

August 2013 Mineral of the Month: Rhodochrosite

This month we are featuring rhodochrosite, an eminently collectible, cherry-red manganese carbonate, from a recently closed mine in China. Our write-up explains the mineralogy and history of rhodochrosite and presents an overview of the element manganese.

OVERVIEW

PHYSICAL PROPERTIES

Chemistry: Manganese Carbonate MnCO_3 Usually contains varying amounts of calcium, iron, magnesium, and zinc.

Class: Carbonates

Subclass: Anhydrous Carbonates

Group: Calcite

Crystal System: Hexagonal (Trigonal)

Crystal Habits: Well-formed, individual crystals, which are uncommon, occur most often as rhombohedrons and occasionally as scalenohedrons. Rhodochrosite also occurs as cleavage masses; in compact, granular, botryoidal, and incrusting forms; and in massive stalactitic and stalagmitic forms.

Color: Pure or nearly pure rhodochrosite is cherry-red, but impurities and participation in solid-solution series can create colors ranging from pale pink and deep pink to orange-red and rose-red. Although usually pinkish-red or red, it can occasionally appear gray, brown, white, green, yellow, or nearly black.

Luster: Vitreous

Transparency: Transparent and translucent to nearly opaque

Streak: White

Cleavage: Perfect in three directions to form a rhombohedron

Fracture: Uneven to subconchoidal, brittle.

Hardness: Mohs 3.5-4.0

Specific Gravity: 3.4-3.6

Refractive Index: 1.590-1.820

Luminescence: None

Distinctive Features and Tests: Best field identification marks are pinkish-red-to-red colors; three-directional, rhombohedral cleavage; and occurrence in polymetallic, hydrothermal veins or oxidized, sedimentary manganese deposits. Can be confused with rhodonite [calcium manganese silicate, $\text{CaMn}_4\text{Si}_5\text{O}_{15}$], which has a similar color but is much harder. Rhodochrosite often exhibits a thin, black surface film of pyrolusite [manganese dioxide, MnO_2]. Rhodochrosite also effervesces slowly in cold hydrochloric acid and rapidly in warm hydrochloric acid. Differentiating rhodochrosite from pink calcite can require a fluorescence test; calcite fluoresces, rhodochrosite does not.

Dana Classification Number: 14.1.1.4

August 2013 Mineral of the Month: Rhodochrosite

NAME: The name “rhodochrosite,” pronounced row-dah-CROW-site, stems from the Greek *rhodon*, “rose” or “red,” and *crôma*, or “color,” literally meaning “red color” and alluding to the mineral’s characteristic color. With its attractive color, wide range of forms, and use as a gemstone, rhodochrosite has acquired many alternative names that include “manganese spar,” “red spar,” “raspberry spar,” “red calcite,” “Inca rose,” “dialogite,” “strömite,” “himbeerspath,” and “rothspatch.” The cobalt-rich variety is known as “cobaltoan rhodochrosite,” the iron-rich variety as “ponite” and “manganosiderite,” and the calcium-rich variety as “kutnahorite.” Tiny rhodochrosite spheroids occurring with manganese-oxide ores are called “sphaerodialogite.” The banded, stalactitic and stalagmitic varieties are known as “rosinca” or “rhodochrosite onyx”; the yellow-gray, banded variety is called “capillitite.” In European mineralogical literature, rhodochrosite appears as *rhodochrosit*, *rhodochrosiet*, and *rodocrosita*.

COMPOSITION: The molecular weight of rhodochrosite is made up of 47.79 percent manganese, 10.45 percent carbon, and 41.76 percent oxygen. Rhodochrosite is one of more than 190 members of the carbonate class of minerals, in which metallic elements combine with the carbonate radical (CO_3^{2-}). The carbonate radical, the fundamental structural unit of all carbonates, has a flat, triangular shape with a central carbon ion (C^{4+}) covalently bonded by shared electrons to three equidistant oxygen ions (3O^{2-}). Within the rhodochrosite crystal lattice, negatively charged carbonate ions ionically bond to positively charged manganese ions to create alternating rows of ions with each manganese ion surrounded by six oxygen ions. Rhodochrosite has three planes of weak ionic bonding that account for its perfect, three-directional cleavage. As an idiochromatic or self-colored mineral, rhodochrosite’s diagnostic red color is due to its inherent chemistry and structure, specifically the presence of the essential element manganese. Manganese creates a unique spacing within the crystal lattice which, when struck by white light, absorbs or “traps” the blue spectral wavelengths, while reflecting or transmitting only the red wavelengths. Although uncommon, rhodochrosite occurs regularly in small quantities in certain hypothermal, mesothermal, and epithermal (high-, medium-, and low-temperature) veins in association with various metal-ore minerals. Rhodochrosite is also found in manganese-rich, sedimentary deposits of marine origin in association with pyrolusite [manganese dioxide, MnO_2].

