

## October 2009 Mineral of the Month: Creedite

This month we are pleased to feature creedite, an uncommon mineral from one of Mexico's most historic mines. Our write-up details creedite's complex chemistry, its distinctive crystal shape and coloration, and the unusual origin of our "starburst" specimens.

### OVERVIEW

### PHYSICAL PROPERTIES

Chemistry:  $\text{Ca}_3\text{Al}_2(\text{SO}_4)(\text{OH})_2\text{F}_8 \cdot 2\text{H}_2\text{O}$  Basic Hydrated Calcium Aluminum Fluorosulfate (Hydrated Calcium Aluminum Sulfate Fluorohydroxide)

Class: Compound Halides

Group: Creedite

Crystal System: Monoclinic

Crystal Habits: Usually prismatic with diamond-shaped cross sections and sharp, asymmetrically slanted terminations; prism faces sometimes curved; often acicular in radiating, spherical groups; also granular, massive, and drusy.

Color: Colorless and white to purple, violet, pink, reddish-orange, brownish-red, and brown; coloration prominently zoned; color intensity decreases noticeably in transmitted light.

Luster: Vitreous to greasy

Transparency: Transparent to translucent

Streak: White

Refractive Index: 1.461–1.485

Cleavage: Perfect in one direction

Fracture: Conchoidal to uneven; brittle.

Hardness: 4.0

Specific Gravity: 2.7

Luminescence: Occasionally fluorescent

Distinctive Features and Tests: Occurrence in oxidized, fluorine-rich mineralogical environments; prominent zoning in colored crystals; asymmetrical termination faces; and decreased color intensity in transmitted light. Can be confused with purple adamite [ $\text{Zn}_2(\text{AsO}_4)(\text{OH})$ ], which is more lustrous and lacks asymmetrical termination faces.

Dana Classification Number: 12.1.4.1.1

**NAME** Creedite, pronounced CREED-ite, is named for the United States Geological Survey's Creede (Colorado) map quadrangle, the area in which it was discovered. Creedite has also been known as "belyankite." In European mineralogical literature, creedite appears as *creediet*, *creedit*, and *creedita*.

**COMPOSITION:** The molecular weight of the complex mineral creedite consists of 24.47 percent calcium, 10.98 percent aluminum, 6.54 percent sulfur, 29.00 percent fluorine, 27.68 percent oxygen, and 1.33 percent hydrogen. Creedite occurs in extensively oxidized, upper levels of sulfur- and fluorine-rich mineralization and is usually found in fluorite and fluorite-barite deposits. As a secondary mineral, creedite forms at low temperature and pressure as a precipitate of acidic hydrothermal solutions that are rich in calcium, aluminum, sulfur, and fluorine ions. As an allochromatic (other-colored) mineral, creedite's colors are caused by trace amounts of nonessential elements called chromophores. Pure creedite is colorless or white, but traces of manganese and iron create pink, purple, violet, reddish-orange, and orange-brown colors.

**COLLECTING LOCALITIES:** The finest creedite specimens come from Mexico, notably from the Navidad Mine near El Rodeo, Durango, and from the Condesa, El Potosí, Inglaterra, and San Antonio mines near

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Aquiles Serdán, Chihuahua. Specimens are also collected in Bolivia at the Colquiri Mine at Colquiri in Inquisivi Province, La Paz Department; in France at the Silverloch Mine and Berghem Quarry at Ribeaupillé, Haut-Rhin; in Tajikistan at the Dzhaambai fluorite deposit in the Pamir Mountains of Viloyati Mukhtori in Gomo-Badakhshan; in Kazakhstan at the Aqshatau Mine at Aqshatau in Qaraghandy Oblasy; in Greece in the Laurium district at Laurium, Attikí; and in South Africa at the N'Chwaning I and II mines in the Kalahari manganese fields of Northern Cape Province.

