

Mineral of the Month Club December 2017

HEMIMORPHITE

This month we are featuring hemimorphite, a basic hydrous zinc silicate named for its tendency to exhibit different habits at opposite ends of the same crystal. Our specimens were collected at Mexico's famed Ojuela Mine.

OVERVIEW

PHYSICAL PROPERTIES:

Chemistry: $Zn_4Si_2O_7(OH)_2 \cdot H_2O$ Basic Hydrous Zinc Silicate (Hydrous Zinc Silicate Hydroxide), often containing copper and iron.

Class: Silicates

Subclass: Sorosilicates (Double-Tetrahedral Silicates)

Group: Hemimorphite

Crystal System: Orthorhombic

Crystal Habit: Usually as elongated, flat, bladed crystals or botryoidal crusts. Blades are vertically striated and form fan-shaped aggregates or coxcomb groups; botryoidal crusts often show rough crystal terminations that create ridged structures. Crystals are hemimorphic and exhibit different habits at opposite ends, one a typical, pyramidal termination, the other composed of slightly domed, pedion (geometrically unrelated) faces. Hemimorphite also occurs in massive, granular, and stalactitic forms.

Twinning uncommon.

Color: Usually colorless or white; sometimes yellow, blue, or green; less commonly reddish or brown.

Luster: Larger crystals are vitreous; botryoidal and other compact forms are dull.

Transparency: Transparent to translucent

Streak: Colorless

Cleavage: Perfect in one direction

Fracture and Tenacity: Uneven to subconchoidal, brittle.

Hardness: 4.5-5.0

Specific Gravity: 3.4-3.5

Luminescence: Occasionally fluoresces blue under shortwave ultraviolet light.

Refractive Index: 1.614-1.636

Distinctive Features and Tests: General field indicators are crystal habit, color, density, and luster. Can be confused with botryoidal forms of smithsonite [zinc carbonate, $ZnCO_3$] and prehnite [basic calcium aluminum silicate, $Ca_2Al_2Si_3O_{10}(OH)_2$], but hemimorphite is lighter than smithsonite and heavier than prehnite. Smithsonite effervesces in cold hydrochloric acid; hemimorphite does not.

Dana Classification Number: 56.1.2.1

NAME: The name "hemimorphite," pronounced hemm-ih-MORF-ite, stems from the Greek words *hēmi*, or "half," and *morphē*, meaning "form." The combined meaning, "half-form,"



Mineral of the Month Club December 2017

alludes to the tendency of hemimorphite crystals to exhibit hemimorphism and exhibit different habits at opposite terminations. Hemimorphite has also been known as “calamine,” “calamina,” “daviesite,” “electric calamine,” “emimorph,” “galmei,” “Geminer,” “Kieselzinkerz,” “Kieselzinkspath,” “hemimorphit,” “wagite,” “hydrowillemite,” “zincglas,” “zinc silicate,” and “maggot-ore.” In European mineralogical literature, hemimorphite appears as *hemimorphit* and *hemimorphita*.

