures in surface or shallow mineralogical environments. For the same reason, atacamite fuses readily in low-temperature flames, coloring the flames blue.

Atacamite is a basic copper chloride, with the word "basic" referring to the presence of hydroxyl ions $(\text{OH})^-$. Each atacamite molecule contains three hydroxyl ions. When atacamite forms, copper ions first combine with chlorine ions to form the incomplete copper-chloride ion $(\text{Cu}_2\text{Cl})^{3+}$. Because this ion lacks the electrical balance necessary for stability, it attracts and bonds to three hydroxyl ions $3(\text{OH})^-$ to create the complete atacamite molecule $\text{Cu}_2\text{Cl}(\text{OH})_3$. In the atacamite lattice, flat layers of molecules form octahedral structures. These sheets are offset so that vacant sites in one layer coordinate with occupied sites in adjacent layers. This close atomic packing and the relatively heavy atomic weight of copper (63.55) account for atacamite's substantial density (specific gravity 3.76). This sheet structure also gives atacamite an unusual ability to absorb water. Atacamite does not become a hydrated (hydrous) mineral, because the water molecules do not attach, but are merely absorbed into the sheet structure and are easily removed by moderate heating. Because intermolecular distances are greatest and thus the ionic bonding is weakest along the plane of the sheets, atacamite exhibits perfect cleavage in one direction. Good cleavage exists along the other two planes where shorter intermolecular distances create stronger ionic bonding. Atacamite crystallizes in the orthorhombic system with three mutually perpendicular axes of different lengths. Orthorhombic crystals are usually blocky in appearance, but in certain minerals, including atacamite, growth conditions or chemistry can elongate one axis to produce thin or tabular crystals.

As an idiochromatic (self-colored) mineral, the characteristic bright-green to dark-emerald-green and blackish-green colors of atacamite are caused by the nature of its crystal structure and essential chemical composition, rather than by traces of accessory elements. Copper, atacamite's essential metal, is a powerful pigmentsing agent for the colors blue and green. The presence of copper ions causes the

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atacamite crystal lattice to absorb all white-light wavelengths except those within a narrow band of green, which it reflects as its diagnostic green color. Shifts in atacamite's basic green color are caused by trace impurities that alter the structure of the crystal lattice.

The Dana mineral-classification number 10.1.1.1 identifies atacamite as an oxyhalide or hydroxyl halide (10), which is a halide containing either free oxygen ions O^{2+} or hydroxyl ions $(OH)^{-1}$. Atacamite is subclassified (1) by the general formula $A_2Xq(O,OH)_3$, in which "A" can be ions of such divalent metals as copper, iron, magnesium, or nickel and "X" is a chlorine ion. Atacamite is then assigned to the atacamite group (1) as the first (1) of two members. The other member is hibbingite [basic iron chloride, $Fe(OH)_3Cl$], which crystallizes in the orthorhombic system and shares a similar chemistry. Mineralogists are currently studying two other minerals, gillardite [basic copper nickel chloride, $Cu_3Ni(OH)_6Cl$] and haydeelite [basic copper magnesium chloride, $Cu_3Mg(OH)_6Cl$] for inclusion into the atacamite group.

Atacamite is one of four polymorphic forms of basic copper chloride. Polymorphic minerals have identical chemical compositions but different crystal structures. These basic copper chloride polymorphs include atacamite (orthorhombic), paratacamite (trigonal), clinoatacamite (monoclinic), and botallackite (monoclinic). Although clinoatacamite and botallackite both crystallize in the monoclinic system, their lattice structures differ. To express this structural difference, the clinoatacamite formula is written as $Cu_2Cl(OH)_3$, while that of botallackite is written as $Cu_2(OH)_3Cl$.

