August 2009 Mineral of the Month: Chrysoprase

We're happy to be featuring chrysoprase, the rarest and most valuable of the gem varieties of chalcedony. Our specimens were collected at a recently reopened gemstone mine in Australia's historic goldfields. Our write-up explains the origin of chrysoprase's beautiful, apple-green color as well as the fascinating gold-mining history of Western Australia–it was the search for gold that lead to finding chrysoprase!

OVERVIEW

PHYSICAL PROPERTIES

Chemistry: SiO_2 Silicon Dioxide, with small amounts of nickel.
Class: Silicates
Subclass: Tectosilicates
Group: Quartz
Subgroup: Microcrystalline Quartz (Chalcedony)
Crystal System: Hexagonal
Crystal Habits: Microcrystalline, occurs in compact form as veins and nodules
Color: Green to apple-green, occasionally yellowish-green
Luster: Waxy and vitreous to dull
Transparency: Translucent to nearly opaque
Streak: White
Refractive Index: 1.530-1.539
Cleavage: None
Fracture: Conchoidal to subconchoidal and irregular, brittle to tough
Hardness: Mohs 6.5-7.0
Specific Gravity: 2.58-2.64
Luminescence: None
Distinctive Features & Tests: Best field marks are translucency, green color, hardness, and occurrence in nickel-rich environments. Can be confused with green varieties of smithsonite [$ZnCO_3$], prehnite [$Ca_2Al_2Si_3O_{10}(OH)_2$], and jade [jadeite, $Na(Al,Fe)Si_2O_6$].
Dana Classification Number: 75.1.3.1

NAME "Chrysoprase," pronounced KRIH-sah-praze, is derived from the Greek *chrysoprasos* (*chrysos*, "gold," and *prason*, "leek"), which translates literally as "golden leek." Although the name was originally used for certain yellow gemstones, chrysoprase now refers exclusively to the green variety of chalcedony. Other names for chrysoprase include "Australian jade," "Australian imperial jade," "quartz jade," "green quartz," "chrysophrase," "prase," "chrysoprasus," "green hornstone," and "jadine." In European mineralogical and gemological literature, chrysoprase appears as *crisoprasa* and *crisoprasio.*

COMPOSITION: Chrysoprase is the nickel-rich, green variety of chalcedony, or microcrystalline quartz. Quartz, chemical formula SiO_2, contains two elements, the semimetal silicon (Si) and oxygen (O). The molecular weight of quartz is made up of 53.26 percent oxygen and 46.74 percent silicon. Quartz is a member of the silicates, the largest of all mineral classes. The fundamental building block of the silicates is the silica tetrahedron $(SiO_4)^{4-}$, which consists of a silicon ion surrounded by four equally spaced oxygen ions positioned at the four corners of a tetrahedron (a four-faced polyhedron). Chrysoprase forms from the weathering of ultramafic (iron- and magnesium-rich) serpentinite rocks that oxidize in a process called laterization to produce laterite (pronounced LATE-er-ite), a residual, crumbly, reddish rock or earth consisting of an indefinite mixture of oxides, hydroxides, and hydrous oxides of iron or aluminum. Silica and nickel ions carried by groundwater then circulate through the laterite where the chemical environment causes them to precipitate simultaneously as chrysoprase in the form of veins and nodules.

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COLLECTING LOCALITIES: Since the 1960s, Australia has produced most of the world's chrysoprase. Important sources include the Yerilla Chrysoprase Mine at Yerilla in Menzies Shire, Western Australia; the Marlborough chrysoprase deposit near Rockhampton in Queensland; Hanging Rock at Nundle in Parry County, New South Wales; and Mount Davies near Pipalyatjara in South Australia. Other sources include the historic mines at Szklary near Ząbkowice Śląskiein in Lower Silesia (Doinośląskie) Poland; Revdinsk near Ekaterinsburg in Russia's southern Urals; the Diethensdorf Quarry at Chemnitz in Saxony, Germany; Hanety Hill at Dodoma in the Central Region of Tanzania; and Saryku-Boldy near Karkaralinsk in Qaraghandy Oblysy (Karaganda Oblast'), Kazakhstan. In Japan, chrysoprase cobbles are found on Oyashirazu Beach at Ohmi in Niigata Prefecture in the Chubu Region of Honshu Island. In the United States, most chrysoprase is collected in Arizona, where important sources include the Old Dominion Mine at Globe in the Globe district and the Inspiration Mine at Inspiration in the Miami-Inspiration district, both in Gila County; the western slopes of the River Mountains in the Weaver district in Mohave County; and the Perry Chrysoprase Mine in the Plamosa district of La Paz County. California localities include the Calaveras Asbestos Mine in Calaveras County and the Visalia Chrysoprase Mine at Visalia in Tulare County. Chrysoprase also occurs in Colorado, Oregon, Rhode Island, and Vermont.