COMPOSITION & STRUCTURE: Hemimorphite is a basic hydrous zinc silicate containing the elements zinc (Zn), silicon (Si), oxygen (O), and hydrogen (H). The molecular weight of hemimorphite is made up of 54.29 percent zinc, 11.66 percent silicon, 33.21 percent oxygen, and 0.84 percent hydrogen. Silicates, the largest and most abundant class of minerals, form when silicon and oxygen combine with one or more metals. The fundamental silicate structural unit, the silica tetrahedron (SiO_4)⁴⁻, consists of four equally spaced oxygen ions 4O^{2-} that surround a silicon ion Si^{4+} at the four corners of a tetrahedron (a four-faced polyhedron). Hemimorphite is a double-tetrahedral silicate or sorosilicate (the Greek word *soro* means “group”) in which silica tetrahedra share one oxygen ion O^{2-} with adjacent silica tetrahedra. Within the hemimorphite lattice, these double-silicate tetrahedra do not join directly, but are linked together by $[\text{ZnO}_3(\text{OH})]^{5-}$ tetrahedra, each consisting of a zinc ion surrounded by three oxygen ions and one hydroxyl ion. These zinc-based tetrahedra share oxygen ions with the double-tetrahedra silicate ions to create a three-dimensional network of tetrahedral structures with channels that accommodate water molecules. As indicated by the “·H₂O” in its chemical formula $\text{Zn}_4\text{Si}_2\text{O}_7(\text{OH})_2 \cdot \text{H}_2\text{O}$, hemimorphite is a hydrous (or hydrated) mineral, with an attached molecule of water (H₂O) called “water of hydration.” The hemimorphite lattice is held together by strong covalent bonding, weaker ionic bonding, and very weak hydrogen bonding. Hemimorphite is an allochromatic or “other-colored” mineral, meaning that its color is due to trace amounts of non-essential elements that act as chromophores (color-causing agents). Pure hemimorphite is colorless or white; impure hemimorphite has a range of colors caused by such non-essential elements as copper and iron. As a secondary mineral, hemimorphite forms from the weathering of sphalerite [zinc sulfide, ZnS] in near-surface oxidation zones of skarns and disseminated hydrothermal replacement deposits in calcareous (limestone) strata. It also forms when silica-rich solutions alter smithsonite [zinc carbonate, ZnCO₃]. Hemimorphite forms only in low temperatures and a basic chemical environment.

COLLECTING LOCALITIES: Hemimorphite is collected in Mexico, China, Australia, Italy, Scotland, England, Slovenia, Romania, Spain, and the United States (Montana, New Mexico, Nevada, Colorado, Idaho, Missouri, and New Jersey).

HISTORY, LORE & GEMSTONE/TECHNOLOGICAL USES: Hemimorphite has been known since antiquity, but prior to the mid-1800s it was confused with smithsonite which has similar forms, colors, and mineralogical occurrence. For many centuries, smithsonite and hemimorphite were thought to be a single species called “calamine.” Although smithsonite was formally described as a distinct mineral in 1832, “calamine” remained a mineralogical puzzle. In 1853, German geologist and mineralogist Gustav Adolph Kenngott (1818-1897) unofficially renamed “calamine” hemimorphite, after its hemimorphic properties. Then in 1868, American

Mineral of the Month Club December 2017

clergyman and mineral dealer Ebenezer Seymour (1801-1879) described the mineral scientifically after studying specimens from the Baita mining district at Rézbánya, Bihar, Romania, now the type locality. By then, growing industrial demand for brass (a copper-zinc alloy) had spurred demand for zinc. Hemimorphite, which contains 54.2 percent zinc, became an important zinc ore in North America and Europe. The old name “calamine” remained in widespread use until the 1930s, when mineralogists positively determined hemimorphite’s chemical composition and formally accepted its current name. X-ray diffraction studies defined hemimorphite’s atomic structure in the 1960s. Hemimorphite, together with smithsonite, has long been the chemical base of the various “calamine lotions” used to treat various skin conditions. Early physicians also used hemimorphite to treat ulcers and blood problems. According to modern metaphysical beliefs, hemimorphite enhances self-esteem and self-respect, facilitates personal evolution, protects against malice, and brings joy and creativity to life. Hemimorphite’s brittleness and moderate hardness (Mohs 4.5-5.0), along with its perfect, one-directional cleavage and a maze of hairline fractures that make faceting difficult, limit its use as a gemstone. Colorless, transparent crystals are occasionally cut into collectors’ gems as large as three carats. Hemimorphite, especially its massive or botryoidal, blue forms, are fashioned into cabochons and beads, or tumbled. Hemimorphite cabochons from 7 to 30 carats in size retail for about \$100 to \$200. Polished blue hemimorphite is very similar in appearance to the gem forms of turquoise [basic hydrous copper aluminum phosphate, $\text{CuAl}_6(\text{PO}_4)_4(\text{OH})_8 \cdot 4\text{H}_2\text{O}$] and smithsonite. For study and display purposes, hemimorphite is popular among mineral collectors for its two distinct, hemimorphic habits and the scarcity of good specimens.