Atacamite usually forms in very arid climates where copper sulfide minerals are exposed to atmospheric oxygen in the presence of chlorine ions and limited amounts of water. Atacamite occurs in shallow, oxidized, mineralogical environments and is often associated with malachite [basic copper carbonate, $Cu_2(CO_3)(OH)_2$], chrysocolla [basic hydrous copper aluminum acid silicate, $(Cu,Al)_2H_2Si_2O_5(OH)_4 \cdot nH_2O$], brochantite [basic copper sulfate, $Cu_4(SO_4)(OH)_6$], pseudomalachite [basic copper phosphate, $Cu_5(PO_4)_2(OH)_4$], connelite [basic hydrous copper chlorosulfate, $Cu_{19}Cl_4(SO_4)(OH)_{32}$], linarite [basic lead copper sulfate, $PbCu(SO_4)(OH)_2$], caledonite [basic lead copper carbonate sulfate, $Pb_5Cu_2(CO_3)(SO_4)_3(OH)_6$], libethenite [basic copper phosphate, $Cu_2(PO_4)(OH)$], cornetite [basic copper phosphate, $Cu_3(PO_4)(OH)_3$], cuprite [copper oxide, Cu_2O], and quartz [silicon dioxide, SiO_2]. Atacamite also occurs in intimate association with the copper minerals kröhnkite [hydrous sodium copper sulfate, $Na_2Cu(SO_4)_2 \cdot 2H_2O$] and natrochalite [basic hydrous sodium copper sulfate, $NaCu_2(SO_4)_2(H_2O,OH)$]. Atacamite is most closely associated with malachite. Atacamite can alter into malachite after reacting with weak carbonic acid (H_2CO_3) in groundwater and forms pseudomorphs, with malachite assuming the external shape of the original atacamite crystals. To a lesser extent, atacamite occurs in volcanic vents and fumaroles, and in subsea "black smoker" deposits. Atacamite is also found in the oxidized coatings on bronze and copper objects of antiquity—the green patina on the Statue of Liberty is comprised of atacamite, brochantite, and antlerite. (We have come close to featuring brochantite in the past, but could never quite get enough nice specimens from one place at one time.)

COLLECTING LOCALITIES

Atacamite is a relatively rare mineral with collecting localities limited largely to arid regions. Our specimens were collected at the Cattlegrid Pit at Mt. Gunson in the Stuart Shelf area of the Andamooka Ranges-Lake Torrens region of South Australia, Australia. Other atacamite localities in South Australia are the Wallaroo and Moonta mines near Kadina on the Yorke Peninsula; and the Princess Royal, Utica, and Burra Burra mines near Burra in the North Mt. Lofty Ranges. Australian specimens are also collected at the Whim Creek copper mine at Whim Creek in Roeburne Shire in Western Australia; the Mount Oxide copper mine in the Selwyn district at Mt. Isa, Queensland; and the Malabunka copper deposit in the Gardiner Range, Northern Territory.

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Atacamite also occurs in the Atacama Desert of the Arica and Parinacota regions of northern Chile. The Atacama Desert, one of the world's most arid regions, is the type locality for atacamite. Important Chilean localities include the Restauradora and Farola mines at Cerro Pintado, Copiapo Province, and the San Pablo and El Rincón mines at El Salado in Chañaral Province, both in the Atacama Region; the Santo Domingo Mine at Caleta Vitor in the Arica and Parinacota Region; the Capaquire copper deposit in the Collahuasi district, Iquique Province, Tarapacá Region; and the copper mines at Caracoles in the Sierra Gorda District, Antofagasta Province, Antofagasta Region.

Other localities include the Lilly Mine at Pico Umay, Ico Department, Peru; the Amelia Mine at Mulegé in the Boleo district, Baja California Sur, Mexico; Mt. Vesuvius in the Somma-Vesuvius Complex, Naples Province, Campania, Italy; the Ramonete copper prospect at Mazarrón-Aguilas, Murcia, Spain; the Mednarudyanskoye copper deposit at Nizhni Tagil, Bogoslovsk, Urals Region, Russia; the Loe Warren Zawn and Botallack mines at St. Just in the St. Just District, Cornwall, England; the Kipushi copper mine at Kipushi, Katanga Province, Democratic Republic of Congo; the Tonglúshan copper-gold-iron deposit in Daye County, Huangshi Prefecture, Hubei Province, China; the Kyzylkain copper deposit near Kyzylkain, Kazakhstanskaye Oblast', Kazakhstan; and the Tsumeb Mine at Tsumeb, Otjukoto Region, Namibia.