In the United States, creedite is collected in New Mexico at the Mex-Tex and Blanchard mines in the Hansonburg district in Socorro County; in California at the Defiance Mine in the Darwin district in Inyo County; in Arizona at the Grand Reef and Iron Cap mines in the Aravaipa district in Graham County; and in Nevada at the La Plata Mine in the Mountain Wells district in Churchill County, the Boulder Hill Mine in the Wellington district in Douglas County, the Rock Hill and Broken Toe mines in the Rock Hill district of Esmeralda County, the Silver Coin Mine in the Iron Point district of Humboldt County, and the Cyprus Tonopah Mine in the Lodi district in Nye County. Colorado sources include the Cresson gold mine at Cripple Creek in Teller County, the Henderson molybdenum mine near Idaho Springs in Clear Creek County, and the type locality at the Colorado Fluorspar Mine at Wagon Wheel Gap in Mineral County.

**HISTORY, LORE, & USES:** Mineralogists identified creedite as a new mineral species in 1916 after studying specimens collected at the Colorado Fluorspar Mine in Mineral County, Colorado. Creedite's basic atomic structure was determined by X-ray diffraction in 1926; details of its structure and atomic-bonding arrangements were defined in 1965. Until the 1950s when new sources were discovered, creedite had been thought to be very rare and obtainable only from two Colorado localities. Because of its rarity and softness, creedite has little use in jewelry, although intensely colored, single crystals are occasionally wire-wrapped to wear as pendants. Mineral collectors value creedite specimens for their rarity, color, unusual chemistry, and distinctive crystal forms. Metaphysical practitioners believe that creedite aids in the understanding of others, helps heal emotional trauma, and promotes clarity of expression. Although creedite has no industrial uses, it has been studied extensively to gain insight into the formation, atomic-bonding arrangements, and chemical stability of secondary minerals with compound anions.

**ABOUT OUR SPECIMENS:** Our specimens were collected at the Navidad Mine, twenty miles northwest of the town of El Rodeo in the state of Durango, Mexico. El Rodeo is located in north-central Mexico, 90 miles north of the state-capital city of Durango. This region has a very complex geology in which marine sediments, primarily limestone, have been intruded by quartz-rich rhyolitic and dacitic magmas. Hydrothermal solutions later emplaced fluorite veins, the uppermost of which eventually oxidized to produce creedite as a secondary mineral. The Navidad fluorite veins trend northwest-southeast for 1.5 miles and range in thickness from 3 to 30 feet. The green-and-purple fluorspar ore is massive, banded, and grades about 78 percent in purity. Since the 1960s, the Navidad deposit has been mined intermittently by open-pit and underground methods. The mine, a noted source of fluorite and creedite specimens, was recently closed.

**10 YEARS AGO IN OUR CLUB:** "Second verse, same as the first!" We featured the same mineral from the same mine ten years ago, in October 1999. Creedite was our 44<sup>th</sup> mineral, in our 44<sup>th</sup> month, and now we are spotlighting it again, in our 164<sup>th</sup> month! Fall 1999 saw us having recently moved into our current home on Orville Avenue, our fledgling mineral endeavor having grown to the point where we actually had a few dollars left in the bank *before* leaving for a show! Fall 1999 was when we purchased the green Ford Aerostar Extended Van we used to haul our material to shows for the last ten years. We traveled to 25 shows in 1999, including both our wholesale show in Tucson and the Tucson Gem & Mineral Show--hard to believe we traveled that much while operating our Club and raising a 15-year old son! Of course, we were ten years younger then (in our forties) and strongly motivated by the need to make a living . . .

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### **COMPREHENSIVE WRITE-UP**

#### *COMPOSITION*

Creedite's chemical formula  $\text{Ca}_3\text{Al}_2(\text{SO}_4)(\text{OH})_2\text{F}_8 \cdot 2\text{H}_2\text{O}$  shows that it contains calcium, aluminum (Al), sulfur (S), fluorine (F), oxygen (O), and hydrogen (H). Its molecular weight consists of 24.47 percent calcium, 10.98 percent aluminum, 6.54 percent sulfur, 29.00 percent fluorine, 27.68 percent oxygen, and 1.33 percent hydrogen. Despite the chemical complexity of the creedite molecule, its structure can be easily understood by remembering that, like all molecules, it consists of an electrically balanced arrangement of positively charged ions called cations and negatively charged ions called anions. Anions sometimes form radicals, which are groups of atoms that act as entities in chemical reactions. Creedite's compound anion contains the sulfate radical  $(\text{SO}_4)^{2-}$ , two hydroxyl radicals  $2(\text{OH})^{1-}$ , and eight fluorine ions  $8\text{F}^{1-}$  that collectively provide an anionic charge of -12. Creedite's compound cation consists of three calcium ions  $3\text{Ca}^{2+}$  and two aluminum ions  $2\text{Al}^{3+}$  with a collective cationic charge of +12. The balance of these cationic and anionic charges provides the creedite molecule with electrical stability.