COLLECTING LOCALITIES: Rhodochrosite is collected in China, Romania, Italy, Greece, Bulgaria, Austria, Argentina, Bolivia, Peru, Mexico, South Africa, Namibia, Japan, Australia, Canada, and the United States (Colorado, Nevada, Pennsylvania, Arkansas, Montana).

HISTORY, LORE & USES: Rhodochrosite has been known since antiquity. The Incas believed that rhodochrosite was their former rulers’ blood that had turned to stone, hence the alternate name “Inca rose.” Mineralogists determined rhodochrosite’s chemical composition in 1813 after the earlier discovery of the element manganese and recognized it as a mineral species. Mineralogists assigned its name in 1836. Although gem-quality crystals are rare and cutting is difficult because of its three-directional cleavage, transparent, deeply colored rhodochrosite crystals can be faceted into stunning gems. Although faceted rhodochrosite gems are too soft (Mohs 3.5-4.0) for jewelry wear, they are very popular among collectors for display purposes. Sub-translucent or opaque forms of banded, stalactitic or stalagmitic rhodochrosite are fashioned into cabochons and beads and are widely used in bracelets, brooches, pendants, and necklaces. Massive rhodochrosite is also fashioned into small decorative objects such as figurines and

August 2013 Mineral of the Month: Rhodochrosite

paperweights. Although rhodochrosite has no specific technological uses, it has occasionally served as a minor ore of manganese. Metaphysical practitioners believe that rhodochrosite aids in achieving spiritual and emotional balance, stimulates feelings of love and compassion, discourages avoidance and denial, and enhances receptivity to new knowledge and experiences. Rhodochrosite is thought to appeal to those who are ready to learn more about their individual spirituality.

ABOUT OUR SPECIMENS: Our rhodochrosite specimens were collected at the Wudong (Wuton) Mine at Liubao, Cangwe County, Wuzhou Prefecture, Guangxi Zhuang Autonomous Region, in southwestern China. Mineralization at the Wudong Mine is unusual in that the host rock consists of mixed sedimentary strata of sandstone, siltstone, and shale that were laid down in the Cambrian Period of the Paleozoic Era about 550 million years ago. As tectonic uplifting fractured these Cambrian sediments, metal-rich hydrothermal solutions associated with deep magmatic intrusions forced their way upward into faults and fissures. At the Wudong deposit, these hydrothermal solutions filled “ladder”-type systems of offset, vertical fractures in three separate phases. The Wudong polymetallic deposit was discovered in 1958 and developed as a small underground mine several years later. It became noted for specimens only during the late 1990s, when miners accessed new, rhodochrosite-rich vein systems. Wudong rhodochrosite first attracted attention at major gem-and-mineral shows in the United States and Europe in 1997. During 50 years of small-scale mining, Wudong has produced 5,000 tons of lead, 3,800 tons of zinc, and 7 tons of silver (roughly 220,000 troy ounces). Operations were halted in 2011 as part of a program to modernize China’s mining industry. Because Wudong is not expected to reopen, the value of Wudong specimens has increased steadily since the mine’s closure.

COMPREHENSIVE WRITE-UP

COMPOSITION

This is the third time in 17 years that we have featured rhodochrosite as our Mineral of the Month. Our previous specimens were from the Uchucchacua Mine in Peru (1997) and the Sweet Home Mine in Colorado in the United States (2004). Now we are fortunate to have acquired rhodochrosite specimens from China.