ABOUT OUR SPECIMENS: Our hemimorphite specimens are from the Ojuela Mine at Mapimí in the Mapimí district, Durango, Mexico. Ojuela is located in north-central Mexico 40 miles northwest of the city of Torreón. One of the Western Hemisphere’s oldest and most productive mines, Ojuela has produced ore or mineral specimens continuously for more than four centuries. Since the late 1500s, Ojuela has yielded an estimated seven million tons of ore that provided huge quantities of silver, lead, and zinc, along with lesser, but still substantial, amounts of gold and copper. Production mining at Ojuela ended after World War II. The Ojuela Mine has more than 200 miles of underground workings, the deepest of which 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 adamite crystals. Collectors and dealers from the United States then began visiting the mine regularly to buy specimens from miners or secure 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 fine specimens of the arsenate minerals austinite [basic calcium zinc arsenate, $\text{CaZn}(\text{AsO}_4)(\text{OH})$] and adamite [basic zinc arsenate, $\text{Zn}_2(\text{AsO}_4)(\text{OH})$].

Mineral of the Month Club December 2017

COMPREHENSIVE WRITE-UP

COMPOSITION AND STRUCTURE

Hemimorphite's chemical formula $Zn_4Si_2O_7(OH)_2 \cdot H_2O$ identifies it as a basic hydrous zinc silicate containing the elements zinc (Zn), silicon (Si), oxygen (O), and hydrogen (H). The molecular weight of hemimorphite is made up of 54.29 percent zinc, 11.66 percent silicon, 33.21 percent oxygen, and 0.84 percent hydrogen. All molecules achieve stability when the cumulative electrical charge of the cations (positively charged ions) equals that of the anions (negatively charged ions). In hemimorphite, the +8 charge of four zinc cations $4Zn^{2+}$ is balanced by the collective -8 charge provided by the silica radical $(Si_2O_7)^{6-}$ and two hydroxyl ions $2(OH)^{1-}$ in the compound anion.

Hemimorphite is a member of the silicates, the largest and most abundant class of minerals. Silicates form when silicon and oxygen combine with one or more metals. The fundamental silicate structural unit, the silica tetrahedron $(SiO_4)^{4-}$, consists of four equally spaced oxygen ions $4O^{2-}$ that surround a silicon ion Si^{4+} to form the four corners of a tetrahedron (a four-faced polyhedron). In silicate minerals, silica anions and metal cations link together like polymers (repeating chains) to form seven different structures: independent-tetrahedral silicates (nesosilicates); framework silicates (tectosilicates); single- and double-chain silicates (inosilicates); ring silicates (cyclosilicates); sheet silicates (phyllosilicates); and double-tetrahedral silicates (sorosilicates). These classifications are based on the number of shared oxygen ions per silica tetrahedron. Silica tetrahedrons may share from none to as many as all four of their oxygen ions with adjacent tetrahedra. The specific type of tetrahedral arrangement largely determines the characteristics of silicate minerals.

Hemimorphite is a double-tetrahedral silicate or sorosilicate (from the Greek *soro*, or "group"). Double-tetrahedral silicates form when a silica tetrahedron shares one oxygen ion (O^{2-}) with an adjacent silica tetrahedron. In this arrangement, two silica tetrahedra $(SiO_4)^{4-}$ share a single oxygen ion to form a $(Si_2O_7)^{6-}$ radical (radicals are groups of atoms that act as entities in chemical reactions). The $(Si_2O_7)^{6-}$ radical is the core component of both the hemimorphite molecule and its crystal lattice. Within this radical, the single shared oxygen is electrically neutral, while the other six each carry a -1 charge. This radical forms a stable molecule by bonding ionically with four zinc ions $4Zn^{2+}$ and two hydroxyl ions $2(OH)^{1-}$.

Within the hemimorphite lattice, the double-silicate tetrahedra do not bond directly, but are instead linked together by $[ZnO_3(OH)]^{5-}$ tetrahedra, each consisting of a zinc ion surrounded by three oxygen ions and one hydroxyl ion. These zinc-based tetrahedra share oxygen ions with the double-tetrahedra silicate ions to form a three-dimensional network of tetrahedral structures with channels that accommodate water molecules.

