Mineral of the Month Club March 2017

ROSASITE

This month's featured mineral is rosasite from the Ojuela Mine at Mapimí, Mexico. We have never before featured this uncommon basic copper zinc carbonate as our Mineral of the Month. Our write-up discusses rosasite's history, properties, and occurrence, and also describes the Ojuela Mine and the town of Mapimí as they appear today.

OVERVIEW

PHYSICAL PROPERTIES:

Chemistry: $(Cu,Zn)_2(CO_3)(OH)_2$ Basic Copper Zinc Carbonate (Copper Zinc Carbonate Hydroxide)
Class: Carbonates
Subclass: Anhydrous Carbonates containing Hydroxyl or Halogen Ions
Group: Rosasite
Crystal System: Monoclinic
Crystal Habits: Usually as crusts, tufts, spherical aggregates, and botryoidal masses, the latter two with radiating, internal structures; well-developed crystals are rare.
Color: Usually greenish-blue to bluish-green; sometimes blue or green.
Luster: Silky to vitreous; massive forms are dull.
Transparency: Transparent to translucent
Streak: Pale bluish-green or green
Refractive Index: 1.672-1.830
Cleavage: Perfect in one direction
Fracture and Tenacity: Fibrous; splintery.
Hardness: 4.0
Specific Gravity: 4.0-4.2
Luminescence: None
Distinctive Features and Tests: Blue-to-green colors; hardness; botryoidal habit; effervescence in acid; exclusive occurrence in oxidized zones of copper-zinc deposits; association with such minerals as smithsonite [zinc carbonate, $ZnCO_3$], hemimorphite [hydrous basic zinc silicate, $Zn_4Si_2O_7(OH)_2 \cdot H_2O$], malachite [basic copper carbonate, $Cu_2(CO_3)(OH)$], aurichalcite [basic zinc copper carbonate, $(Zn,Cu)_5(CO_3)_2(OH)_6$], and calcite [calcium carbonate, $CaCO_3$]. Rosasite can be confused with aurichalcite, although it is much harder.
Dana Mineral-Classification Number: 16a.3.1.1

NAME: Rosasite, pronounced ROSE-us-ite, is named after the Rosas Mine in Sardinia, Italy, where it was first discovered. Rosasite has also been known as "parauriculate"; a dark-green, nickel-rich variety is called "nickeloan rosasite." In European mineralogical literature, rosasite appears as *Rosasit* and *rosasita*.

www.celestialearthminerals.com Ph. #800-941-5594 Email: info@celestialearthminerals.com

COMPOSITION & STRUCTURE: Rosasite [basic copper zinc carbonate, $(Cu,Zn)_2(CO_3)(OH)_2$] contains the elements copper (Cu), zinc (Zn), carbon (C), oxygen (O), and hydrogen (H). Rosasite's ideal molecular weight is made up of 42.93 percent copper, 14.72 percent zinc, 5.41 percent carbon, 36.03 percent oxygen, and 0.91 percent hydrogen. Rosasite is one of 192 carbonate minerals, a class in which one or more metals combine with carbon and oxygen. Rosasite crystallizes in the monoclinic system, which is characterized by three axes of different lengths, two of which are perpendicular. The third axis is not perpendicular to the common plane of the other two, but makes an angle to create crystals that appear as deformed, orthorhombic crystals. Minerals such as rosasite that are chemically complex or complexly bonded often crystallize in the monoclinic system. Because relatively weak ionic bonding dominates throughout rosasite's crystal lattice, it is only moderately hard at Mohs 4.0. Weak ionic bonding also explains rosasite's tendency to effervesce in acids. Because copper and zinc, two moderately heavy metals, account for nearly half of its molecular weight, rosasite has a substantial density (specific gravity 4.0-4.2). As an idiochromatic or "self-colored" mineral, rosasite's color is caused by its essential elements and the nature of its crystal lattice. Copper is a strong, blue-green chromophore (color-causing agent). When pure or nearly pure, rosasite has a clean, bright, bluish-green or greenish-blue color. But shifts in the proportions of copper and zinc, as well as substitution of other divalent metal ions for those of copper and zinc, can shift the color toward pure blue or pure green. Rosasite occurs exclusively in the shallow, oxidized portions of copper-zinc deposits, where it forms under conditions of low temperature and low pressure from the action of acidic, zinc-bearing solutions on copper mineralization. It is associated with such minerals as smithsonite [zinc carbonate, $ZnCO_3$], hemimorphite [hydrous basic zinc silicate, $Zn_4Si_2O_7(OH)_2 \cdot H_2O$], malachite [basic copper carbonate, $Cu_2(CO_3)(OH)$], aurichalcite [basic zinc copper carbonate, $(Zn,Cu)_5(CO_3)_2(OH)_6$], calcite [calcium carbonate, $CaCO_3$], and limonite (an indefinite mixture of iron oxides and hydroxides).