The " $\cdot 2\text{H}_2\text{O}$ " in creedite's chemical formula means that it is a hydrous (or hydrated) mineral with two molecules of water ( $2\text{H}_2\text{O}$ ) attached to each parent molecule. These attached water molecules, called "water of hydration," are electrically neutral and do not affect the electrical balance of the parent molecule. The water molecule is configured with two hydrogen ions ( $2\text{H}^{1+}$ ) grouped closely together on one side of a large oxygen ion ( $\text{O}^{2-}$ ). These grouped hydrogen ions retain a small positive charge, while the opposite side of the molecule, dominated by the large oxygen ion, retains a small negative charge. The resulting polarity enables water molecules to behave as tiny dipole magnets that can attach themselves to other molecules by a weak attraction called "hydrogen bonding."

Chemical complexity has made creedite difficult to classify mineralogically. Minerals are usually classified by chemistry, most often by their predominant anion, into such groups as sulfides, silicates, oxides, sulfates, halides, etc. Creedite, however, has two dominant anions—the sulfate radical  $(\text{SO}_4)^{2-}$  and eight fluorine ions  $8\text{F}^{1-}$ , both of which contribute to its physical properties. Sulfate radicals usually form minerals that are light in color, transparent to translucent, relatively soft, and fragile, which are precisely the properties of creedite. Although the sulfate radical is the foundation of the creedite crystal lattice, the weak bonding of the fluorine ions contributes to other properties such as solubility and lack of hardness. Accordingly, creedite has been variously classified as a sulfate and as a halide (a mineral compound of the halogen elements chlorine, bromine, fluorine, or iodine). The New Dana Mineral Classification System, the standard used in our write-ups, classifies creedite as a compound halide and assigns it the Dana mineral classification number 12.1.4.1. Compound halides (12) are a group of only 11 minerals with compound anions consisting of fluorine or chlorine ions together with sulfate, phosphate, carbonate, or selenate radicals. Creedite is subclassified as a compound halide with miscellaneous cations (1) which, in the case of creedite, are calcium and aluminum. Finally, creedite is assigned to the creedite group (4) as the first (1) and only member.

Although classified as a compound halide, creedite's structure is based on the sulfate radical  $(\text{SO}_4)^{2-}$ , in which a single sulfur ion is surrounded by and covalently bonded to four oxygen atoms positioned at the corners of a tetrahedron. Each of the four oxygen ions has a -2 charge and the sulfur ion has a +6 charge, thus creating a collective -2 charge. Because these two negative charges are distributed evenly across the four oxygen ions, the sulfate radical can bond with different metal cations to form complex lattice configurations that can accommodate other anions such as halogen ions and hydroxyl radicals, as well as the attachment of water molecules.

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It is easiest to visualize the creedite crystal lattice by reconstructing it from the sulfate radical. In creedite, chains of negative sulfate radicals bond ionically to positive calcium and aluminum ions (opposite charges attract) to form the intermediate and incomplete calcium aluminum sulfate radical  $[\text{Ca}_3\text{Al}_2(\text{SO}_4)]^{10+}$ . This arrangement provides sufficient space to accommodate various anions. In the oxidizing chemical environment in which creedite forms, fluorine and hydroxyl anions are abundant and bond ionically in a 4:1 ratio with the calcium aluminum sulfate radical to form the not-yet-complete creedite molecule  $\text{Ca}_3\text{Al}_2(\text{SO}_4)(\text{OH})_2\text{F}_8$ . Although this molecule is electrically balanced, its uneven distribution of charges enables two dipolar water molecules to attach themselves by hydrogen bonding to complete the creedite molecule  $\text{Ca}_3\text{Al}_2(\text{SO}_4)(\text{OH})_2\text{F}_8 \cdot 2\text{H}_2\text{O}$ . Creedite molecules, in which ionic bonding predominates, are arranged in flat, sheet-like structures with the greatest bonding strength exerted lengthwise and laterally within each sheet. The ionic bonding between these sheets, however, is weak, and it accounts for creedite's perfect cleavage in one direction, along with its brittleness and relative softness of Mohs 4.0. As in all halides, weak ionic bonding makes creedite moderately soluble in water. Creedite has fairly close atomic packing, but its relatively light constituent elements give it a low specific gravity of 2.7, only slightly more than that of quartz [silicon dioxide,  $\text{SiO}_2$ ]. Like many minerals with complex chemistries and bonding arrangements, creedite crystallizes in the monoclinic system, which is characterized by three axes of different lengths, two of which are perpendicular. Creedite most often forms prisms that are oriented in the direction of the longest axis.