As indicated by the " $\cdot H_2O$ " in its chemical formula $Zn_4Si_2O_7(OH)_2 \cdot H_2O$, hemimorphite is a hydrous (or hydrated) mineral with an attached molecule of water (H_2O) called "water of

Mineral of the Month Club December 2017

hydration.” Water molecules consist of a large oxygen ion O^{2-} and two tiny, closely grouped hydrogen ions $2H^{1+}$. Although they are electrically neutral, the two grouped hydrogen ions retain a small positive charge that imparts polarity. The large oxygen ion that dominates the opposite side of the molecule retains a small negative charge. Water molecules thus act as tiny dipolar magnets that attach themselves to certain other molecules to create hydrous compounds. Because they are electrically neutral, attached water molecules do not affect the electrical balance of the parent molecule.

The hemimorphite lattice is held together by strong covalent bonding, weaker ionic bonding, and very weak hydrogen bonding. Because its zinc ions are completely shielded by oxygen and hydroxyl ions, hemimorphite exhibits no metallic properties. Of the three structural planes within the lattice structure, two are dominated by covalent bonding and one by weaker ionic bonding. Hemimorphite’s perfect, one-directional cleavage occurs along the plane dominated by the weak ionic bonding. But because covalent bonding predominates within the overall lattice, hemimorphite is relatively hard at Mohs 4.5-5.0. Close molecular packing within the lattice, together with zinc’s relatively high atomic weight (65.39), accounts for hemimorphite’s moderately high density (specific gravity 3.4-3.5). The prismatic faces of hemimorphite are usually prominently striated.

The Dana mineral-classification number of 56.1.2.1 first describes hemimorphite as a sorosilicate containing $(Si_2O_7)^{6-}$ silica groups with oxygen, hydroxyl, or fluorine cations and attached water molecules (56). Hemimorphite is then subclassified (1) as having a four-coordination cation, which is seen in its four-zinc cation. Finally, hemimorphite is assigned to the hemimorphite group (2) as the first (1) and only member.

Hemimorphite is an allochromatic or “other-colored” mineral, meaning its colors are caused by trace amounts of non-essential elements that act as chromophores (color-causing agents). Pure hemimorphite is colorless or white; impure hemimorphite has a range of colors that are caused mainly by the non-essential, chromophoric elements copper and iron. Trace amounts of copper (cupric, Cu^{2+}) substituting for zinc ions in the lattice produce blue and green hues; iron produces yellow and brown hues.

Hemimorphite is a secondary mineral that forms from the weathering of sphalerite [zinc sulfide, ZnS] in the near-surface oxidation zones of skarns, and in disseminated hydrothermal replacement deposits within calcareous (limestone) strata. It also occurs when silica-rich solutions alter smithsonite [zinc carbonate, $ZnCO_3$]. Hemimorphite formation requires low-temperature conditions and a basic chemical environment. Common mineral associations include smithsonite, gypsum [hydrous calcium sulfate, $CaSO_4 \cdot 2H_2O$], hematite [iron oxide, Fe_2O_3], calcite [calcium carbonate, $CaCO_3$], anglesite [lead sulfate, $PbSO_4$], cerussite [lead carbonate, $PbCO_3$], and aurichalcite [basic zinc copper carbonate, $(Zn,Cu)_5(CO_3)_2(OH)_6$]. Hemimorphite sometimes occurs as pseudomorphs after calcite and smithsonite.

COLLECTING LOCALITIES

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Mineral of the Month Club December 2017

Although not abundant, hemimorphite is widely distributed and is present in most oxidized or partially oxidized zinc deposits. Our specimens are from the Ojuela Mine at Mapimí, Durango, Mexico. Other Mexican sources include the Potosí and San Antonio mines in the Santa Eulalia (Aguiles Serdan) district and the Congreso-Leon Mine at Casas Grandes, both in Chihuahua.