HISTORY, LORE, & USES: Because of its rarity, soft translucency, rich green color, and workability, chrysoprase has been valued as a gemstone and a decorative stone since antiquity. Today, chrysoprase is fashioned into cabochons and beads for use in rings, pendants, necklaces, bracelets, and brooches, and carved into a variety of figurines and decorative objects. Top grades of gem-quality chrysoprase have a clean, uniform, vivid, apple-green color, soft translucency, and few visible inclusions. As the rarest and most costly of the chalcedony gemstones, the finest grades of chrysoprase are often sold on a carat basis. Top-quality chrysoprase in finished cabochons is valued as high as $5 per carat, meaning a large cabochon weighing one-half ounce (64 carats) can cost $300. Metaphysical practitioners believe that chrysoprase imparts a sense of grace that facilitates meditation, promotes general healing, encourages open-mindedness and acceptance of one's self and others, prevents depression, and protects against anguish, nightmares, and bad influences

ABOUT OUR SPECIMENS: Our specimens were collected in Australia at the recently reopened Yerilla Chrysoprase Mine at Yerilla in Menzies Shire in the state of Western Australia. Yerilla, a historic, abandoned gold-mining town in the remote outback of Western Australia, is 400 air miles east-northeast of the coastal city of Perth. Chrysoprase was discovered at Yerilla in the 1980s. Mining was initially conducted from 1992 to 1995. The mine then became inactive until it was sold and new owners reopened it in 2007. Mining at the Yerilla chrysoprase deposit is now conducted by mechanized, surface trenching to a depth of about 25 feet. When the chrysoprase-bearing host rock is exposed, miners visually inspect it for chrysoprase veins and nodules, extract them mechanically, then sort the stones by hand.

The cause of chrysoprase's lush green color is explained in the last paragraph under "Composition" in the comprehensive portion of the write-up. The color of chrysoprase sometimes fades upon exposure to prolonged high heat or intense sunlight, so avoid both when displaying your piece. Gemologists believe that the layers of willemseite platelets in chrysoprase absorb water and that color fading is caused by loss of this water when the stone is heated. Color intensity can be restored by storing the chrysoprase in dark, humid, cool conditions to replace the lost water. Light or thermal energy that displaces the chromophoric nickel ions from their positions within the crystal lattice can also contribute to color fading.

10 YEARS AGO IN OUR CLUB: Thenardite, Soda Lake, Carrizo Plain, San Luis Obispo County, California, a rare evaporate mineral named for French chemist Baron Louis Jacques Thenard (1777-1857). This is the only mineral we've featured from our home county! We moved into our present home on Orville Ave in Cambria in August 1999, after moving to Quartz Hill in 1991 and to Cambria in 1995.

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COMPREHENSIVE WRITE-UP

COMPOSITION

As you can imagine, it is always exciting to feature an especially beautiful mineral like chrysoprase! We were used to seeing small amounts in the stock of our Australian suppliers over the years, until last year in Tucson when one of our sources had a huge amount! Of course by then, it had been picked over, so we made arrangements with him to see what was new this year in Quartzsite, and hand pick your pieces before all the best were gone, and the rest, as they say, is history! Prior to mailing out your specimen, we had one of the most impressive lots of gorgeous chrysoprase ever!

Quartz occurs in both macrocrystalline and microcrystalline forms. Macrocrystalline quartz exhibits large, transparent-to-translucent, individual crystals or groups of crystals and includes such varieties as amethyst, rock crystal, milky quartz, smoky quartz, and rose quartz. Microcrystalline quartz or chalcedony, which is compact and consists of interlocked, microscopic silica grains or fibrous silica crystals, includes such varieties as agate and jasper. Chrysoprase is a rare, green color variety of chalcedony. For an in-depth discussion of how the microcrystalline and macrocrystalline forms of quartz differ, see "Microcrystalline Quartz" in our August 2008 write-up on Mookaite jasper. Contact us if you need a copy.

As shown by its chemical formula SiO_2, quartz contains two elements, the semimetal silicon (Si) and oxygen (O). The molecular weight of quartz is made up of 53.26 percent oxygen and 46.74 percent silicon. The cation (positively charged ion) in the quartz molecule is the silicon ion Si^{4+} with a +4 charge. The anion (negatively charged ion) consists of two oxygen ions $2O^{2-}$ with a collective -4 charge. The balance of these +4 cationic and -4 anionic charges provides the quartz molecule with electrical stability.