COLLECTING LOCALITIES: Rosasite specimens are collected in Mexico, Morocco, Greece, Namibia, Zambia, Germany, Italy, England, and Australia. In the United States, rosasite is found in Arizona, Nevada, New Mexico, California, Colorado, Idaho, Utah, and Wisconsin.

HISTORY, LORE & GEMSTONE/TECHNOLOGICAL USES: Rosasite was discovered by the noted Italian geologist Domenico Lovisato (1842-1916) after studying specimens of oxidized copper mineralization that he had collected from the Rosas Mine at Narcao, Cagliari, Carbona-Iglesesias Province, Sardinia, Italy, in 1906. Lovisato succeeded in chemically differentiating rosasite from other copper minerals of similar composition, then named this new mineral in 1908 after the Rosas Mine where he had collected his specimens. The atomic structure of rosasite was first studied by X-ray diffraction methods in 1928. Despite its attractive colors, rosasite has little use as a gemstone because of its lack of hardness and the rarity of well-developed crystals. Its botryoidal forms are difficult to cut and polish because of their radiating, internal assemblages of acicular crystals. Rough, botryoidal rosasite is sometimes wrapped in silver wire for wear as pendants. Rosasite is widely collected for its saturated, greenish-blue and bluish-green colors and its occurrence in attractive, textured botryoidal forms. It is especially popular in composite specimens with other colorful, oxidized copper minerals. Rosasite formerly served as a minor ore of copper, but has no other technological uses. According to modern metaphysical practitioners, rosasite is a calming stone that facilitates coping with stress, aids memory, and encourages confidence

ABOUT OUR SPECIMENS: Our rosasite specimens are from the Ojuela (oh-HWAY-la) Mine at Mapimí in the Mapimí district, Durango, Mexico. One of the Western Hemisphere's most historic and productive mines, Ojuela is located in north-central Mexico about 40 miles northwest of the city of Torreón. The Ojuela Mine has produced ore or mineral specimens continuously for more than four centuries. Since the late 1500s, Ojuela has produced more than seven million tons of ore that yielded huge quantities of silver, lead, and zinc, along with lesser amounts of gold and copper. Ore production at Ojuela ended after World War II. The Ojuela Mine has more than 200 miles of underground workings, the deepest of which are now flooded. On average, a ton of its remarkably rich ore contained 15 troy ounces of silver, 15 percent lead, 12 percent zinc, 0.1 troy ounce of gold, and small amounts of copper. Ojuela mineral specimens first gained public attention in 1946, when miners leasing sections of the mine found large vugs filled with extraordinary crystals of adamite [basic zinc arsenate, $Zn_2(AsO_4)(OH)$]. Collectors and dealers from the United States then began visiting the mine regularly to buy specimens from miners or to pay for permission to collect their own specimens. Encouraged by today's high metal prices, mine-owner Compañía Minera de Penoles is now studying the feasibility of resuming production to recover previously overlooked sulfide ores of silver, lead, and zinc. Ranking among the world's top-ten specimen-producing localities, Ojuela has yielded more than 126 different mineral species and is the type locality for 6 species. Today, professional collectors and miners lease sections of the mine to recover specimens to sell on the international collectors' market. Ojuela is best known among mineral collectors for its superb specimens of the arsenate minerals adamite and austinite [basic calcium zinc arsenate, $CaZn(AsO_4)(OH)$].