The chemical formula MnCO_3 shows that rhodochrosite contains the elements manganese (Mn), carbon (C), and oxygen (O). The molecular weight of rhodochrosite is made up of 47.79 percent manganese, 10.45 percent carbon, and 41.76 percent oxygen. As in all molecules, those of manganese consist of positively charged cations and negatively charged anions. Manganese is a simple carbonate mineral with a single cation and a single anion. The cation is the manganese ion Mn^{2+} with its +2 charge; the anion is the carbonate radical $(\text{CO}_3)^{2-}$ with its collective -2 charge. A radical is a group of ions of different atoms that act as entities in chemical reactions. Within the rhodochrosite molecule, the +2 charge of the manganese cation Mn^{2+} balances the -2 charge of the carbonate anion $(\text{CO}_3)^{2-}$ to provide electrical stability.

Rhodochrosite is one of more than 190 members of the carbonate class of minerals, in which metallic elements combine with the carbonate radical $(\text{CO}_3)^{2-}$. The carbonate radical, which is

August 2013 Mineral of the Month: Rhodochrosite

the fundamental structural unit of all carbonate minerals, has a triangular shape with a central carbon ion (C^{4+}) covalently bonded by shared electrons to three equidistant oxygen ions ($3O^{2-}$). Within this radical, the +4 charge of the carbon ion C^{4+} and the collective -6 charge of the three oxygen ions $3O^{2-}$ provide the carbonate radical with a total -2 charge. Carbonate minerals form when negatively charged carbonate radicals bond ionically with positively charged metal ions.

Rhodochrosite is also one of the 70 anhydrous-carbonate minerals. The term “anhydrous” refers to minerals that do not have attached water molecules (H_2O). Carbonates are the inorganic salts of carbonic acid (H_2CO_3), which consists of hydrogen ions (H^+) and bicarbonate ions (HCO_3)¹⁻. Carbonic acid generally forms in relatively shallow or surface conditions when atmospheric carbon dioxide (CO_2) dissolves in water. Under proper conditions of temperature, pressure, and chemistry, metal ions will then combine with the bicarbonate ions of carbonic acid, freeing hydrogen ions and forming carbonates. The carbonate anion (CO_3)²⁻ is a flat, triangular structure held together by strong covalent bonds with shared electrons. Within the rhodochrosite crystal lattice, negatively charged carbonate ions bond ionically with positively charged manganese ions to create rows of alternating ions in which each manganese ion is surrounded by six oxygen ions. Because these oxygen ions completely shield the manganese ions, rhodochrosite exhibits no metallic properties. Rhodochrosite has three planes of weak ionic bonding that accounts for its perfect, three-directional cleavage.

To visualize the rhodochrosite lattice, picture a cube that has been distorted into the shape of a rhombohedron. This occurs because the axes of the triangular carbonate radicals can align with only one of the three cubic axes, leaving the two unaligned carbonate axes to distort the lattice into a rhombohedral shape in which the cleavage planes intersect at angles of other than 90 degrees.

Although uncommon, rhodochrosite is found in small quantities in certain hypothermal, mesothermal, and epithermal (high-, medium-, and low-temperature) veins where it occurs in association with chalcopyrite [copper iron sulfide, $CuFeS_2$], galena [lead sulfide, PbS], and sphalerite [zinc sulfide, ZnS]; and in massive, hydrothermal replacement deposits with bornite [copper iron sulfide, Cu_5FeS_4], tetrahedrite [copper iron antimony sulfide, $Cu_6Cu_4(Fe,Zn)_2(Sb,As)_4S_{13}$] and sphalerite. Rhodochrosite is also found in manganese-rich, sedimentary deposits of marine origin in association with pyrolusite [manganese dioxide, MnO_2].

The Dana mineral classification number 14.1.1.4 first identifies rhodochrosite as an anhydrous carbonate (14). The subclassification (1) defines it by the general formula ACO_3 , in which “A” can be divalent ions of calcium, magnesium, iron, manganese, zinc, cadmium, or nickel. Rhodochrosite is then assigned to the calcite group (1) as the fourth (4) of seven members, all of which are simple carbonates that differ only in cationic composition:

1. Calcite	$CaCO_3$	calcium carbonate
2. Magnesite	$MgCO_3$	magnesium carbonate
3. Siderite	$FeCO_3$	iron (ferrous) carbonate
4. Rhodochrosite	$MnCO_3$	manganese carbonate
5. <i>Sphaerocobaltite</i>	$CoCO_3$	<i>cobalt carbonate (DISCREDITED)</i>
6. Smithsonite	$ZnCO_3$	zinc carbonate