Quartz is a member of the silicates, the largest and most abundant of all mineral classes. The silica tetrahedron $(SiO_4)^{4-}$, the fundamental building block of the silicates, consists of a silicon ion surrounded by four equally spaced oxygen ions positioned at the four corners of a tetrahedron (a four-faced polyhedron). In the quartz-crystal lattice, all four oxygen ions in each silica tetrahedron bond covalently to the silicon ions of adjacent tetrahedra. Each silicon ion is thus surrounded by four oxygen ions, and each oxygen ion by two silicon ions. This arrangement satisfies the -4 charge of each individual tetrahedron and creates the infinite, three-dimensional structure of quartz, in which each balanced molecular unit is represented by the formula SiO_2. Silicon and oxygen are the most abundant elements in the Earth's crust, comprising three-quarters of the total crustal weight. Quartz is a component of most igneous, metamorphic, and sedimentary rocks. In silicate minerals, silica anions bond with metallic or semimetallic cations to form repeating chains that have seven distinct, structural configurations: independent tetrahedral silicates (nesosilicates); double tetrahedral silicates (sorosilicates); single- and double-chain silicates (inosilicates); ring silicates (cyclosilicates); sheet silicates (phyllosilicates); and framework silicates (tectosilicates). Quartz is a framework silicate or tectosilicate.

Because the covalent bonding within the quartz lattice exerts omnidirectional strength, quartz crystals have neither symmetry nor cleavage planes. This lack of cleavage and the high bonding strength achieved through close atomic packing explain quartz's substantial hardness of Mohs 7.0 (6.5-7.0 for chalcedony). Despite its close atomic packing, the light atomic weights of silicon (28.09) and oxygen (16.00) give quartz a relatively low specific gravity of 2.65 (slightly lower for chrysoprase and other chalcedonic forms). Because of its microcrystalline nature, chalcedony lacks quartz's structural homogeneity. Homogenous crystal structure and higher purity make macrocrystalline forms of quartz transparent to translucent; chalcedony, less pure and non-homogenous, is translucent to opaque. Chalcedony is also slightly softer and less dense than macrocrystalline quartz.

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Unlike macrocrystalline quartz, which grows by adding molecules of silica to new layers on a crystal's surface, chalcedony forms from solidification of silica solutions. Chalcedony consists of silica that has been weathered free from silicate minerals and transported by groundwater as microscopic particles in colloidal suspensions called silica gels. In the low temperatures and low pressures of shallow mineralogical environments, these gels eventually crystallize into solid masses of chalcedony composed of interlocking, microscopic crystals. The formation of the chrysoprase variety of chalcedony, however, is somewhat more complex and requires very specific chemical conditions. Chrysoprase formation begins with the weathering of nickeliferous (containing nickel), ultramafic (iron- and magnesium-rich) rocks such as serpentinite. Serpentinite consists primarily of serpentine-group minerals derived from the oxidation of ferromagnesian minerals of the olivine and pyroxene groups. Under certain conditions, serpentinite rocks weather in a process called laterization to produce laterite, a residual, crumbly, reddish rock or earth made up largely of iron oxides and aluminum hydroxides. When groundwater rich in silica and nickel ions circulates through laterite bodies, the chemical environment causes these ions to precipitate together as the nickel-rich chrysoprase variety of chalcedony.

The Dana mineral classification number 75.1.3.1 first identifies chrysoprase (quartz) as a framework silicate or tectosilicate (75). The subclassification (1) defines it by its four-oxygen coordination, in which each silicon cation is bound to four oxygen anions, as defined by the chemical formula of the silica tetrahedron $(SiO4)^{4-}$. Quartz is then assigned to the quartz group (3) as the first (1) and only member.

As an allochromatic (other-colored) mineral, quartz colors are caused not by essential elemental components or the nature of its crystal structure, but by traces of nonessential, color-producing elements called chromophores. Pure quartz is colorless or white, but various impurities create a wide range of colors. The diagnostic green color and much of the translucency of chrysoprase are due to the presence of between 1.0 and 2.5 percent nickel, an element that acts as a strong green chromophore. The exact chromophoric mechanism that creates the green color of chrysoprase is complex and not fully understood, but mineralogists believe that nickel is present in two forms. The first is as microscopic inclusions of nickel-bearing minerals. The second is as nickel ions within the quartz crystal lattice. The included nickel occurs mainly as layers of microscopic platelets of the green mineral willemseite [basic nickel magnesium silicate, $(Ni,Mg)_3Si_4O_{10}(OH)_2$]. The nickel ions ($Ni^{2+}$) within the crystal lattice substitute for silicon ions and distort the lattice in a manner that causes it to absorb the red, yellow, and blue ends of the white-light spectrum, and thus to reflect green. The combination of these chromophoric effects produces the deep, bright greens of chrysoprase. Light reflecting from the layers of willemseite (pronounced will-EM-see-ite) platelets create the soft, deep translucent "glow" exhibited by some chrysoprase specimens.