COMPREHENSIVE WRITE-UP

COMPOSITION & STRUCTURE

Since the Mineral of the Month Club was founded in 1996, our members have received specimens of 122 different mineral species. This is the first time that we have featured rosasite as our Mineral of the Month. Rosasite [basic copper zinc carbonate, $(Cu,Zn)_2(CO_3)(OH)_2$] contains the elements copper (Cu), zinc (Zn), carbon (C) , oxygen (O), and hydrogen (H). Rosasite's ideal molecular weight is made up of 42.93 percent copper, 14.72 percent zinc, 5.41 percent carbon, 36.03 percent oxygen, and 0.91 percent hydrogen.

Rosasite is one of 192 carbonate minerals, a class in which one or more metals combine with carbon and oxygen. As with all molecules, those of rosasite consist of positively charged cations and negatively charged anions. Rosasite's compound cation consists of two copper-zinc units $2(Cu,Zn)^{2+}$ in which the proportions of copper and zinc vary somewhat from the average ratio of 3:2, but the cationic charge remains fixed at +2. This provides the rosasite cation with a total +4 charge. Rosasite's compound anion consists of two radicals, which are groups of atoms that act as entities in chemical reactions and function as ionic units. The first is the carbonate radical $(CO_3)^{2-}$, which consists of one carbon ion C^{4+} with its +4 charge and three oxygen ions $3O^{2-}$ with their combined -6 charge. This arrangement creates the carbonate radical $(CO_3)^{2-}$ with its collective -2 charge. Rosasite's second anionic radical is the double hydroxyl radical $2(OH)^{1-}$ with its -2 charge. Rosasite's complete, compound anionic radical is written as $[(CO_3)(OH)]^{4-}$. The total -4 anionic charge balances the total +4 cationic charge to provide the rosasite molecule with electrical stability.

The creation of the rosasite molecule begins when a carbon ion C^{4+} covalently bonds with shared electrons to three oxygen ions $3O^{2-}$ to form the carbonate radical $(CO_3)^{2-}$. Each carbonate radical then bonds ionically to two copper-zinc units $2(Cu,Zn)^{2+}$ to form the incomplete and electrically unbalanced copper-zinc carbonate radical $[(Cu,Zn)_2(CO_3)]^{2+}$. This incomplete copper-zinc carbonate radical becomes balanced by ionically bonding to two hydroxyl radicals $2(OH)^{1-}$ to complete the rosasite molecule $(Cu,Zn)_2(CO_3)(OH)_2$.

Rosasite crystallizes in the monoclinic system, which is characterized by three axes of different lengths, two of which are perpendicular. The third axis is not perpendicular to the common plane of the other two, but makes an angle with one to create crystals that appear to be deformed orthorhombic crystals. Minerals such as rosasite that are chemically complex or have complex bonding arrangements often crystallize in the monoclinic system. The rosasite crystal lattice is built upon chains of copper-zinc units that share edges to form long, octahedral columns that explain rosasite's acicular habit and perfect, one-directional cleavage. The copper-zinc units in these columns are linked to carbonate radicals; spaces between them accommodate the hydroxyl ions. Because relatively weak ionic bonding dominates throughout the crystal lattice, rosasite is relatively soft at Mohs 4.0. Weak ionic bonding also explains rosasite's tendency to effervesce in acids. Rosasite has a substantial density (specific gravity 4.0-4.2) because copper and zinc, two moderately heavy metals, account for nearly half of its molecular weight.

As an idiochromatic or "self-colored" mineral, rosasite's color is caused by its essential elements and the nature of its crystal lattice. Copper is a strong chromophore (color causing agent) for blue and green colors. When pure or nearly pure, rosasite has a clean, bright, greenish-blue to bluish-green color. But variations in the proportions of copper and zinc, as well as the substitution of other divalent metal ions for those of copper and zinc, create a slight color shift toward pure blue or pure green. Rosasite's saturated color is a function of reflected light; transmitted light that passes through thin rosasite crystals or coatings is light blue or nearly colorless. Rosasite is also pleochroic, meaning that its colors vary somewhat when viewed along different crystal axes. Pleochroism, an optical phenomenon seen in doubly-refractive crystals, is caused by variations in light-wavelength absorption along different axes. In rosasite crystals, this pleochroic shift is from greenish-blue and bluish-green toward purer shades of green and blue.