Creedite occurs only in extensively oxidized, upper levels of sulfur- and fluorine-rich mineralization, most often in fluorite [calcium fluoride,  $\text{CaF}_2$ ] deposits and fluorite-barite [barium sulfate,  $\text{BaSO}_4$ ] deposits. As a secondary mineral, creedite forms at low temperature and pressure as a precipitate of acidic hydrothermal solutions that are rich in calcium, aluminum, sulfur, and fluorine ions. When space is not available for crystal development, creedite occurs in massive and granular forms. But when space is available, as is often the case in the altered rock of oxidation environments, creedite forms well-developed crystals.

As an allochromatic (other-colored) mineral, creedite's colors are caused by small amounts of nonessential elements. Pure creedite is colorless or white, but impurities such as manganese and iron can distort the crystal lattice to alter the manner in which it absorbs and reflects light. Small amounts of divalent manganese ( $\text{Mn}^{2+}$ ) substituting for calcium ions within the creedite lattice create pink, purple, and violet hues. Substitution of divalent iron (ferrous,  $\text{Fe}^{2+}$ ) imparts reddish-orange or reddish-brown coloration. Creedite is unusual in that its color intensity varies in reflected and transmitted light. The color of a creedite crystal is most intense in reflected light, yet the same crystal can appear nearly colorless when viewed by transmitted light. This is because reflected white light has been absorbed and re-emitted by the crystal lattice within specific band wavelengths. But transmitted light is not absorbed and re-emitted; instead, it passes directly through the lattice to emerge largely as unaltered white light.

### ***COLLECTING LOCALITIES***

Creedite is an uncommon mineral with few sources of fine specimens. Our specimens were collected at the Navidad Mine near El Rodeo in the state of Durango, Mexico. Other Mexican creedite localities include the Condesa, El Potosí, Inglaterra, and San Antonio mines in the Santa Eulalia district near Aquiles Serdán, Chihuahua.

Creedite is also collected in Bolivia at the Colquiri Mine at Colquiri in Inquisivi Province, La Paz Department; in France at the Silverloch Mine and Bergheim Quarry at Ribeauvillé, Haut-Rhin; in Italy at the Funtana Raminosa Mine at Gadoni in Nuro Province, Sardinia; in Tajikistan at the Dzhaambai fluorite deposit in the Pamir Mountains of Viloyati Mukhtori in Gomo-Badakhshan; in Kazakhstan at the Aqshatau Mine at Aqshatau in Qaraghandy Oblasy; in China at the Qinglong antimony-gold deposit in Qinglong County, Qianxi'nan Prefecture, Guizhou Province; in Greece at the Laurium district mines at Laurium,

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Attikí; and in South Africa at the N'Chwaning I and II mines in the Kalahari manganese fields in Northern Cape Province.

In the United States, creedite is collected in New Mexico at the Mex-Tex and Blanchard mines at Bingham in the Hansonburg district in Socorro County; in California at the Defiance Mine in the Darwin district in Inyo County; and in Arizona at the Grand Reef and Iron Cap mines in the Aravaipa district in Graham County. Colorado sources include the Cresson open-pit gold mine at Cripple Creek in Teller County; the Henderson molybdenum mine near Idaho Springs in Clear Creek County; and the type locality at the Colorado Fluorspar Mine at Wagon Wheel Gap in Mineral County. Among Nevada sources are the La Plata Mine in the Mountain Wells district in Churchill County; the Boulder Hill Mine in the Wellington district in Douglas County; the Rock Hill and Broken Toe mines in the Rock Hill district in Esmeralda County; the Silver Coin Mine in the Iron Point district in Humboldt County; and the Cyprus Tonopah Mine in the Lodi district in Nye County.