The Element Nickel

The chemical element nickel, with its chemical symbol Ni, atomic number 28, and atomic weight of 58.70, is a silvery white metal that takes a high polish. A member of the iron-cobalt group of metals, it is hard, malleable, ductile, somewhat ferromagnetic, and a fair conductor of heat and electricity.

Nickel was first isolated and classified as a chemical element in 1751 by Swedish chemist Axel Fredrik Cronstedt (1722-1765). In medieval Saxony, a red mineral was found in the Erzgebirge (Ore Mountains) which resembled copper ore. However, when miners were unable to extract copper from it, they superstitiously blamed a mischievous sprite of German mythology named Nickel (a.k.a. St. Nicholas or Old Nick). They called it "kupfernickel," which means "Satan's copper" or "Old Nick's copper." Cronstedt kept this name when he later published his discovery.

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Today, nickel is extensively used for making stainless steel and other corrosion-resistant alloys, nickel steel for armor plates and burglar-proof vaults, and in coin making. In the U.S., the term "nickel" or "nick" was originally applied to the copper-nickel Indian cent coin introduced in 1859. Later, the name was used to designate the three-cent coin introduced in 1865; the following year, a five-cent nickel was introduced, and has been known as a nickle ever since.

Nickel ranks 24th in abundance among elements comprising the Earth's crust, just between rubidium and zinc. It is found in most meteorites, including those from Sikhote-Alin, Russia, that we sent to Club members in April 2004. The presence of nickel is one of the criteria for distinguishing a meteorite from other minerals. Most earthly nickel is thought to be in the earth's core, which is theorized to consist of an iron-nickel alloy.

COLLECTING LOCALITIES

Chrysoprase is relatively rare and has few notable collecting localities. Our specimens were collected in Australia at the recently reopened Yerilla Chrysoprase Mine at Yerilla in Menzies Shire, Western Australia. Smaller deposits of chrysoprase are found 25 miles south of Yerilla at Binti Binti, and at Jamieson and Wingellina on Aboriginal reservations in Ngaanyatjarraku Shire near the Western Australia-Northern Territory border. Other Australian sources are the Marlborough Chrysoprase Mine north of Rockhampton in Queensland; Hanging Rock at Nundle in Parry County, New South Wales; and Mount Davies near Pipalyatjara in South Australia.

Worldwide localities include the historic mines at Szklary near Ząbkowice Śląskiein in Lower Silesia (Dolnośląskie), Poland (see "History & Lore"); Revdinsk near Ekaterinsburg in Russia's southern Urals; the Diethensdorf Quarry at Chemnitz in Saxony, Germany; Hanety Hill at Dodoma in the Central Region of Tanzania; and Saryku-Boldy near Karkaralinsk in Qaraghandy Oblysy (Karaganda Oblast'), Kazakhstan. In Japan, chrysoprase cobbles are found on Oyashirazu Beach at Ohmi in Niigata Prefecture in the Chubu Region of Honshu Island.

In the United States, chrysoprase is collected in Arizona's Gila County at the Old Dominion Mine at Globe in the Globe district and the Inspiration Mine at Inspiration in the Miami-Inspiration district. Additional Arizona localities are the western slopes of the River Mountains in the Weaver district of Mohave County and the Perry Chrysoprase Mine in the Plamosa Mining District of La Paz County. Other U.S. localities include the Calaveras Asbestos Mine in the Valley Springs area of Calaveras County and the Visalia Chrysoprase Mine at Visalia in Tulare County, both in California; the Sedalia Mine near Salida in Chaffee County, Colorado; the slopes of Nickel Mountain in the Riddle district, Douglas County, Oregon; Diamond Hill at Cumberland in Providence County, Rhode Island; and the Adams Brook nickel prospect, Windham County, Vermont.