The Dana mineral-classification number 16a.3.1.1 first describes rosasite as a member of the carbonate class of minerals that contains hydroxyl or halogen ions (16a). Rosasite is then defined (3) by the formula $(A,B)_2(CO_3)Zq$, in which "A" and "B" can be such divalent metals as copper, zinc, nickel, cobalt, or magnesium; "Z" is a hydroxyl or halogen ion; and "q" is a quantifier. Rosasite is then assigned to the rosasite group (1) as the first (1) of five members. The four other group members, which differ only in their cationic elements, are:

glaucosphaerite	basic copper nickel carbonate	$(Cu,Ni)_2(CO_3)(OH)_2$
kolwezite	basic copper cobalt carbonate	$(Cu,Co)_2(CO_3)(OH)_2$
zincrosasite	basic zinc copper carbonate	$(Zn,Cu)_2(CO_3)(OH)_2$
mcquinessite	basic magnesium copper carbonate	$(Mg,Cu)_2(CO_3)(OH)_2$

Rosasite occurs exclusively in the shallow, oxidized portions of copper-zinc deposits. It forms under conditions of low temperature and low pressure from the action of acidic, zinc-bearing solutions on copper mineralization. Rosasite is usually associated with smithsonite [zinc carbonate, $ZnCO_3$], hemimorphite [hydrous basic zinc silicate, $Zn_4Si_2O_7(OH)_2 \cdot H_2O$], malachite [basic copper carbonate, $Cu_2(CO_3)(OH)$], aurichalcite [basic zinc copper carbonate, $(Zn,Cu)_5(CO_3)_2(OH)_6$], calcite [calcium carbonate, $CaCO_3$], and limonite (an indefinite mixture of iron oxides and hydroxides). Rosasite also forms in "post-mine" environments where mining has altered the acidity and chemical composition of groundwater to facilitate new mineral growth.

COLLECTING LOCALITIES

Our rosasite specimens are from the Ojuela (oh-HWAY-la) Mine at Mapimí in the Mapimí district, Durango, Mexico. Other Mexican sources are the San Antonio Mine in the Santa Eulalia district near Aquiles Serdán; the Leon mines at San Pedro Corralitos; and the Naica Mine at Saucillo in the Naica district, all in Chihuahua.

Other localities include the Agouizi Mine in the Bou Skor District, Quarzazate Province, Souss-Maasa-Draā Region, Morocco; the Sounion mines in the Lavrion District, Attiki Province, Greece; the Tsumeb Mine at Tsumeb, Otjikoto Region, Namibia; the Kabwe Mine at Kabwe, Kabwe District, Central Province, Zambia; and the Rohdenhaus Quarry at Rohdenhaus, Wulfrath, North Rhine-Westphalia, Germany. Italian sources include the Rosas Mine (type locality) at Narcao, Cagliari, Carbona-Iglesesias Province, Sardinia; and the Crevoladossoia Quarry at Crevaladossoia in the Ossoia Valley, Verbano-Cusio-Ossola Province, Piedmont. In England, rosasite is collected at the Graystone Quarry in the Callington District in Cornwall and the Roughton Gill Mine at Calbeck Falls in Cumbria. Australia's localities include the Mount Isa mines at Mount Isa Shire, Queensland; and the Anticline Prospect at Ashburton Down Station, Ashburton Shire, Western Australia.