In the United States, Arizona, with its arid climate and numerous copper deposits, is the leading source of atacamite specimens. Arizona localities include the Southwest Mine at Bisbee in the Warren district, Cochise County; the Rowley Mine in the Painted Rock district, Maricopa County; the Mission Mine Complex in the Pima district, Pima County; numerous copper prospects near Casa Grande in the Casa Grande district, Pinal County; the United Verde Mine at Jerome in the Verde district, Yavapai County; and the Sanchez mines in the Lone Star district, Graham County. Nevada specimens come from the Turquoise King prospects in the Battle Mountain district of Lander County; the Lovelock Mine in the Table Mountain district of Churchill County; and the Silver Coin Mine in the Iron Point district of Humboldt County. Specimens are also collected at the Blanchard Mine at Bingham in the Hansonburg district, Socorro County, New Mexico; and the Tintic district mines in Juab County, Utah.

JEWELRY & DECORATIVE USES

Atacamite has no use in jewelry, although occasionally small specimens of crystals on matrix are set in wire jewelry to stunning effect. Atacamite is popular among collectors for its rarity, unusual green colors and crystal habits, and interesting mineralogical associations with other colorful, oxidized copper minerals.

HISTORY & LORE

Atacamite was recognized as a mineral species in the 1790s after mineralogists had studied specimens of oxidized copper minerals from the Atacama Desert of northern Chile. The name "atacamite" was assigned by Russian ambassador and mineralogist Prince Dmitrii Aleksyevich Golitsyn (also Gallitzen, 1734-1803). Basic copper chloride was assumed to be a single mineral until botallackite, a monoclinic polymorph, was discovered in 1865. Paratacamite, a trigonal polymorph, was identified in 1873. The atomic structures of these three polymorphs were defined in 1926 by X-ray diffraction methods. In the early 1990s, mineralogists employed thin-section, electron microscopy and polarization to discover a fourth polymorph of basic copper chloride that, like paratacamite, crystallized in the monoclinic system, but with a different crystal-lattice structure. This new polymorph was named clinoatacamite in 1996.

Atacamite appears on the official emblem of the Mineralogical Society of South Australia, a region known for fine atacamite specimens. According to modern metaphysical beliefs, atacamite facilitates self-motivation, enhances self-confidence and enthusiasm, helps to attain independence, and removes energy blocks. It is also considered a healing stone that increases fertility and strengthens the nervous system.

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TECHNOLOGICAL USES

Atacamite has served as a minor component of oxidized copper ores. Ancient Egyptians used finely powdered atacamite as a green pigment in cosmetics, glass, and ceramics. During medieval times, powdered atacamite was the green pigment in the inks used to illuminate manuscripts. With its ability to absorb water (see "Composition"), powdered atacamite also served as an ink-blotting material before the availability of blotting paper.

Atacamite has served as the model for its own laboratory synthesis. Synthetic atacamite, known as "dicopper chloride trihydroxide," is valuable as a green coloring agent in pyrotechnics, and as a feedstock chemical for the manufacture of other copper compounds, an agricultural fungicide, and, most importantly, a nutritional supplement in animal feeds to provide the essential dietary element copper. About 500 tons of synthetic atacamite are manufactured worldwide annually.