### ***JEWELRY & DECORATIVE USES***

Because of its rarity and softness, creedite has very limited use as a gemstone. Some jewelry makers occasionally use single, intensely colored creedite crystals in wire-wrap pendant mounts. Mineral collectors value creedite specimens for their rarity, color, unusual chemistry, and distinctive crystal form.

### ***HISTORY & LORE***

Creedite was discovered at the Colorado Fluorspar Mine at Wagon Wheel Gap, eight miles southeast of the silver-mining town of Creede in Mineral County, Colorado. Prospectors discovered the Wagon Wheel Gap deposit of fluorspar, the commercial term for the ore of fluorite [calcium fluoride,  $\text{CaF}_2$ ], in 1900. The mine was developed in 1912 to supply a flux for the steel mills at Pueblo, Colorado, 240 railroad miles to the east. As was customary at the time, United States Geological Survey (USGS) mineralogists often visited new mines to collect and study minerals. When USGS field surveyor Esper Signius Larsen (1879-1961) visited the Colorado Fluorspar Mine in 1915, he collected two specimens from the mine dumps that he could not immediately identify. One proved to be the rare mineral gearsutite [basic hydrous calcium aluminum fluoride,  $\text{CaAl}(\text{OH})\text{F}_4 \cdot \text{H}_2\text{O}$ ]. Larsen initially thought the other was also gearsutite, but closer laboratory study revealed a different index of refraction. When qualitative analysis later found sulfur in the second specimen, Larsen realized that he had discovered a new mineral—one of the very few known to contain both sulfate and fluoride ions as essential constituents. When his published conclusions were accepted by the National Academy of Sciences in 1916, Larsen named the new mineral “creedite” after its occurrence near the center of the USGS Creede map quadrangle.

Until new sources were discovered in the 1950s, creedite was thought to be very rare and obtainable only from two Colorado localities: the type locality at Wagon Wheel Gap and the Cripple Creek gold-mining district at Cripple Creek. Although X-ray diffraction had revealed creedite's basic atomic structure in 1926, mineralogists did not define its precise structure and the nature of its atomic bonding until 1965.

A milestone in the history of creedite is highlighted by Bob Jones in the March 1970 *Rocks and Minerals* magazine, where he reported an exceptional find of creedite at Santa Eulalia, Chihuahua, Mexico. In a limestone replacement lead-zinc-silver ore body were found crystals up to one inch in length, most colorless, some tinted lavender to violet! The 1981 *Mineralogical Record* called subsequent finds at Santa Eulalia “easily the largest and best ever found.” In the 1980's, equally gorgeous violet colored creedite crystals were dug first in central Kazakhstan, then in the U.S.S.R. A group of lustrous purple creedite crystals graced the cover of the *Mineralogical Record* during this period.

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The earliest reference to creedite from Navidad Mine is the 1989 *Mineralogical Record*, where two specimens, 5 x 7 cm and 4 x 4 cm in size, were seen at a mineral show in Germany, offered for sale at \$275 and \$140, respectively. "Not too pricey" said the magazine. Navidad creedite made "What's New in Minerals" three more times, in 1990, 1997, and 1999, showing the obvious delight sophisticated collectors have in these wonderful specimens!

Metaphysical practitioners believe that creedite enhances the understanding of others, helps heal emotional trauma, and promotes clarity of expression.