In the United States, most rosasite localities are in Arizona; these include the Silver Bill and Defiance mines at Gleeson in Cochise County; the Copper Creek Canyon mines in the Bunker Hill district in the Galiuro Mountains and the Mammoth-St. Anthony Mine at Tiger in the Mammoth District, both in Pinal County; the Christmas Mine in the Banner district, Gila County; the Chief Mine in the Empire Mountains, Empire District, Pima County; and the Morenci Mine at Morenci, Greenlee County. In Nevada, rosasite is collected at the Yellow Pine Mine, Goodsprings District, Spring Mountains, Clark County; the Silver Coin Mine at Valmy, Iron Point district, Humboldt County; and the Cortez Mine in the Alhambra Hills, Cortez District, Eureka County. Sources in New Mexico include the Stephenson-Bennett Mine, Organ Mountains, Doña Ana County; and the Blanchard Mine at Bingham in the Hansonburg District and the Kelly Mine at Magdalena in the Magdalena district, both in Socorro County. Other localities are the Cerro Gordo Mine, Cerro Gordo district, Inyo Mountains, Inyo County, California; the Sherman Tunnel at Leadville in the Leadville district in Lake County and the Sedalia Mine in the Sedalia District in Chaffee County, both in Colorado; the Iron Mask and Excelsior mines in the Spring Mountain district, Lemhi County, Idaho; the Hidden Treasure Mine at Ophir in the Ophir district in the Oquirrh Mountains of Tooele County and the Centennial Eureka Mine at East Tintic in the Tintic district of Juab County, both in Utah; and the Flambeau Mine at Ladysmith, Rusk County, Wisconsin.

JEWELRY & DECORATIVE USES

Despite its attractive colors, rosasite is rarely used as a gemstone because of its softness and the rarity of well-developed crystals. Cutting and polishing its botryoidal forms is difficult because of its internal, radiating, acicular crystals. Pieces of rough botryoidal rosasite are sometimes wrapped in silver wire for wear as pendants. Rosasite crystals are occasionally faceted into collectors' gems, but these are usually flawed and weigh less than one carat.

Rosasite is widely collected for its saturated, greenish-blue, bluish-green, green, and blue colors and attractive, textured, botryoidal forms. It is especially popular in composite specimens with other colorful, oxidized copper minerals.

HISTORY & LORE

Rosasite was discovered in 1906 by the noted Italian geologist Domenico Lovisato (1842-1916) after studying specimens of oxidized copper mineralization that he had collected from the Rosas Mine at Narcao, Cagliari, Carbona-Iglesesias Province, Sardinia, Italy. After chemically differentiating rosasite from other copper minerals having similar compositions, Lovisato named this new mineral in 1908 after the Rosas Mine where he had collected his specimens. Lovisato was one of the first scientists to promote the theory of continental-plate movement or tectonic drift. Although he proposed this idea in 1870, it took 42 more years for the theory to be published by German geophysicist and meteorologist Alfred Wegener (1860-1930) and given serious scientific consideration. The atomic structure of rosasite was defined by X-ray diffraction methods in 1928.

According to modern metaphysical practitioners, rosasite is a calming stone that aids memory, encourages confidence in personal insights, and enables one to cope with stress.

OJUELA-MAPIMÍ TODAY: A VIRTUAL TOUR

The Ojuela Mine, the ghost town of Ojuela, and the nearby town of Mapimí are of great interest to mineral collectors and mining historians. Spanish prospectors discovered the Ojuela mineral deposit in 1598 (see "About Our Specimens"). The community (and now-ghost town) of Ojuela was founded that same year. The nearby town of Mapimí, which survives today, dates to the early 1600s. Over more than four centuries, both the mine and the towns have had their ups and downs. Today, although the Ojuela Mine no longer produces ore, it continues to yield mineral specimens. And the town of Mapimí is currently experiencing a revival in its economy and an increase in its population.

Ojuela is located in north-central Mexico northwest of the city of Torreón. From Torreón, it is reached by taking Mexico Route 49 north for 25 miles to Bermejillo, then taking Mexico Route 30 west for 12 miles and following the signs south for 4 miles to Mapimí and the Ojuela Mine. In this part of the arid Chihuahuan Desert, rugged mountain ranges separate broad plains. The higher mountain elevations host thin, scrub-oak forests; the plains are sparsely vegetated with cacti, thorny brush, and coarse grass. The elevation of the Ojuela Mine is 6,800 feet. Ojuela-Mapimí is becoming an increasingly popular destination among adventure travelers, mining and colonial historians, and mineral collectors. Attractions include the area's deep canyons, along with its rich history, historic buildings and ruins, underground-mine tours, a remarkable suspension bridge, and the opportunity to purchase mineral specimens directly from the miners who recover them.