August 2013 Mineral of the Month: Rhodochrosite

7. Otavite	CdCO_3	cadmium carbonate
8. Gaspeite	$(\text{Ni,Mg,Fe})\text{CO}_3$	nickel magnesium iron carbonate

All calcite-group members crystallize in the hexagonal (trigonal) system and are closely related. Rhodochrosite forms complete solid-solution series with calcite and siderite. In the rhodochrosite-siderite and rhodochrosite-calcite series, iron cations and calcium cations substitute for manganese cations and vice versa. This creates two continuous, graded series with the end members being nearly pure rhodochrosite and siderite, or nearly pure rhodochrosite and calcite. The intermediate stages of the rhodochrosite-siderite series have the general formulas $(\text{Mn,Fe})\text{CO}_3$ or $(\text{Fe,Mn})\text{CO}_3$, while the intermediate stages of the rhodochrosite-calcite series have the formulas $(\text{Mn,Ca})\text{CO}_3$ or $(\text{Ca,Mn})\text{CO}_3$, depending upon the degrees of cationic substitution. Technically, when the weight of manganese exceeds that of calcium, the mineral is rhodochrosite; when the weight of calcium exceeds that of manganese, the mineral is calcite.

As an idiochromatic or self-colored mineral, rhodochrosite's basic red color is due to its inherent chemistry and structure, specifically the presence of the essential element manganese. Manganese creates a unique spacing within the crystal lattice which, when struck by white light, absorbs or "traps" the blue spectral wavelengths, while reflecting or transmitting only the red wavelengths. The wide color variations in rhodochrosite are caused by impurities or by participation in solid-solution series. In the rhodochrosite-calcite solid-solution series, the end members are white or colorless calcite and cherry-red rhodochrosite, with intermediate phases showing every possible shade of pink. Rhodochrosite sometimes exhibits a thin, black coating of particulate pyrolusite.

COLLECTING LOCALITIES

Although rhodochrosite is a widely distributed mineral, relatively few localities produce notable specimens. Rhodochrosite is collected in China at the Wudong (Wuton) Mine at Liubao, Wuzhou Prefecture, Guangxi Zhuang Autonomous Region. Other Chinese localities are the Zuta and Maola manganese deposits in Ningxiang County, Changsha Prefecture, Hunan Province; and the Zunyi, Tuanxi, and Tongluojing manganese deposits in Zunyi Prefecture and the Yanglizhang and Datanpo manganese deposits in Tangren Prefecture, both in Guizhou Province.

In Europe, rhodochrosite is collected at the Kapnic Mine (type locality) at Kapnic and Sacaramb, Maramureş County, Romania; the Valgraveglia and Cassagna mines in the Graveglia Valley, Genova Prefecture, Liguria, Italy; the Plaka mines in the Lavrion District, Attiki Prefecture, Greece; the Madan ore field in the Rhodope Mountains, Smolyan Oblast', Bulgaria; and the Plankogel polymetallic deposit at Hüttenberg, Carinthia, Austria.

Argentina has produced fine specimens of stalactitic and stalagmitic rhodochrosite, notably from the Cerro Vangarola Mine at Macizo del Deseavo, Santa Cruz; and the Farallón Negro Mine at Farallón Negro, Belen Department, and the Capallitas Mine at Capallitas, Andagalá, both in Catamarca. Rhodochrosite is also collected in Bolivia at the Negrillos and Carangas mines in the Todos Santos District, Carangas Province, Oruro Department; and in Peru in the Castrovirreyna district, Castrovirreyna Province, Huancavelica Department.

August 2013 Mineral of the Month: Rhodochrosite

Mexican specimens come from mines at Magdalena and Cananea in Sonora, and the Contessa Mine in the Santa Eulalia district at Aquiles Serdán in Chihuahua. Other localities include the Hotazel Mine in the Kalahari manganese field, Northern Cape Province, South Africa; the Tsumeb Mine at Tsumeb, Otjikoto District, Namibia; the Showa Mine at Midori, Gumma Prefecture, Kanto Region, Honshu Island, Japan; the Broken Hill mines at Broken Hill in Yancowinna County, New South Wales, Australia; and the Placentia Bay Mine at Placentia Bay, Newfoundland, Newfoundland and Labrador, Canada.