THE MINERAL HERITAGE OF AUSTRALIA

When you think of Australia, what minerals come to mind? Opal, of course, and perhaps gold, crocoite, large selenite clusters in different colors, chrysoprase, Mookaite jasper, and others. Well-known for its mines and minerals, Australia ranks high among the world's top producers of gold, aluminum, copper, iron, zinc, lead, nickel, zirconium, and uranium. Commercially mined Australian gemstones include opal [mineraloid, hydrous silicon dioxide, $\text{SiO}_2 \cdot n\text{H}_2\text{O}$]; diamond [carbon, C]; sapphire [corundum, aluminum oxide, Al_2O_3], and bright-green chrysoprase [silicon dioxide, SiO_2]. Australia is also the leading source of specimens of such minerals as crocoite [lead chromate, PbCrO_4], gold [native metal, Au], and atacamite.

Australia's mineral heritage goes back to prehistoric times when Aboriginal cultures fashioned tools and weapons from several types of microcrystalline quartz and used powdered, oxidized copper minerals as pigments in paint. In 1788, Great Britain founded Australia as a penal colony. Within ten years, coal mining had begun at Newcastle, New South Wales. Australia's first economic metal deposit (silver-lead) was discovered near Adelaide, South Australia, in 1841. Copper was discovered the following year in the nearby Mt. Lofty Ranges. A succession of South Australian copper discoveries followed at Kapunda, Burra, and Callington-Kanmantoo. By 1851, Australia accounted for 10 percent of the world's annual copper production. That same year, prospectors discovered rich gold deposits in Victoria that triggered a major gold rush. Just six years later, Australia was accounting for one-third of the world's annual gold production. The Australian gold rush dramatically accelerated emigration and agricultural and industrial development. Prospectors made additional gold discoveries in Western Australia in the 1880s.

The 20th century began with the opening of opal mines in Queensland, New South Wales, and South Australia. Then came the discovery of tin in Tasmania; silver, lead, and zinc at Broken Hill, New South Wales; and iron in South Australia. Nevertheless, industrial-mineral development stagnated, with the only major new discovery being the multi-metal deposit at Mt. Isa in Queensland. After World War II had demonstrated the importance of secure domestic

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sources of metals, Australia launched a nationwide, mineral-exploration program that revealed the likely existence of major mineral deposits. Attracted by Australia's political stability, overseas mining companies helped discover bauxite ore in the Northern Territory and in Queensland in the 1950s; enormous iron deposits in Western Australia in the 1960s; and nickel in Western Australia and uranium in the Northern Territory in the 1970s. Meanwhile, gold mining had revived in Western Australia to become a major industry by the 1980s. Throughout the 1900s, four great mines—Broken Hill in New South Wales (silver-lead-zinc); Mt. Lyell in Tasmania (copper); and Mt. Morgan (copper and gold) and Mt. Isa (silver-lead-zinc) in Queensland—accounted for most of Australia's metal output.

Discovery and development of the Anakie sapphire deposits in Queensland and the Argyle diamond pipes in Western Australia in the 1980s, coupled with continuing production of opal, increased Australia's importance as a source of gems and gemstones. The newest major Australian mine is South Australia's world-class Olympic Dam copper-uranium-gold mine (see "About our Specimens). Along with its rich mineral deposits, the proximity of nearby Asian markets, particularly in Japan and China, give Australia's mining industry an economic advantage. Today, Australia leads the world in production of aluminum, opal, and chrysoprase. It ranks second in production of iron, zinc, lead, nickel, zirconium, and uranium; third in gem- and industrial-grade diamonds; fourth in gold; and fifth in silver, copper, cobalt, and manganese. In 2010, Australia's mining industry recorded revenues of \$210 billion—a remarkable achievement for a nation with a population of only 25 million.

Since the Australian gold rush of the 1850s, mineral collecting has become an ingrained part of Australian culture. Mineral collecting and prospecting, known locally as "fossicking," has become increasingly popular. This term, first used by miners in Cornwall, England, to describe their searches through mine waste heaps for bits of valuable, high-grade ore, came to Australia in the 1840s. Interest in fossicking and mineral collecting in Australia has increased substantially since the 1970s. Australia now has more than two dozen officially designated and state-regulated "fossicking areas," where the public is encouraged to collect minerals.