Most visitors to Ojuela-Mapimí pass through Bermejillo, a small city of 9,000 residents at the junction of Mexico routes 30 and 49. Heading west from Bermejillo on Mexico Route 30 toward Mapimí, the highway traverses a broad valley that is a major agricultural area. The chicken farms that line the highway were established in the 1990s by Tyson de Mexico, and have recently been acquired by Brazilian-owned Pilgrim's Pride Corporation, one of the world's largest chicken producers. This area raises and processes much of the chicken that is marketed in Mexico and the United States. Many of the 5,000 chicken-industry workers reside in Mapimí.

A few miles before entering Mapimí, old smelter ruins appear in the distance and signs for the Ojuela Mine and the Ojuela Bridge mark a turnoff to the south. Two rock shops welcome visitors and display their specimens on roadside blankets. Driving south toward the Ojuela Mine, the gravel road soon turns to cobblestone as the uphill grade increases. This road is built on the bed of the old cog railway that once carried ore from the Ojuela Mine to the smelters in the valley. Farther along, a gate stands at the entrance to the Ojuela Mine site. Visitors pay a small fee and continue driving up a narrow, one-lane road that offers beautiful views of the surrounding mountains and desert. Gatekeepers at both ends of this road control the one-way traffic by radio.

The road ends at a parking area lined with stone ruins and the shops and stands of craftspeople and souvenir vendors. Some shops are built directly into the ruins, which are actually the northern part of the ghost town of Ojuela where the mine's managers once lived. Across a deep canyon is the southern part of Ojuela which consists of stone ruins that once housed working miners and their families. When the mine was in full production, the two-part, Ojuela town site bustled with 5,000 residents.

The main attraction is the "Ojuela Bridge," a narrow, 1,000-foot-long, cable-suspension footbridge that crosses a 250-foot-deep arroyo to connect the northern part of the Ojuela town site with the mine. Originally built by American civil engineer Washington Augustus Roebling

(1837-1926) in 1897, this bridge was rebuilt for its 100th anniversary in 1997. The new construction closely resembled the original bridge, but is much stronger and safer. Nevertheless, because the bridge sways in the wind, walking on it is not recommended for anyone afraid of heights. The timber walkway is only five feet across and must sometimes be shared with xthe burros and mules of miners hauling equipment and supplies to the mine, and loads of mineral specimens back. From the midpoint of the bridge, visitors can look down to the canyon floor and see the dark opening of the *descubridora*—the "discovery hole" where Spanish colonists first mined Ojuela ore more than four centuries ago.

At the south side of the bridge is a maze of shafts and tunnel entrances, some of which have been sealed with metal grating for safety purposes. A dozen makeshift wooden stands offer cold drinks, souvenirs, and mineral specimens. Visitors should be aware that many of these specimens are not from the Ojuela Mine, but from Brazil or other parts of Mexico. Several underground mine tours are also available. For modest fees, visitors are issued hard hats with carbide cap lamps and guided into the tunnels. The carbide cap lamps are a fascinating bit of mining history. They were the main source of underground light for individual miners from the early 1800s until electric cap lamps were developed in the 1930s. These self-contained lamps function when water drips onto calcium carbide to generate flammable acetylene gas which escapes through a nozzle and is ignited. The lamps, which hiss and sputter, provide just enough light to illuminate the underground.

The town of Mapimí is two miles from the Ojuela mine. When the Ojuela Mine was in full production in the 1930s, Mapimí had 7,000 residents. After the mine closed following World War II, its population dropped to just 1,000. Today, its population has risen to 5,300, thanks to the growth of tourism, ongoing specimen mining in the Ojuela Mine, and jobs provided by the region's agricultural industry. Mapimí has good lodging, several excellent restaurants, a palm-tree-lined plaza, and a church dating to the early 1800s. There are also numerous rock shops, some selling top-quality Ojuela mineral specimens to those willing to pay high prices. In addition, the town also has two museums, the Casa Museo Miguel Hidalgo and the Museo Comuntario, both of which display mining relics and historic artifacts.