The United States has produced many extraordinary rhodochrosite specimens, most notably from Colorado, where localities include the Sweet Home Mine in the Alma district in Park County; the Camp Bird and Eldorado mines at Ouray in Ouray County; the Leadville district mines and the Climax molybdenum mine in Lake County; the Mary Murphy and St. Elmo Mines in the Chalk Creek district, Chaffee County; the Sunnyside Mine at Gladstone in the Eureka district, San Juan County; the Hidden Treasure Mine at Lake City in the Lake City district, Hinsdale County; and the Revenue and Rico Aspen mines in the Rico district, Dolores County. Other American localities are the Sequoia Pit in the Buffalo Mountain district, Eureka County, Nevada; the French Creek Mines at St. Peters, Chester County, Pennsylvania; the Batesville Quarry at Batesville in the Batesville district, Independence County, Arkansas; and the Butte district mines at Butte in Silver Bow County, Montana.

JEWELRY & DECORATIVE USES

Despite the rarity of gem-quality material and the difficulty of cutting because of three-directional cleavage, deeply colored, transparent rhodochrosite crystals are faceted into stunning gems. Although faceted rhodochrosite gems are too soft (Mohs 3.5-4.0) for jewelry wear, they are quite popular among collectors for display purposes. With an index of refraction as high as 1.820, rhodochrosite gems can have greater brilliance than those of the corundum gems sapphire and ruby [aluminum oxide, Al_2O_3]. Rhodochrosite collectors' gems range in size from only a few carats to as many as 50 carats and cost about \$100 to \$200 per carat, depending upon depth of color, lack of inclusions, and degree of transparency. Transparent rhodochrosite crystals are also cleaved into rhombohedrons and wrapped in silver wire or gold wire for use in pendants.

Sub-translucent or opaque forms of banded, stalactitic or stalagmitic rhodochrosite are fashioned into cabochons and beads and are widely used in bracelets, brooches, pendants, and necklaces. Nicely banded rhodochrosite cabochons of 20 carats sell for about \$50. Massive rhodochrosite is also fashioned into small decorative objects such as figurines and paperweights.

Rhodochrosite is in great demand by collectors both as individual and composite specimens. Cabinet-sized specimens, with intensely colored, transparent, rhombohedral crystals on matrices of crystalline quartz, fluorite, and metal-sulfide minerals, are widely exhibited in museums and can cost thousands of dollars each. Massive forms of rhodochrosite are collected for their wide variety of banding patterns.

August 2013 Mineral of the Month: Rhodochrosite

HISTORY & LORE

Rhodochrosite has been known since antiquity. The Incas believed that rhodochrosite was their former rulers' blood that had turned to stone, hence the alternate name "Inca rose" or "*rosa del Inca*." Mineralogists determined rhodochrosite's chemical composition nearly four decades after the discovery of the element manganese in 1774 (see "About Manganese"). In 1813, German mineralogist Johann Friedrich Ludwig Hausmann (1782-1859) studied a specimen collected from the type locality at Kapnic, Romania (recent research indicates that the type locality is actually Sacaramb, Romania), correctly identified its components as manganese, carbon, and oxygen, and recognized it as a new mineral species. The name "rhodochrosite" was formally assigned in 1836. Because of its striking red color and relative rarity, rhodochrosite has always been an eminently collectible mineral. Rhodochrosite may have been the first ore mineral to be valued solely for aesthetic reasons. In the 1870s and 1880s, before mineral collecting had even gained popularity in the United States, miners in the western silver and base-metal mines collected rhodochrosite specimens as a trading commodity. Mineralogists used X-ray diffraction methods to determine the atomic structure of rhodochrosite in 1924.

As evidence of the soaring specimen value of rhodochrosite, commercial specimen miners reopened the 139-year-old Sweet Home silver mine in Colorado's Alma mining district in the early 1990s specifically to recover rhodochrosite crystals for the collectors' market. The most famous and valuable rhodochrosite specimen ever recovered was found in the Sweet Home Mine in 1992. It was a six-inch, 5.5-pound, perfect rhombohedron of transparent, gem-quality, cherry-red rhodochrosite on a matrix consisting largely of white quartz needles. Named the Alma King and valued at over \$1 million, this spectacular specimen is now part of the permanent gem-and-mineral collection of the Denver Museum of Nature & Science. In 2002, the Colorado General Assembly designated rhodochrosite as Colorado's official mineral.