Australia's interest in minerals and mineral collecting is reflected in its six prestigious mineralogical societies, one each in New South Wales, Queensland, South Australia, Tasmania, Victoria, and Western Australia. Together these societies, whose members include both professional and amateur mineralogists, sponsor the biannual publication of the prestigious Australian Journal of Mineralogy. Australia also boasts more than 200 gem-and-mineral and lapidary clubs. Six of its major museums have internationally acclaimed mineral collections that focus largely on Australian specimens: the Edward de Courcy Clarke Earth Science Museum in Crawley, the Australian Mining Hall of Fame in Kalgoorlie, and the Perth Australian Museum in Perth, all in Western Australia; the Museum of Victoria in Melbourne, Victoria; and the Australian Fossil and Mineral Museum in Bathurst and the Australian Museum in Sydney, both in New South Wales.

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The Australian Museum in Sydney, founded in 1829, is the home of the nation's largest public mineral collection—nearly 50,000 mineral specimens from both Australian and worldwide localities. Along with superb examples of Australian metal-ore minerals from the great mines at Mt. Isa, Mt. Morgan, Mt. Lyell, and Broken Hill, the Australian Museum also has spectacular displays of Australian gems and gemstones. Opal is well-represented by opalized fossils and specimens from the early days of the opal boom. Anakie sapphires from Queensland are represented by a 12-carat golden sapphire and a green-brown, pleochroic gem of 34 carats. The display from Western Australia's diamond fields features a five-carat, brilliant-cut gem from an Argyle diamond pipe.

ABOUT OUR SPECIMENS

This is the second time we have featured atacamite. The first time was in September 1999, when we had about 180 members. (Now we have about 480.) The specimens we sent them were from La Farola Mine, Cerro Pintado, Las Pintadas district, Tierra Amarilla, Copiapó Province, Atacama Region, Chile, the type locality for atacamite. The specimens were different than those we sent this month—they were on an earthy brown matrix, and most specimens had only atacamite crystals, as short, thin needle-like crystals of intense green color. Most specimens did not have the mineral association described later, as many of our pieces do this month. One reason we wanted to feature atacamite again was so we could examine the history and importance of this amazing Australian locality where our pieces originated.

Our atacamite specimens were collected at the Cattlegrid Pit at Mt. Gunson in the Stuart Shelf area of the Andamooka Ranges-Lake Torrens region of South Australia, Australia. Although the state of South Australia, which is located in south-central Australia, has an area of 379,000 square miles (about that of the combined “four-corner” states of Arizona, New Mexico, Utah, and Colorado), its population is only 1.7 million. More than two-thirds of all South Australians live in or near the capital city of Adelaide on the coast. Apart from the temperate coastal areas, most of South Australia consists of arid, sparsely populated desert or semidesert lands and low mountain ranges.

Mt. Gunson is located in sparsely vegetated desert 240 miles north-northeast of Adelaide and 80 miles north-northeast of the seaport of Port Augusta. The map coordinates for Mt. Gunson are 31° 26' 42" south latitude and 137° 8' 46" east longitude. It is 35 miles southeast of Woomera and the Woomera Prohibited Area, known locally as the “Woomera Rocket Range” which, during the 1950s and 1960s, was one of the world's most active and top-secret rocketry- and weaponry-test ranges. Mt. Gunson lies at an elevation of 300 feet in the Andamooka Ranges, a heavily eroded chain of low hills. It is 30 miles west of the shoreline of Lake Torrens, a 100-mile-long, saline rift lake that covers 5,700 square miles, an area larger than that of the state of Connecticut. Lake Torrens is a vast salt flat that has only filled with water once during the last 170 years.