### **THE MINERALS OF MEXICO**

*This month marks the 14th time that we have featured a mineral from Mexico, a nation that is one of the great sources of fine mineral specimens. Thanks to its diverse and abundant mineralization, Mexico has more than a dozen classic localities that provide the best specimens of a particular species and some 60 type localities where mineral species were first discovered. Mexico's status as an extraordinary source of fine specimens is based on its complex, richly mineralized geology and a vibrant mining industry. Mexico's topography is dominated by three major mountain systems—the Sierra Madre Occidental in the northwest, the Sierra Madre Oriental in the northeast, and the Sierra Madre Sur in the south. The nation's mineral wealth is concentrated in an area 900 miles long and up to 150 miles wide that follows the northwest-southeast trend of the Sierra Madre Occidental and extends from the states of Sonora and Chihuahua in the north to just beyond Mexico City in the south. This geologically complex region has hosted virtually all of Mexico's metal and non-metal mining activity and provided most of its mineral specimens.*

*The complex geology and rich mineralization of the Sierra Madre Occidental is due to its position near the junction of the North American, Caribbean, Cocos, and Pacific tectonic plates. The stresses generated by the collision, subduction, and grinding of these tectonic plates faulted and weakened the crust over much of Mexico, leaving it susceptible to magmatic intrusion, volcanism, uplifting, folding, and tilting. The original basement rock consisted largely of marine sediments laid down between 150 and 70 million years ago that lithified into limestone and dolomite. The Sierra Madre Occidental was formed roughly 65 million years ago when huge blocks of this basement rock were uplifted during the Laramide Orogeny, a mountain-building episode that was driven by tectonic stresses. The Laramide Orogeny also created the Rocky Mountains in the United States and Canada, and geologists consider the Sierra Madre Occidental as a southern extension of the greater Rocky Mountains.*

*Some 30 million years after the uplifting of the Sierra Madre Occidental, huge volumes of magma surged into the intensely fractured crust beneath the range to form both intrusive bodies of granitic rocks and extrusive formations of rhyolitic and dacitic (quartz-rich) volcanic rock. These volcanic episodes created the Trans-Mexican Volcanic Belt, a range of volcanic mountains that extends from the central Sierra Madre Occidental southeast toward Mexico City. This volcanic activity was accompanied by surges of highly mineralized hydrothermal solutions that emplaced many mineral deposits in areas that are now parts of the Mexican states of Sonora, Chihuahua, Durango, Zacatecas, San Luis Potosí, Jalisco, Querétaro, and Guanajuato.*

*The metal mineralization in the Sierra Madre Occidental included deposits of lead, zinc, copper, and especially silver. Spanish prospectors discovered the silver mineralization in 1534 at Taxco, Guerrero, the first of many major strikes that extended northward for 600 miles. Spanish miners initially exploited shallow, oxidized deposits with open pits, then later sunk shafts into deeper silver-lead sulfide deposits. The huge output of these mines made Spain's Viceroyalty of Mexico the world's largest silver producer for nearly three centuries. After Mexico won its independence in 1821, mine production declined, but*

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eventually recovered with the influx of European and American development capital in the late 1800s. By 1900, Mexico had regained its position as a major producer not only of silver, but also lead, zinc, and copper. Mexico has provided about one-third of all the silver ever mined in the world throughout history. Today, it still ranks second in production with an output of 100 million troy ounces (3,085 metric tons) per year. Mexico also ranks second in output of bismuth and fluorspar, fifth in lead and arsenic, sixth in zinc and cadmium, seventh in gypsum, eighth in molybdenum and manganese, and eleventh in copper.

Despite its diverse mineralization, huge metal production, and long mining history, Mexico's reputation as a major source of fine mineral specimens was slow in developing. For nearly three centuries, countless superb specimens were destroyed in the mining process. Mexican mineral specimens received virtually no attention at all until European and American geologists began surveying the regional mines in the late 1800s. American mineralogists who visited Mexican mines in the 1920s provided the first true awareness of the astounding diversity of the nation's minerals. Mexican minerals finally began reaching collectors' markets in the late 1940s, when specimen-savvy, retired Americans living in the region brought their specimens to dealers in the United States. As collector interest grew, Mexican miners learned that they could earn additional income by preserving and selling specimens that they encountered in their work. During the 1950s and 1960s, rock shops opened in the mining regions of the Sierra Madre Occidental, while magazine articles drew attention to the quality of Mexican specimens. Mineral dealers and serious collectors from the United States then began visiting Mexico regularly to buy directly from miners, rock shops, and mining companies, and even to pay for permission to collect in various underground mines. By 1970, when mineral collecting was becoming big business in the United States and Europe, Mexico was well-established as a major source of fine specimens. Many Mexican miners are now competent mineral collectors who contribute to the market supply of mineral specimens. Other specimens are supplied by commercial collectors from both the United States and Mexico who contract with mining companies to obtain permission to collect large lots of specimens.