JEWELRY & DECORATIVE USES

With its rarity, soft translucency, rich green color, and workability, chrysoprase has been valued as a gemstone and decorative stone since antiquity. Chrysoprase is traditionally fashioned into cabochons and beads for mounting in rings, pendants, necklaces, bracelets, and brooches. The top grades of gem-quality chrysoprase have a clean, uniform, vivid, apple-green color, soft translucency, and few visible inclusions. The most valuable chrysoprase has a soft, "glowing" translucency; stones with greater opacity have less value. Chrysoprase is the most costly of all chalcedony gemstones and the only chalcedony gemstone routinely priced by the carat. Top-quality chrysoprase in finished cabochons can cost as much as $5 per carat, meaning a large cabochon weighing one-half ounce (64 carats) can have a retail price of $300.

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Australia now supplies 90 percent of all gem-quality chrysoprase. Much Australian chrysoprase is shipped to Hong Kong for cutting into figurines and other small decorative objects to satisfy the booming Oriental demand for jade-like decorative objects, especially in China and Japan. Much of this chrysoprase is marketed as “Australian jade,” “Australian imperial jade,” or “quartz jade.” A substantial amount is misrepresented as green jadeite and sold at considerably higher prices.

The color of chrysoprase sometimes fades upon exposure to prolonged high heat or intense sunlight. Gemologists believe that the layers of willemseite platelets in chrysoprase absorb water and that color fading is caused by loss of this water when the stone is heated. Color intensity can be restored by storing the chrysoprase in dark, humid, cool conditions to replace the lost water. Light or thermal energy that displaces the chromophoric nickel ions from their positions within the crystal lattice can also contribute to color fading. Although natural chrysoprase is never color-enhanced, white and gray chalcedony is often dyed green in solutions of nickel or chromium salts to imitate chrysoprase. Chemical and optical tests can detect such imitations. A yellow-green gem material sold as “lemon chrysoprase” or “citron chrysoprase” is not chrysoprase at all, but a nickel-rich, silicified magnesite (see “About Our Specimens”).

Rough chrysoprase is valued by collectors for study and display purposes. Composite specimens such as ours, in which bright-green chrysoprase contrasts with the reddish-brown matrix rock, are especially attractive and interesting.

HISTORY & LORE

Scarabs, seals, signet rings, cabochons, beads, intaglio and cameo pieces, and figurines fashioned from chrysoprase have been recovered from Egyptian, Greek, and Roman tombs and archaeological sites. The Byzantine historian and philosopher Michael Psellos (Psellius, ca. 1018–ca. 1080) described how contemporary physicians used chrysoprase to strengthen vision and relieve internal pain. Medieval physicians also believed that when held in the mouth, chrysoprase could make one invisible, a power that Psellos thought would especially appeal to thieves and condemned prisoners. The German philosopher, theologian, and naturalist Albertus Magnus (Albert Count von Bollstädt, Albert the Great, ca. 1200-1280) wrote that Alexander the Great (Alexander III of Macedon, 356-323 B.C.) carried a “magic” chrysoprase into battle as a “victory stone.” Legend tells how, after Alexander had defeated the ancient Persian Empire, a serpent seized the chrysoprase stone and dropped it into the Euphrates River as a sign that Alexander had won his last great victory.

According to a medieval Romanian legend, a wealthy princess once possessed a golden lizard with eyes of green chrysoprase. A wizard had advised her never to part with the golden lizard, for its powers would some day help her to understand the language of animals and bring her great wealth. Later, during a terrible famine, the princess sold all her treasures—except the golden lizard—in a desperate effort to feed her starving people. As she grew weak from starvation herself, a lizard with glittering green eyes appeared at her window and said in a reptilian tongue which the princess could understand, “Help will arise for thee out of a river, go and seek.” The princess searched the green waters of the Râul Doamnei and found a great treasure of chrysoprase, which she used to acquire food for her people and to initiate a long period of prosperity. Today, the Râul Doamnei, a river in south-central Romania, is noted for its beautiful, chrysoprase-like green waters.

The first great chrysoprase source was the Szklary deposit at Ząbkowice Śląskiein in Lower Silesia (Dolnośląskie), Poland. The so-called Holy Roman Emperor Charles IV (1316-1378) used Szklary chrysoprase to decorate the Wenceslas Chapel (now part of St. Vitus Cathedral) in Prague. After Prussian King Frederick II (Frederick the Great, 1712-1786) conquered Silesia in 1745, his soldiers explored the deposit, finding a vein three miles long with solid pieces of chrysoprase as thick as eight inches. Frederick ordered systematic mining and used the chrysoprase extensively in his personal jewelry and to decorate his Sans Souci summer palace in Potsdam (near present-day Berlin, Germany). Frederick's extensive use of chrysoprase helped popularize the gemstone throughout Europe. Over the centuries, many members of English royalty acquired chrysoprase jewelry, among them Queen Anne (1665-1714) and Queen Victoria (1819-1901). When Victoria was crowned in 1837, fine chrysoprase was so costly that it was considered a precious gem. Peter Carl Fabergé (1846-1920), jeweler to the czar and the Imperial Russian Court, also brought attention to chrysoprase by using it in his most exquisite creations, including his celebrated "Fabergé eggs." During the late 1800s, chrysoprase enjoyed great popularity in Victorian jewelry.