Chinese specimens are collected at the Wenshan zinc mine near Wenshan in Yunnan Province, and the Ningdu zinc mine at Ningdu in Jiangxi Province. In Australia, hemimorphite occurs at the Kintore open pit at Broken Hill in New South Wales, the Mt. Isa-Cloncurry mining complex in Queensland, and the zinc-lead-silver deposits at Kununurra and Carlton Hill in Western Australia. In Italy, specimens have been found at the Seddas Moddizzia, San Giovanni, and Mosua mines at Iglesias, Sardinia. In the United Kingdom, hemimorphite occurs at Leadhills in Dumfries, Scotland, and in England at the Bayle Hill Mine in the Alston-Moor district and the Roughton Gill Mine at Roughton Gill in Cumbria. In Slovenia, the Banská Štiavnica Mine in the Banská Štiavnica district at Banskobystrický Kraj yields nice specimens. Hemimorphite is also found at its type locality, the Baita mining district at Rézbánya, Bihar, Romania. In Spain, colorless hemimorphite crystals occur in the lead-zinc mines of the Picos de Europa Mountains in the northern provinces of Asturias and Cantabria.

In the United States, hemimorphite is collected at the Summit Mine, Lone Mountain district, Broadwater County, Montana. Hemimorphite also occurs in New Mexico at the Stephenson-Bennett Mine in the Organ Mountains of Doña Ana County, and in Socorro County at the Blanchard Mine in the Hansonburg district and the Anchor and Graphic mines in the Magdalena district. Numerous mines in the Goodsprings district of Clark County, Nevada, and those of the Leadville district of Lake County, Colorado, have produced specimens. In Idaho, hemimorphite is found in the Bunker Hill and Sullivan mines at Kellogg in the Coeur d'Alene district of Shoshone County. Other hemimorphite sources include the Aurora and Lone Elm mines in the Tri-State district of Jasper County, Missouri, and Ogdensburg and Franklin in the Franklin district of Sussex County, New Jersey.

JEWELRY & DECORATIVE USES

Hemimorphite's brittleness and only moderate hardness (Mohs 4.5-5.0), along with its perfect, one-directional cleavage and frequently occurring maze of hairline fractures that complicates cutting, limit its use as a gemstone. Colorless, transparent crystals are occasionally cut into collectors' gems as large as three carats. Hemimorphite, especially the blue, massive and botryoidal forms, are fashioned into cabochons and beads, or tumbled. Hemimorphite cabochons of 7 to 30 carats in size retail for about \$100. Polished blue hemimorphite is similar in appearance to gem forms of turquoise [basic hydrous copper aluminum phosphate, $\text{CuAl}_6(\text{PO}_4)_4(\text{OH})_8 \cdot 4\text{H}_2\text{O}$] and smithsonite. Hemimorphite gemstones are often treated with epoxy to enhance strength and color intensity of massive and botryoidal forms.

Mineral of the Month Club December 2017

For study and display purposes, hemimorphite is popular among mineral collectors for its hemimorphic habits and the scarcity of good specimens.

HISTORY & LORE

Hemimorphite has been known since antiquity, but until the mid-1800s was confused with smithsonite, which has similar colors and mineralogical occurrences. For many centuries, smithsonite and hemimorphite were considered to be a single species called “calamine.” The first suspicions that “calamine” might include two distinct minerals arose during early investigations of pyroelectricity (electrical current generated by heating certain mineral crystals.). Both French mineralogist René Just Haüy (1743-1822) and English chemist James Smithson (1766-1829) noted that while certain “calamine” specimens exhibited strong pyroelectrical properties, others did not.

Although smithsonite was formally described as a distinct mineral species in 1832, the remaining “calamine” mineral remained a mystery. In 1853, German geologist and mineralogist Gustav Adolph Kenngott (1818-1897) unofficially renamed “calamine” hemimorphite, after its hemimorphic properties. Then in 1868, American clergyman and mineral dealer Ebenezer Seymour (1801-1879) described the mineral scientifically after studying specimens from the Baita mining district at Rézbánya, Bihor, Romania, now the type locality. That same year, New Jersey geologist George H. Cook (vita uncertain), provided another name for the mineral—“electric calamine,” after its pyroelectrical properties. In 1895, another researcher renamed the mineral “hydrowillemite,” believing that it was a hydrous form of willemite [zinc silicate, Zn_2SiO_4].

By then, growing industrial uses for brass (a copper-zinc alloy) had spurred demand for zinc. Hemimorphite, which contains 54.2 percent zinc, became an important zinc ore in North America and Europe. Miners at the New Jersey Zinc Company mines in Ogdensburg and Franklin, New Jersey, gave hemimorphite the popular name of “maggot ore,” because its botryoidal surface resembled the shape of a mass of maggots. But by the early 1900s, after the shallow hemimorphite deposits were exhausted and zinc miners turned to large, deep deposits of sphalerite [zinc sulfide, ZnS], hemimorphite was no longer an important ore.