Today, Mexico is especially noted for specimens of the following minerals:

**Creedite** Our current Mineral of the Month, from the Navidad Mine near El Rodeo, Durango. Also featured in October 1999.

### **Silver [Ag]**

**Quartz [silicon dioxide, SiO<sub>2</sub>]** Our Mineral of the Month for June 2003, from the Liliani Mine near Ciudad Chihuahua, Chihuahua, as unique and beautiful scepter crystals.

**Hemimorphite [basic hydrous zinc silicate, Zn<sub>4</sub>Si<sub>2</sub>O<sub>7</sub>(OH)<sub>2</sub>·H<sub>2</sub>O]** Our Mineral of the Month for October 2000, from Santa Eulalia, Chihuahua.

**Adamite [basic zinc arsenate, Zn<sub>2</sub>(AsO<sub>4</sub>)(OH)]** Our Mineral of the Month for May 1998 and May 2008, from the Ojuela Mine, Mapimí, Durango.

### **Fluorite [calcium fluoride, CaF<sub>2</sub>]**

**Wulfenite [lead molybdate, PbMoO<sub>4</sub>]** Our upcoming Mineral of the Month for November 2009, from the Ojuela Mine, Mapimí, Durango.

**Legrandite [basic hydrous zinc arsenate, Zn<sub>2</sub>(AsO<sub>4</sub>)(OH)·H<sub>2</sub>O]**

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***Mapimite [basic hydrous zinc iron arsenate,  $\text{Zn}_2\text{Fe}_3(\text{AsO}_4)_3(\text{OH})_4 \cdot 10\text{H}_2\text{O}$ ]***

***Danburite [calcium borosilicate,  $\text{CaB}_2(\text{SiO}_4)_2$ ]*** Our Mineral of the Month for February 1999, from the Charcas District, San Luis Potosí.

***Smithsonite [zinc carbonate,  $\text{ZnCO}_3$ ]*** Our Mineral of the Month for April 2001, from the San Antonio Mine, Santa Eulalia, Chihuahua; and October 2008, from the Refugio Mine, Choix, Sinaloa.

***Vanadinite [lead chlorovanadate,  $\text{Pb}_5(\text{VO}_4)_3\text{Cl}$ ]***

***Calcite [calcium carbonate,  $\text{CaCO}_3$ ]*** Our Mineral of the Month for November 1996, from the Buena Tierra Mine, Santa Eulalia, Chihuahua.

***Malachite [basic copper carbonate,  $\text{Cu}_2(\text{CO}_3)(\text{OH})_2$ ].***

***Rosasite [basic copper zinc carbonate,  $(\text{Cu,Zn})_2(\text{CO}_3)(\text{OH})_2$ ]***

***Aurichalcite [basic zinc copper carbonate,  $(\text{Zn,Cu})_5(\text{CO}_3)_2(\text{OH})_6$ ]***

***Anhydrite [calcium sulfate,  $\text{CaSO}_4$ ]*** Our Mineral of the Month for June 1998, from the Naica District, Saucillo, Chihuahua.

***Köttigite [hydrous zinc arsenate,  $\text{Zn}_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$ ].***

***Carminite [basic lead iron arsenate,  $\text{PbFe}_2(\text{AsO}_4)_2(\text{OH})_2$ ]***

***Conichalcite [basic calcium copper carbonate,  $\text{CaCu}(\text{AsO}_4)(\text{OH})$ ]*** Our Mineral of the Month for September 2002, from the Ojuela Mine, Mapimí, Durango.

***Grossular [calcium aluminum silicate,  $\text{Ca}_3\text{Al}_2(\text{SiO}_4)_3$ ]*** Our Mineral of the Month for December 2002, from Lake Jaco, Chihuahua.

### ***TECHNOLOGICAL USES***

Although creedite has no industrial uses, the mineral has been studied extensively to better understand the formation, atomic-bonding arrangements, and chemical stability of secondary minerals with unusual compound anions.