Mt. Gunson is one of the copper deposits discovered in the 1800s that brought the first measure of economic prosperity to South Australia. Copper production at Mt. Gunson began in 1899 from an open pit known as the Main Open Cut. Over the following years, several smaller mines, some underground, were developed within a few miles of the Main Open Cut. Production was stepped up during World War II to help satisfy the Allied demand for copper. From 1941 to 1943, Mt. Gunson mined 32,000 tons of ore grading 3.5 percent copper and 0.5 troy ounces of silver per ton, along with small amounts of zinc, lead, and bismuth. Mt. Gunson shut down after the war as both ore grades and metal prices declined, but reopened in 1970 on a larger scale utilizing a new flotation-separation concentrator to treat lower-grade ores. Within three years of reopening, Mt. Gunson had yielded 234,000 tons of ore grading 0.79 percent

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copper and 0.4 troy ounces of silver per ton. In 1974, the Cattlegrid Deposit, the source of our specimens, was developed as an open pit adjacent to the old Main Open Cut. By the time the Cattlegrid Pit shut down in 1986, it had produced 7.2 million metric tons of ore grading 1.9 percent copper to yield 127,000 metric tons of copper and 62 metric tons (more than 1.9 million troy ounces) of silver.

Mt. Gunson is part of South Australia's Stuart Shelf-Adelaide Geosyncline Copper Province that stretches from the York Peninsula west of Adelaide more than 320 miles north-northwest through Mt. Gunson to the Olympic Dam area. All copper deposits within this trend are related geologically. Looking at a map of South Australia, Lake Torrens is geographically aligned with the Spencer Gulf, the biggest bay along Australia's southern coast. Both these long, narrow, north-south-trending topographical features are part of the same rift valley. Rift valleys form when regional, magmatic upwelling creates crustal domes that stretch and fracture the crust. The crust can separate along major fault systems, causing blocks of crust within the fault systems to drop relative to the adjacent, solid crustal sections. (For a detailed discussion of rift-valley formation, see "The Great Rift Valley" in our June 2011 write-up on aegerine.) The formation of the Spencer Gulf-Lake Torrens rift valley is the key to understanding the genesis of South Australia's copper deposits.

The Australian landmass represents the world's oldest geological record. Along South Australia's trend of copper mineralization, the crystalline basement rock formed from the solidification of magma early in the Proterozoic Eon more than 1.8 *billion* years ago. About 1.5 billion years ago, deep magmatic activity caused the region to dome. Subsequent crustal stretching and faulting created a rift valley, a subsidence that filled with layered sediments to depths of several thousand feet, creating a formation now known as the Stuart Shelf. Renewed magmatic activity then forced copper-rich hydrothermal solutions upward through the basement rock into the layered Stuart Shelf sediments where they emplaced large zones of stratigraphically controlled copper-sulfide mineralization. Long periods of slow uplifting balanced by surface erosion eventually reduced the depth of the Stuart Shelf sediments, finally exposing the copper sulfides to atmospheric oxygen and groundwater. Oxidation then formed surface outcrops and shallow deposits of oxidized copper minerals, including atacamite, our Mineral of the Month.

At Mt. Gunson, the primary ore mineral is chalcopyrite [copper iron sulfide, CuFeS_2]. Other copper-sulfide minerals are bornite [copper iron sulfide, Cu_5FeS_4], chalcocite [copper sulfide, Cu_2S], and covellite [copper sulfide, CuS]. Lead and silver are present as argentiferous (silver-bearing) galena [lead sulfide, PbS]. In the oxidized, upper portions of the deposit, secondary copper minerals include azurite [basic copper carbonate, $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$], brochantite [basic copper sulfate, $\text{Cu}_4(\text{SO}_4)(\text{OH})_6$], chrysocolla [basic hydrous copper aluminum acid silicate, $(\text{Cu,Al})_2\text{H}_2\text{Si}_2\text{O}_5(\text{OH})_4 \cdot n\text{H}_2\text{O}$], and malachite [basic copper carbonate, $\text{Cu}_2(\text{CO}_3)(\text{OH})_2$]. Also present are the polymorphic basic copper chloride minerals atacamite and paratacamite [both $\text{Cu}_2\text{Cl}(\text{OH})_3$]. Atacamite and paratacamite formed in unusually large quantities in the oxidized copper deposits at Mt. Gunson because of proximity to the dry, saline bed of Lake Torrens. The lake bed and adjacent sediments, including those at Mt. Gunson, are rich in the evaporite mineral halite [sodium chloride, NaCl]. Halite is the source of the chlorine ions (Cl^{1-}) that enter into the chemical oxidation process that converts copper-sulfide minerals into copper-chloride minerals.