In 1810, German chemist Martin Klaproth (1743-1817) correctly determined that nickel caused the green color of chrysoprase. At the time, however, mineralogists did not yet recognize chalcedony as a form of quartz. It was not until 1824 that Swedish chemist Baron Jöns Jacob Berzalius (1779-1848) showed that chalcedony and quartz were actually microcrystalline and macrocrystalline forms of the same mineral.

By the early 1900s, the great Szklary chrysoprase deposit in Poland, still the largest ever discovered, had been mined out. As the chrysoprase supply decreased, its use in jewelry declined. Chrysoprase jewelry finally regained its popularity again in the 1960s after the discovery of the large Marlborough deposit in Queensland, Australia, again made the stone available at reasonable prices.

Chrysoprase, in both rough and gem forms, is featured on the six-cent Australian postage stamp of 1973. Chrysoprase is an alternative birthstone for the month of May. Modern metaphysical practitioners believe that chrysoprase instills a sense of grace that facilitates meditation, promotes general healing, encourages open-mindedness and acceptance of one's self and others, prevents depression, and protects against anguish, nightmares, and bad influences.

THE GOLDFIELDS OF WESTERN AUSTRALIA

Our chrysoprase specimens were collected at the abandoned gold-mining town of Yerilla in a region of the Australian state of Western Australia that is generally known as the "Eastern Goldfields." The Eastern Goldfields has a rich and colorful history and an ongoing mining legacy as the site of Australia's biggest modern gold mine. The Eastern Goldfields were opened in 1892 when a modest gold discovery triggered a small rush that founded the mining town of Coolgardie. A year later, three Irish prospectors, Dan Shea, Tom Flanagan, and Paddy Hannan, made a much bigger discovery of gold-bearing quartz veins 20 miles to the northeast. Because Paddy Hannan filed the "reward claims" as required by Australian law, the discovery site was first called "Hannan's Find." Within a year, Hannan's Find became a ramshackle boomtown with a population of 2,000 miners. When it came time to register the name "Hannan's Find," the government rejected it in favor of the site's Aboriginal name—Calgoorlie. But the Australian postal authorities, aware that the similarity between the names "Calgoorlie" and "Coolgardie" would certainly confuse mail delivery, demanded that the spelling be changed to its present form—"Kalgoorlie."

By the time Kalgoorlie was formally named in 1894, it had 10,000 residents and more than 100 underground mines. But mining had already begun to deplete the gold-bearing quartz veins and the boom seemed destined to turn to bust. Fortunately, government geologists then discovered that the quartz veins actually carried very little of the local gold. Far more gold occurred in deep, complex veins of breccia (fragmented rock cemented together by secondary mineralization). Now that they knew what to look for, miners soon discovered a huge maze of gold-bearing breccia veins that they named the "Golden Mile," a bonanza that would rank among the richest gold deposits ever found. By 1902, the booming city of

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Kalgoorlie had 30,000 residents, 93 hotels, eight breweries, and 400 mines. It was also linked to the distant city of Perth by a railroad and a pipeline that supplied drinking water. Kalgoorlie served as the trading center for a vast area of outback, where prospectors made dozens of other gold strikes and founded such settlements as Menzies, Leonara, and Yerilla. By 1905, mines at Kalgoorlie and outlying areas of the Eastern Goldfields were turning out more than one million troy ounces of gold per year. But production then declined rapidly, and many of the smaller mining camps, including Yerilla, became ghost towns (see "About Our Specimens"). After World War II, only a few large mines at Kalgoorlie remained in operation. But by then, the Eastern Goldfields had yielded more than 40 million troy ounces of gold.

The Eastern Goldfields (geologic) Province is part of the Archaean Yilgon Craton of Western Australia. This craton or continental plate consists mostly of mafic (iron- and magnesium-rich) and ultramafic basaltic lavas that erupted some 2.7 billion years ago. These rocks were later intruded by intermediate-silica magmas that formed bodies of the dolerite variety of gabbro. After eons of faulting, alteration, and deformation, gold- and silica-rich hydrothermal solutions intruded the porous, fractured dolerite to emplace veins of gold-bearing, silicified breccia. Gold concentrations were highest in the Golden Mile section where countless breccia veins crisscrossed and intersected. On average, these veins contained more than 1troy ounce of gold per ton, and sometimes as many as 20 or 30 troy ounces per ton.