Rhodochrosite has appeared on the United States' 10-cent stamp of 1974 and on Central Africa's 600-franc stamp of 1998. According to modern metaphysical belief, rhodochrosite aids in achieving spiritual and emotional balance, stimulates feelings of love and compassion, discourages avoidance and denial, and enhances receptivity to new knowledge and experiences. Rhodochrosite is thought to appeal to those who are ready to learn more about their individual spirituality.

TECHNOLOGICAL USES

Rhodochrosite has no specific technological uses. When present in sedimentary deposits of altered manganese-oxide ores, rhodochrosite has served as a minor ore of manganese.

ABOUT MANGANESE

Unlike such familiar metals as lead, copper, and silver, the element manganese (pronounced MAN-guh-nee-z), the metal cation in our rhodochrosite specimens, is rarely seen in its metallic

August 2013 Mineral of the Month: Rhodochrosite

state. Nevertheless, manganese plays a big role in society and technology, and has an interesting history.

Manganese minerals such as pyrolusite [manganese dioxide, MnO_2] have been known since antiquity. Along with carbon (as charcoal), pyrolusite was one of the first black pigments. Anthropologists believe that Neanderthal cultures used pyrolusite as a cosmetic and pigment more than 30,000 years ago. Pyrolusite is the pigment in the black paints in the famed, 14,000-year-old cave paintings at Lascaux, France. In the 1st century A.D., the Roman scholar Pliny the Elder (Gaius Plinius Secundus, A.D. 23-79) described how pyrolusite was used in the manufacture of colorless glass.

Early mineralogists initially assumed that pyrolusite was a compound of iron. But in 1740, German chemist Johann Heinrich Pott (1692-1777) proposed that the metal in pyrolusite was actually a new element. Swedish mineralogist and crystallographer Johan Gottlieb Gahn (1745-1818) confirmed Pott's theory in 1774 by heating pyrolusite with carbon in a reduction reaction to isolate the new metallic element, which was named "manganese." Today, the origin of the word "manganese" has become somewhat confused. It most likely stems from the Latin *mangnes*, meaning "magnet," but also referring to the compound (pyrolusite) used by the Romans to decolor glass.

Manganese is a transition metal that is closely related to iron. In its elemental state, it is a silvery-white, brittle metal with an atomic number of 25, atomic weight of 54.94, Mohs hardness of 3.5-4.0, specific gravity of 3.7, and a melting temperature of 2271° F. (1245° C.). Although many of its properties are similar to those of iron, manganese is not magnetic. Ranking 12th among the elements in crustal abundance, it is roughly as common as phosphorus and fluorine. Although elemental manganese has been found in meteorites, mineralogists are still uncertain if it occurs free in nature on Earth.

Manganese is a major industrial metal. About 90 percent of the world's manganese supply is used in steelmaking as sulfur-fixing and deoxidizing fluxes or as an alloying agent, the latter to improve the hardness, stiffness, toughness, and strength of steel. It is also used to produce carbon steel, stainless steel, cast iron, high-temperature steel, and superalloys. Tough, durable manganese-steel alloys are particularly well-suited for use in steels intended to withstand high stresses. Typical uses include certain forms of military armor and railroad wheels and rails. Safes are constructed of an extremely tough steel that contains 12 percent manganese. Manganese is also added to copper, tin, brass, bronze, and zinc to improve workability or to create corrosion-resistant, specialized alloys for such applications as marine propellers. Aluminum beverage cans consist of an aluminum-manganese alloy containing one percent manganese that enhances the stiffness and extrusion properties of the aluminum. "Manganin" alloys of manganese, copper, and nickel are standard in wire used in precision electrical measurements, because its conductivity remains constant despite broad thermal changes.