The old name “calamine” remained in widespread use until the 1930s, when mineralogists precisely determined hemimorphite’s chemical composition and formally accepted its current name. X-ray diffraction studies finally defined hemimorphite’s atomic structure in the 1960s.

Hemimorphite, together with smithsonite, has traditionally been the chemical base of the “calamine lotions” used to treat various skin conditions. Early physicians also used hemimorphite to treat ulcers and blood problems. According to modern metaphysical beliefs, hemimorphite enhances self-esteem and self-respect, facilitates personal evolution, protects against malice, and brings joy and creativity to life.

Mineral of the Month Club December 2017

THE MINERALOGICAL PHENOMENON OF HEMIMORPHISM

Like many complex minerals, hemimorphite crystallizes in the orthorhombic system, which is characterized by three mutually perpendicular axes of different lengths. But the most unusual aspect of hemimorphite's crystallography is its hemimorphism, one of the mineral kingdom's more unusual phenomena. In hemimorphic crystals, the ends or poles of the central crystallographic axis are not symmetrical. Although hemimorphite crystals retain their basic orthorhombic structure throughout, their opposite terminations exhibit different crystal habits.

Hemimorphism results from abnormal crystal growth. The crystallization process begins when a minute crystal, called a seed crystal, forms from solution. As this seed crystal accumulates more of the same mineral constituents from its fluid environment, it continues to grow. Growth progresses from the base termination to the top termination. At the completion of growth, most mineral crystals exhibit the same habit throughout the crystal. Crystals that exhibit different habits at opposite terminations are called hemimorphic. Hemimorphism sometimes occurs when the chemical compositions of mineral fluids change during crystal growth, and the introduction of non-essential elements distorts the growing crystal lattices to create different termination habits.

In hemimorphite and a few other minerals, hemimorphism is an inherent part of crystal-lattice growth that is likely caused by internal stresses that accumulate during the growth process. Remember that the hemimorphite lattice consists of $[\text{ZnO}_3(\text{OH})]^{5-}$ tetrahedra that share oxygen ions with $(\text{Si}_2\text{O}_7)^{6-}$ double-silica tetrahedra. Both the zinc-based tetrahedra and the double-silica tetrahedra are directionally aligned, with parallel bases and apices oriented in the same direction. But as the lattice grows, accumulating stresses alter this uniform alignment so that upon completion of growth, the habit at the top termination differs from that at the base termination. In hemimorphite, hemimorphism occurs in all crystal habits, including botryoidal. But unless both terminations are visible, the hemimorphism cannot be seen. Hemimorphism can be observed only in doubly terminated crystals or in specimens in which crystal clusters have opposing orientations.

Several other minerals exhibit hemimorphism, but none as prominently as hemimorphite. Among these are the tourmaline-group minerals of basic aluminum boron silicates with the general formula $\text{Na}(\text{Mg,Fe})_3\text{Al}_6(\text{BO}_3)_3(\text{Si}_6\text{O}_{18})(\text{OH,F})_4$. Others include zincite [zinc manganese oxide, $(\text{Zn,Mn})\text{O}$], greenockite [cadmium sulfide, CdS], and wurtzite [zinc iron sulfide, $(\text{Zn,Fe})\text{S}$].

Hemimorphism is related to the phenomena of pyroelectricity and piezoelectricity, in which heat or mechanical stress generate electrical potentials on crystal faces. Pyroelectric and piezoelectric crystals are able to directly convert thermal or mechanical energy to electrical energy. All have interlocked, three-dimensional structures, rigidity, and great spatial stability (exhibiting little expansion or contraction when heated). When heated, pyroelectric crystals do not expand; instead, the thermal energy displaces ions from their normal positions in the crystal lattice. In

Mineral of the Month Club December 2017

piezoelectric crystals, mechanical stress also displaces ions from their normal positions, rather than deforming the crystal. The accumulating effects of ionic displacement throughout the crystal lattice create measurable electrical potentials on certain opposing crystal faces. Hemimorphite has unusually strong pyroelectrical and piezoelectrical properties because its inherent hemimorphic (asymmetrical) nature increases the degree of ionic displacement throughout the crystal lattice.