The hydrothermal solutions that emplaced the Golden Mile gold veins also permeated the surrounding host rock to deposit gold in low concentrations. These low-grade deposits were worthless until the 1970s, when the development of advanced cyanidation-extraction technologies and mass-mining methods, together with soaring gold prices, suddenly made them quite valuable. By 1989, Kalgoorlie Consolidated Gold Mines, a joint venture of Barrick Gold Corporation and Newmont Mining Corporation, two of the world's largest gold-mining companies, had consolidated dozens of old Golden Mile mining properties and began designing the Fimiston Open-Pit Mine. That same year, Kalgoorlie and the adjoining community of Boulder were consolidated into a single municipality—Kalgoorlie-Boulder.

The Fimiston Open-Pit Mine, better known as the "Super Pit," opened in 1995 as one of the world's largest gold mines. Although its ore averages a mere 0.058 troy ounces per ton, the Super Pit's 1,500 employees work 24/7 year-round to annually mine 15 million tons of ore and extract 800,000 troy ounces (26 metric tons) of gold. Gold and by-product silver is recovered by cyanidation extraction, then melted and poured into bars as a 75-25 gold-silver alloy. At a depth of 1,620 feet, the Super Pit is the largest excavation in the Southern Hemisphere. The area mined by the Super Pit once contained an estimated 1,800 miles of underground stopes, crosscuts, shafts, and haulage drifts, many dating back to the gold-rush days of the late 1890s. Drilling and blasting operations in the big pit regularly expose these old workings, some of which still contain rock drills, drill steels, timbers, rail, ore cars, lamps, and other century-old mining artifacts. The Super Pit has already yielded 12 million troy ounces of gold. By the time it closes in 2018, it will have turned out an additional 10 million troy ounces. In the end, the Super Pit will have produced more than one-third of the Eastern Goldfields' total output of 60 million troy ounces—nearly 2,000 metric tons!

ABOUT OUR SPECIMENS

As noted, our specimens were collected in Australia at the recently reopened Yerilla Chrysoprase Mine at Yerilla in Menzies Shire in the state of Western Australia. This area is about 400 air miles east-northeast of the coastal city of Perth, the capital of Western Australia. Yerilla, 100 road miles north of the city of Kalgoorlie-Boulder, is located at the junction of the Kookynie-Yarri and Cranky Jack roads, part of the network of "tracks" or graded gravel roads that connect outback towns. Kalgoorlie-Boulder, a gold-mining center with 30,000 residents, is the communications, transportation, and supply center for a vast area of outback. The Kalgoorlie-Boulder area is about 1,100 feet in elevation and, because of its arid climate with only nine inches of rain per year, is sparsely vegetated. Winters are pleasant, but summers are long and hot with daily high temperatures nearing 100˚ F.

Yerilla was one of many small mining towns founded during the Kalgoorlie gold rush of the 1890s (see "The Goldfields of Western Australia"). Yerilla reached its peak of development in 1905 with 600 residents and about a dozen small, underground gold mines. It then declined rapidly as miners depleted the shallow gold-quartz veins. Today, Yerilla is a ghost town marked only by a few crumbling stone walls. The nearest settlement, Leonara, population 500, is 30 miles to the northwest. Few modern maps note the site of Yerilla, but its exact location can be plotted on atlas maps by referencing latitude 29.50 south and longitude 121.49 east.

During a wave of renewed mineral-exploration activity for gold and nickel in the 1980s, prospectors discovered chrysoprase near Yerilla. The chrysoprase deposit, which consists of the Old Yerilla Mine and New Pit leases, was filed with the mining warden at Kalgoorlie in 1986. At the time, Australia was already the world's largest source of chrysoprase, thanks to the large production coming from the Marlborough chrysoprase deposit in Queensland. But because much of the Marlborough production was shipped to Hong Kong to be carved into decorative objects to satisfy Oriental market demand, chrysoprase remained in short supply on the North American and European markets. The subsequent high prices for quality chrysoprase encouraged the start of mining at Yerilla.

Bellmount Holdings Ltd. began mining the Yerilla deposit under the name of the Yerilla Chrysoprase Mine in 1992. Despite the high quality and excellent color of Yerilla chrysoprase, the leaseholders, citing high operating costs, closed the mine in late 1995. When the mine was put up for sale in 2002, it attracted considerable international attention. Along with the two government mining leases, the sale package included substantial amounts of previously mined material, including 2.46 metric tons of high-quality chrysoprase packed in 8 drums, and 5 tons of lower-grade chrysoprase packed in 20 drums. Also listed were 70 tons of nickeliferous magnesite in varying grades and colors, and a similar amount of chalcedony "plate"—vein sections of chalcedony and jasper in a variety of colors. The mine was finally sold in 2007 and reopened the next year under the name Chrysoprase Mines of Australia. Our specimens were mined by the new owners in 2008.