About 100 Mapimí residents are *risqueros* who earn their livings mining mineral specimens, called *riscos*, in the Ojuela Mine. *Risqueros*, many of whom are the grandsons and great-grandsons of former Ojuela miners, work as teams that lease sections of the mine. Their work is difficult because the mine no longer has electricity and thus has no pumps, operating shafts, mechanical haulage, artificial ventilation, or electric lighting. Mining is performed manually, just as it was a century ago. Wearing hard hats and carbide cap lamps, these miners drill with hammers and hand steels, then blast with dynamite. Most mining teams consist of two *tumbadores*, who drill and blast, and two *cargodores*, who haul specimens out of the mine in sacks or by hand-tramming old ore cars over rusted rails. Teams working on the lower mine levels must sometimes descend and ascend more than 1,200 vertical feet on old wooden ladders. Mining teams sell their recoveries to middlemen or visiting dealers and collectors from the United States and Europe. On average, *risqueros* earn considerably more than employees of the local agricultural industry.

TECHNOLOGICAL USES

Rosasite served as a former ore of copper, but has no other technological uses.

ABOUT OUR SPECIMENS

Our rosasite specimens were collected at the Ojuela Mine at Mapimí in the Mapimí district, Durango, Mexico. This historic mine has produced ore or mineral specimens continuously for 419 years and was a rich source of silver for the Spanish Crown and later, for the Republic of Mexico.

The Ojuela Mine exploits one of the major carbonate-replacement deposits within the Mexican Fold Belt, a 900-mile-long zone of folded carbonate rocks. The fold-belt sediments were deposited by ancient seas 150 million to 65 million years ago. They later lithified into limestone, a rock consisting primarily of calcite [calcium carbonate, $CaCO_3$] and dolomite rock, which is very similar to limestone but consists mainly of the mineral dolomite [calcium magnesium carbonate, $CaMg(CO_3)_2$]. During the early Tertiary Period some 60 million to 40 million years ago, tectonic stresses deformed these limestone and dolomite formations into the convoluted folds of today's Mexican Fold Belt. Finally, between 40 million and 25 million years ago, regional volcanism and deep magmatic intrusions forced mineral-laden, hydrothermal solutions into fractures within the Fold Belt. Mineralization occurred when these solutions dissolved sections of the limestone and dolomite, replacing them with metal-sulfide minerals. Rich in silver, lead, and zinc, and containing lesser amounts of gold and copper, these deposits formed at depth and were later exposed by surface erosion. Contact with groundwater and atmospheric oxygen altered the upper portions of the sulfides into many secondary arsenate, phosphate, carbonate, oxide, and halide minerals.

Spanish prospectors discovered rich outcrops of chlorargyrite [silver chloride, AgCl] and argentiferous cerussite [silver-bearing lead carbonate, $PbCO_3$] at Ojuela in 1598. After depleting the rich, oxidized surface ores, the Spanish turned to underground mining and developed Ojuela into a major source of silver. By the early 1800s, Ojuela had yielded millions of troy ounces of silver and huge tonnages of lead. Production declined during the Mexican war of independence; when Mexico gained its independence in 1821, the Ojuela Mine and its smelters were largely in ruins. Production subsequently resumed, but was limited by outdated mining practices, poor roads, raids by outlaws, and government instability.

In the late 1870s, when the Mexican government was encouraging foreign mining investment, an American company briefly took over Ojuela, but went bankrupt. In 1890, Compañía Minera de Penoles, which was backed by American and European capital, bought the mine and hired American mining engineers to modernize the operation. The company built a railroad and a modern smelter, electrified the town and the mine, constructed employee housing, and brought in American civil engineer Washington Augustus Roebling (1837-1926), the designer and builder of New York's Brooklyn Bridge, to construct a narrow, 1,000-foot-long, cable-suspension footbridge over a 250-foot-deep arroyo to connect the town with the mine. Roebling also increased the mine's depth to access an overlooked ore body. By 1910, some 1,200 Ojuela miners were recovering one million troy ounces of silver per year, along with large tonnages of lead and zinc. But operations ceased again with the onset of the Mexican Revolution. During the post-Revolution years of the early 1920s, core-drill exploration revealed deeper ore bodies. Production soared during the late 1920s, but profits were soon curtailed by the Great Depression. Ojuela never again approached its former production rates. In 1946, Compañía Minera de Penoles ended its unified management and began leasing mine sections to independent cooperatives of miners, a system that survives today among *risquero* specimen miners.