Manganese compounds serve as depolarizers in dry-cell batteries and charge-stabilizers in rechargeable manganese-lithium batteries. They are also used in inks, varnishes, dyes, fertilizers, and pharmaceuticals, and as colorants for ceramics. Pyrolusite retains its two ancient uses: as a brown-black pigment in paints and as a decoloring agent in glassmaking. In the latter

August 2013 Mineral of the Month: Rhodochrosite

use, manganese eliminates the green color caused by small amounts of iron that are present in most glass mixtures. When added to glass, manganese forms a violet silicate that cancels the green color caused by iron. Manganese sulfate (MnSO_4) is used in dyeing cotton, while potassium permanganate (KMnO_4), a powerful oxidizing agent, is used in disinfectants and in water-purification processes. Manganous chloride (MnCl_2) is an additive in animal foods.

Manganese is a powerful chromophoric (color-causing) agent. It produces the red colors of rhodochrosite and rhodonite [calcium manganese silicate, $\text{CaMn}_4\text{Si}_5\text{O}_{15}$], and also the purple color of purpurite [manganese phosphate, MnPO_4]. In minerals and compounds, manganese can be present in the +2, +3, +4, +6, or +7 oxidation (or valence) states. The various oxidation states of manganese can produce compounds that are brown, black, red, green, or purple.

Among the most interesting manganese occurrences are potato-sized, seafloor nodules that consist largely of manganese dioxide with smaller amounts of iron, copper, cobalt, and nickel oxides. Oceanographers estimate that the floors of the oceans and large lakes contain 1.5 *trillion* tons of these nodules. However, no economic method of mining the nodules has yet been developed.

Although small amounts of manganese are recovered from mining iron and chromium ores, its primary ore is pyrolusite, about 42 million metric tons of which are mined worldwide each year and processed to yield 14 million metric tons of elemental manganese. China, the leading producer, mines 17 million metric tons of manganese ore per year, about one-third of the world's production. Australia is second at seven million metric tons of ore, but because of far higher ore grades actually recovers more elemental manganese than China. Other important manganese sources include Gabon, Kazakhstan, South Africa, and Brazil. With no domestic manganese-mining industry, the United States imports all of the 700,000 thousand metric tons of manganese it uses each year. The current price of refined manganese metal ready for alloy use is \$1.60 per pound. Ore grading 45 percent manganese sells for \$9 per metric ton.

ABOUT OUR SPECIMENS

Our rhodochrosite specimens were collected at the Wudong (Wuton) Mine at Liubao, Cangwe County, Wuzhou Prefecture, Guangxi Zhuang Autonomous Region, China. The Guangxi Zhuang Autonomous Region is located in southwestern China and is bordered on the southwest by the Socialist Republic of Viet Nam and on the south by the Gulf of Tonkin. Guangxi Zhuang, population 48 million, covers 91,400 square miles and is nearly the size of the state of Oregon. Much of Guangxi Zhuang is mountainous, with peaks as high as 7,100 feet. The climate is humid and semitropical. Guangxi Zhuang has a vibrant, diverse economy based on agricultural production, manufacturing, and mineral-resource development. Regarding the latter, the province is rich in bauxite, the ore of aluminum. Guangxi Zhuang also has one-third of China's deposits of tin and manganese, along with numerous small lead-zinc-silver mines.

Wudong, a small, underground, lead-zinc-silver mine and the source of our specimens, is located near Liubao in Wuzhou Prefecture. Wuzhou Prefecture is in eastern Guangxi Zhuang, 175 miles west-northwest of the coastal city of Hong Kong. Liubao is near the city of Wuzhou, population

August 2013 Mineral of the Month: Rhodochrosite

3.2 million. Located on the Xi Jiang River, Wuzhou is a major inland port and gem-synthesizing center where many small laboratories produce an array of synthetic gems, notably the corundum gems sapphire and ruby [aluminum oxide, Al_2O_3], spinel [magnesium aluminum oxide, MgAl_2O_4], and cubic zirconia [zirconium oxide, ZrO_2].