Although mining and ore concentration at Mt. Gunson's Cattlegrid Pit ended in 1986, copper is still recovered by acid-leaching old mine dumps and shallow, in situ bodies of low-grade copper ore. Metallic copper is recovered electrolytically from copper-bearing leach solutions. Exploration geologists are now completing a five-year exploration program of core drilling and underground drifting that has revealed the existence of a massive ore body grading nearly three-percent copper along with lesser amounts of silver, lead, zinc, and bismuth. By today's standards, three-percent copper ore is quite rich. When full-scale underground mining resumes in 2014, Mt. Gunson will become Australia's oldest operating mine. It will again be a major source of copper, although not nearly as large as the new Olympic Dam Mine 70 miles to

November 2011 Mineral of the Month: Atacamite

the north. The Olympic Dam copper-uranium-gold mine ranks as the world's largest single source of uranium, the fourth largest source of copper, and the fifth largest source of gold.

Commercial collectors have long gathered specimens at Mt. Gunson from the oxidized portions of both the Main Open Cut and the Cattlegrid Pit. As you study your specimen, note first its bright-green to dark-emerald-green and blackish-green colors and vitreous luster that are characteristic of atacamite. The small crystals are tabular- or scale-shaped, which is typical of atacamite from Mt. Gunson. Using a loupe, it is possible to discern longitudinal striations, another characteristic of atacamite, on crystal faces. Remember that atacamite is closely associated with malachite (see "Composition") and can alter into malachite by reacting with weak carbonic acid (H_2CO_3) in groundwater. The lightest green colors in your specimen may be malachite. Because atacamite does not occur in botryoidal form, any botryoidal forms, which will usually be a lighter green, are malachite. Your specimen also has considerable "heft" in the hand, because copper, a relatively heavy metal (atomic weight 63.55), makes up nearly 60 percent of its composition. The small, reddish-brown crystals atop the atacamite are quartz [silicon dioxide, SiO_2] that is included with hematite [iron oxide, Fe_2O_3], the latter a major component of the reddish Australian soils.

We mentioned earlier that when we featured atacamite for the first time back in September 1999, we had about 180 members. In anticipation of featuring it in 1999, we purchased 150 Gold-level size pieces and 100 Silver-level pieces. (Back then, of course, we hadn't even conceived of having a Platinum-level membership.) Those original specimens are long gone, but we do see nice specimens from Chile offered from time to time, and often pick up a dozen or two to sell at shows, as they are quite attractive.

We also mentioned earlier that we now have about 480 members. Before the economic crisis took place in September-October 2008, we had around 510 members, and thought we might reach 600 by the end of 2008, as typically a number of new gift memberships are given every December. We did reach 550, but in the months that followed, some members dropped out or did not renew. Since then, we have averaged about 475 to 500 members, roughly about a third of membership in each of our three levels.

The Platinum-level membership has grown steadily over the years, and in the near future, we may have more in this level than in either of the others—to the point that, several times this year, we brought in additional small shipments of the featured mineral in Platinum-level size due to increased demand! There are several advantages to being a Platinum member. Of course, all Club members receive the same newsletter and mineral write-up every month, but Platinum members have the option of choosing the size specimen they wish to have, and of getting a larger, better specimen if they choose to, and many do. Obtaining one excellent specimen at a fair price from a source you can trust is a great way to slowly but surely build a marvelous collection! And we are so happy to have a part in assisting you to build your collection while learning so much each month about the featured mineral. Our thanks to all of you!

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