TECHNOLOGICAL USES

For centuries, hemimorphite was an important ore of zinc. Limited quantities of hemimorphite are still mined in China and other parts of the world today. Modern uses for zinc include corrosion-resistant galvanic coatings for steel, the manufacture of brass alloys, and the fabrication of battery casings. Zinc compounds, notably zinc oxide (ZnO) are valuable as pigments. Ten million metric tons of zinc are now mined worldwide each year. The leading producers are China, Peru, and Australia. Zinc ingots currently sell for about \$1 per pound.

Zinc is an essential trace element in the human body. Modern “calamine lotions,” which contain synthetic zinc hydroxy-carbonates and -silicates, are essentially the same as those formerly made from hemimorphite and smithsonite.

ABOUT OUR SPECIMENS

Our hemimorphite specimens were collected at the Ojuela (oh-HWAY-la) Mine at Mapimi in the Mapimi district, Durango, Mexico. This historic mine has produced ore or mineral specimens almost continuously for 418 years. It was a rich source of silver for the Spanish Crown and, later, for the Republic of Mexico. 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 Mapimi. 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.

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 marine sediments of the Fold Belt were deposited 150 million to 65 million years ago. They lithified into limestone, a rock consisting primarily of calcite [calcium carbonate, CaCO_3] and dolomite, a rock made up mainly of the mineral dolomite [calcium magnesium carbonate, $\text{CaMg}(\text{CO}_3)_2$]. During the late 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

Mineral of the Month Club December 2017

occurred when these solutions dissolved sections of the limestone and dolomite, replacing them with metal-sulfide minerals. Rich in silver, lead, and zinc, along with lesser amounts of gold and copper, these deposits were emplaced 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, and halide minerals.

Spanish prospectors discovered rich outcrops of chlorargyrite [silver chloride, AgCl] and argentiferous cerussite [silver-bearing lead carbonate, PbCO₃] 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 amounts of lead. Production then 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 began encouraging foreign mining investment, an American company took over Ojuela, only to go bankrupt. In 1890, Compañía Minera de Penoles, 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 noted designer and builder of New York's Brooklyn Bridge, to construct a narrow, 1,000-foot-long, cable-suspension bridge 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, and 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 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, phosphates, and arsenates. Ojuela ores are 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, Zn₂(AsO₄)(OH)]. Collectors and dealers from the United States then began visiting the mine regularly to buy from the miners or to pay Compañía Minera de Penoles for permission to collect their own specimens.

The Ojuela Mine has more than 200 miles of underground workings, the deepest of which are flooded. Throughout its long history, miners have extracted more than seven million tons of ore. On average, a ton of this remarkable ore contained 15 troy ounces of silver, 15 percent lead, 12

Mineral of the Month Club December 2017

percent zinc, 0.1 troy ounce of gold, and small amounts of copper. 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.

As you study your specimen, note first that the hemimorphite crystals are colorless, which indicates a high degree of chemical purity. With the aid of a loupe or magnifying glass, observe the prominent, parallel striations, one of the diagnostic features of hemimorphite, on the prismatic faces of the crystals. The most unusual aspect of hemimorphite's crystallography is its hemimorphism (see "The Mineralogical Phenomenon of Hemimorphism"), in which individual crystals maintain the basic orthorhombic structure throughout, but exhibit different habits at opposite terminations. In our specimens, the bladed, orthorhombic crystals have a typical pyramidal termination at the top end and a slightly domed, pedion (geometrically unrelated) termination at the opposite or basal end. The pyramidal terminations are readily apparent, but the pedion terminations at the base of the crystals may be more difficult to observe.

The matrix of your specimen consists of massive, orange-brown limonite, an indeterminate mixture of hydrous iron oxides, which is common in most oxidation environments, along with dark-brown goethite [basic iron oxide, $\text{FeO}(\text{OH})$]. 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 to dark-brown matrix is an identifying characteristic of virtually all oxidized-mineral specimens from the Ojuela Mine.

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Mineral of the Month Club December 2017