At Wudong, the host rock is mixed sedimentary strata of sandstone, siltstone, and shale that were deposited in the Cambrian Period of the Paleozoic Era about 550 million years ago. Much later, several orogenies or mountain-building episodes, most recently the Tertiary Himalayan Orogeny that occurred about 40 million years ago, deformed the crust when tectonic stresses generated by the colliding South China and North China plates uplifted the ancient sediments to form the highlands of today's Guangxi Zhuang Autonomous Region. As uplifting fractured the Cambrian sediments, metal-rich, hydrothermal solutions associated with deep magmatic intrusions forced their way upward into faults and fissures. At the Wudong polymetallic deposit, these hydrothermal solutions filled "ladder"-type systems of offset, vertical fractures in three separate phases. The first emplacement was a pre-ore phase that deposited quartz [silicon dioxide, SiO_2] and calcite [calcium carbonate, CaCO_3]. The second phase deposited quartz and hübnerite [manganese tungstate, MnWO_4]. The third and final emplacement phase deposited lead, zinc, silver, iron, and copper, along with rhodochrosite, fluorite [calcium fluoride, CaF_2], and additional quartz and calcite. The presence of hübnerite and rhodochrosite at Wudong reflects the richness of manganese mineralization throughout the Guangxi Zhuang Autonomous Region. Erosion later reduced the surface to expose the upper, oxidized portions of the metal-rich veins.

The Wudong polymetallic deposit was discovered in 1958 and developed as a small underground mine several years later. Wudong became one of thousands of small metal mines that helped to build the resource base from which China would later launch its spectacular economic growth of the 1990s and 2000s. The Wudong Mine is a shaft-accessed, relatively shallow operation that exploits vertical ore veins. The ore minerals are acanthite [silver sulfide, Ag_2S], galena [lead sulfide, PbS], sphalerite [zinc sulfide, ZnS], and small amounts of metallic silver [element, Ag]. Accessory minerals include quartz, calcite, hübnerite, fluorite, barite [barium sulfate, BaSO_4], chalcocite [copper sulfide, Cu_2S], pyrite [iron disulfide, FeS_2], and rhodochrosite.

The Wudong Mine became noted for specimens in the late 1990s, when miners accessed new, rhodochrosite-rich vein systems. The rhodochrosite occurs as flattened masses with smooth cleavage planes and, in veins where open space permitted crystal development, as small rhombohedrons. Wudong rhodochrosite first attracted attention at major gem-and-mineral shows in the United States and Europe in 1997. As collector demand grew for Wudong rhodochrosite, Wudong instituted a specimen-collection system that did not interfere with mine production, but that enabled miners and managers to earn secondary income. When rhodochrosite-filled veins and vugs are encountered, production is shifted to other veins, while small crews of miners experienced in collecting specimens recover the rhodochrosite. The specimens are then sold to visiting Chinese dealers, usually from Changsha in Hunan Province 350 miles to the northeast. Foreign dealers sometimes personally visit Wudong to buy specimens directly from the mine. Proceeds from the sale of specimens are distributed between miners and management.

During 50 years of small-scale mining, Wudong has produced 5,000 tons of lead, 3,800 tons of zinc, and 7 tons of silver (roughly 220,000 troy ounces). Operations were halted in 2011, when

August 2013 Mineral of the Month: Rhodochrosite

the mine placed on “care-and-maintenance” status as part of a program to modernize China’s mining industry. The Chinese government, which tightly controls all industries, is aware that its old system of hundreds of small mines has become very inefficient. The government now contends—and international mining analysts agree—that the future of China’s mineral production rests not in numerous small mines, but in a lesser number of large, highly mechanized operations that exploit massive, low-grade ore deposits and process ores on-site. Accordingly, the government has ordered the closure of hundreds of small metal mines such as Wudong. The production of these closed mines has already been replaced by that from new, modern, open-pit mines. Because Wudong is not expected to reopen, the value of Wudong specimens has increased steadily since the mine’s closure.

As you study your specimen, note first its bright, pink-red color. This particular color, which is not an intense cherry-red, indicates that calcium has replaced about 10 percent of the manganese in the rhodochrosite. To fully appreciate this color and its soft translucency, view the specimen with intense backlighting. Now notice the glassy, smooth surfaces that are cleavage planes. Because these specimens developed in conditions of restricted vein space, they did not form crystal faces. Observe also that the stress-fracture lines seen on the cleavage surfaces intersect to form rhombohedral shapes. Your specimen has a noticeably greater “heft” in the hand than a similarly sized piece of quartz. This is due to rhodochrosite’s density (specific gravity 3.5-4.0), which is about 25 percent greater than that of quartz (specific gravity 2.68). Finally, the white matrix material in your specimen is either quartz or calcite, or both. Some specimens will also have bits of glittering pyrite and purple fluorite. Your rhodochrosite specimen was collected in a Chinese mine that will never produce again.

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