Mining at the Yerilla chrysoprase deposit is conducted by mechanized, surface trenching to a depth of about 25 feet. When the chrysoprase-bearing laterite layers (see "Composition") are exposed, they are visually inspected for three materials of value: veins and nodules of chrysoprase, non-chrysoprase chalcedony, and nickeliferous magnesite. Valuable material is extracted mechanically, then sorted by hand. Chrysoprase is the most valuable product. The mine also produces white and gray chalcedony, some of it with attractive dendrites (fern-like, patterned inclusions of dark iron or manganese minerals), that is used for carving and is often color enhanced with chemical dyes. Another valuable material is red and brown jasper. The final product is a nickel-rich, silicified magnesite [magnesium carbonate, $MgCO_3$]. Although pure, massive magnesite is white and relatively soft (Mohs 3.5-4.5), the magnesite at Yerilla has been altered by nickel- and silica-rich groundwater. The silica hardens and toughens the magnesite, while the substantial nickel content imparts a pleasant green-yellow color. This nickel-rich, silicified magnesite (which is not chrysoprase) is marketed as "lime prase," "lemon chrysoprase," and "citron chrysoprase" and is fashioned into cabochons and decorative objects. We have sold dozens of lemon chrysoprase bead strands over the years, and Australian dealers often have koala and other animal figures carved of this creamy, greenish-yellow stone.

Chrysoprase has a density, hardness and surface texture identical to that of agate or jasper. Like all varieties of chalcedony, chrysoprase takes an excellent polish. The distinctive, apple-green color of the chrysoprase in your specimen comes from two chromophoric effects of nickel. The basic green color is due to the manner in which nickel ions substitute for silicon ions in the crystal lattice. Microscopic inclusions of tiny platelets of the nickel mineral willemseite [basic nickel magnesium silicate, $(Ni,Mg)_3Si_4O_{10}(OH)_2$] provide a complementing green color and much of the translucency. The reflected and transmitted colors of chrysoprase are quite different. To view the particularly intense apple-green color of the transmitted light, backlight the specimen with a suitable light source.

The matrix rock in your specimen is reddish-brown laterite, which consists mainly of iron oxides and hydrous iron oxides. Laterite is usually too soft and crumbly to be polished. In our specimens, however, the laterite is silicified, meaning that it was infused with silica solutions that crystallized to form an interlocking network of chalcedony microcrystals. Because silicification has increased both the hardness and durability of the laterite, it takes a very good polish. In studying your specimen, remember that the laterite formed first and the chrysoprase was deposited later as veins and nodules within the laterite. Initially, the laterite was soft, crumbly, and quite porous. Its great porosity enabled nickel- and silica-rich groundwater to circulate completely through it to deposit the chrysoprase and silicify the laterite—a complex formation process that befits the rarest and most costly of the chalcedony gemstones.

The Bible references chrysoprase in the description of the holy city “New Jerusalem” found in Revelation chapter twenty-one. The four walls of this resplendent city are constructed of jasper, and are supported by twelve foundation gemstones. The fourth wall rests on foundation stones of chrysoprase, hyacinth (now known as a gemstone variety of zircon), and amethyst. Each foundation stone is engraved with the name of one of the twelve apostles. In the Scriptures, gemstones are sometimes used to symbolize precious qualities of heavenly things or persons, in this context emphasizing the unique and transplendent beauty of this symbolic city.

The abundance of chrysoprase we noted last year and this year in Tucson no doubt means that much fine cutting rough is reaching factories throughout Asia. As noted, the finest chrysoprase gemstones, cut into cabochons, are sold for big bucks in China and Japan, where people love jade and similarly colored stones like chrysoprase. Some of these gorgeous gemstones and beads may find their way into the American market, where it will likely be available for a time, and then vanish, depending on how active and how successful the mining company is at Yerilla. We will be looking for both cabochons and beads as we attend the large gem and mineral shows in Denver and Tucson. When we first went to Tucson in 1995, one of our first major purchases was a strand of apple-green chrysoprase beads–we still remember the striking beauty of the stones! Cheryl took the strand apart and used the individual beads to create gorgeous necklaces. In all the years since, we’ve never seen another strand as beautiful! We hope this new strike will allow us to find even more of this rare and valuable gemstone/mineral in future years!

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