Ojuela's fame as a world-class specimen locality is due to the extraordinarily large volume and depth of its oxidized mineralization. Much of its original sulfide mineralization has oxidized into colorful carbonates, oxides, halides, phosphates, and arsenates. Ojuela ores are quite rich in arsenic, and thus in unusual iron, lead, zinc, and copper arsenates. Ojuela specimens first gained public attention in 1946, when lease miners found large vugs filled with extraordinary crystals of adamite [basic zinc arsenate, $Zn_2(AsO_4)(OH)$]. Collectors and dealers from the United States then began visiting the mine regularly to buy specimens from the miners or to pay Compañía Minera de Penoles for permission to collect their own specimens.

Throughout its long history, miners have extracted more than seven million tons of ore. On average, each ton contained 15 troy ounces of silver, 15 percent lead, 12 percent zinc, 0.1 troy ounce of gold, and small amounts of copper. The Ojuela Mine has more than 200 miles of underground workings, the deepest of which are now flooded. Nevertheless, encouraged by today's high metal prices, mine-owner Compañía Minera de Penoles is currently studying the feasibility of resuming full-scale operations to recover previously overlooked sulfide ores of silver, lead, and zinc. Although Ojuela has not produced ore in decades, teams of independent miners continue to lease mine sections from Compañía Minera de Penoles to recover mineral specimens (see "Ojuela-Mapimí Today: A Virtual Tour").

As you study your specimen, note that the rosasite is present as crusts, radiating tufts, spherical aggregates, and botryoidal masses, the latter two with radiating internal structures. Some spherical aggregates and botryoidal structures are covered with fine, acicular crystals that lend a velvety appearance. The forest-green color of the rosasite indicates an unusually high zinc content. The rosasite rests atop a matrix of massive, orange-brown limonite, an indeterminate mixture of hydrous iron oxides which, along with dark-brown goethite [basic iron oxide, $FeO(OH)$], is common in many oxidized environments. Goethite is an alteration product of the oxidation of such iron-sulfide minerals as pyrite [iron disulfide, FeS_2, cubic], marcasite [iron disulfide, FeS_2, orthorhombic], and arsenopyrite [iron arsenic sulfide, FeAsS], all of which are abundant at Ojuela. This orange-brown matrix is an identifying characteristic of virtually all oxidized-mineral specimens from the Ojuela Mine.

References: *Dana's New Mineralogy*, Eighth Edition, Richard Gaines, Catherine Skinner, et al, Wiley-Interscience, 1997; *Encyclopedia of Minerals*, Second Edition, William Roberts, Thomas Campbell, Jr., and George Rapp, Van Nostrand Reinhold Company, 1990; *2014 Fleischer's*

Glossary of Mineral Species, Malcolm E. Back, The Mineralogical Record, Inc.; *Mineralogy*, John Sinkankas, Springer-Verlag, 1993; *Manual of Mineralogy*, Cornelius Hurlbut and Cornelia Klein, 21st Edition, John Wiley & Sons; “Mapimí: Mineral Collectors’ Capital of Mexico,” P. W. Johnson, *The Mineralogist*, May-June 1962; “High-Temperature, Carbonate-Hosted Lead-Zinc-Silver Massive Sulfide Deposits of Mexico,” Peter Megaw and Juan Ruíz, *Economic Geology*, Volume 83, 1988; *Mines and Minerals of Mexico: The Ojuela Mine*, Volume 2, Thomas Moore and Peter Megaw, The Mineralogical Record, Inc., 2003; *Handbook of Mineralogy*, J. W. Anthony, R. A. Bideaux, K. W. Bladh, and M. C. Nichols, Volume 4, Mineral Data Publishing, 2000; “Famous Localities: The Ojuela Mine, Mapimí, Durango, Mexico,” Thomas P. Moore and Peter Megaw, *The Mineralogical Record*, September-October 2003; “Tales from Mexico (Parts I and II),” B. Smith and C. Smith, editors, *Rocks & Minerals*, January-February and March-April 1999.