### ***ABOUT OUR SPECIMENS***

Our specimens were collected at the Navidad Mine (Mina Navidad, "Christmas Mine") near the town of El Rodeo in the state of Durango, Mexico. El Rodeo is located on Mexico Route 45 in north-central Mexico, 90 miles north of the city of Durango, the state capital. The Navidad Mine, 20 miles northwest of El Rodeo, is accessible by a graded gravel road. This area, part of the Chihuahuan Desert, is characterized by an arid climate and rugged mountains separated by broad plains. The plains are about 5,000 feet in elevation and sparsely vegetated with cacti, thorny brush, and coarse grass; to the west, the ridges of the Sierra Madre Occidental are covered by thin scrub-oak and pine forests. The Navidad Mine is located at an elevation of 6,200 feet in the foothills of the Sierra San Juan de Minas, an eastern sub-range of the Sierra Madre Occidental.

## ***October 2009 Mineral of the Month: Creedite***

The richly mineralized Sierra Madre Occidental hosts some of the world's largest fluorite sources, including both primary fluorite deposits and fluorite-rich polymetallic deposits of gold, silver, lead, zinc, and copper. The Navidad fluorite mine lies within the Mexican Fold Belt, a geological province in which the original bedrock consisted of marine sediments laid down between 150 million and 70 million years ago. These sediments eventually lithified into limestone, which consists largely of calcite [calcium carbonate,  $\text{CaCO}_3$ ], and dolostone, a rock consisting mainly of calcite and the mineral dolomite [calcium magnesium carbonate,  $\text{CaMg}(\text{CO}_3)_2$ ]. Some 60 million to 40 million years ago, tectonic stresses deformed these limestone and dolostone formations into the folds and thrusts of today's Mexican Fold Belt. Later, in middle Tertiary time some 40 million to 25 million years ago, regional volcanism and deep magmatic intrusions forced fluorine-rich, high-silica rhyolitic and dacitic magma into the folded sediments. Associated hydrothermal solutions then circulated through the interspersed formations of calcium-rich limestone and fluorine-rich rhyolite to become saturated with calcium and fluorine ions. Later, in conditions of reduced temperature and pressure within dacitic host rock, these solutions precipitated calcium and fluorine ions as massive veins of fluorite [calcium fluoride,  $\text{CaF}_2$ ].

Erosion later exposed the upper sections of this fluorite deposit to atmospheric oxygen and groundwater, and thus to intensive chemical oxidation. Groundwater circulating through the upper part of the deposit became saturated with fluorine ions from the fluorite veins, calcium and sulfur ions from adjacent limestone, and aluminum ions from the intruded rhyolite and dacite. These solutions eventually filled voids where, in conditions of low temperature and low pressure, they precipitated their ions as creedite. The oxidation and physical weathering processes that altered the upper parts of the fluorite deposit created numerous voids that provided sufficient space for the development of creedite crystals.

Although the Navidad fluorite deposit was discovered in the late 19<sup>th</sup> century, its remoteness initially precluded development. Mining began in the 1960s only after construction of a suitable access road and the establishment of Mexico's fluorite-export program. The Navidad ore veins consist of massive, banded, green-and-purple fluorspar ore and contain about 78 percent fluorite. The veins trend northwest-southeast for 1.5 miles and are between 3 and 30 feet thick. The mine was originally developed as an open pit; later, several underground levels were dug to exploit the deeper parts of the deposit. Over the years, the Navidad Mine operated when fluorspar prices were strong, and suspended operations when prices weakened. Navidad miners crushed the fluorspar on-site, hand-cobbed or manually separated it to a purity of about 90 percent, then shipped it by truck.

As a specimen source, Navidad first gained attention for pink and purple fluorite octahedrons on plates of white chalcedony that occurred in small cross-veins of fluorite and quartz running perpendicular to the main ore veins. Miners often spent their lunch time cleaving fluorite octahedrons to sell to outlets and specimen dealers in El Rodeo and Durango. But Navidad's reputation as a creedite source did not emerge until later. Creedite was not even known in Mexico until the late 1970s, when the silver mines at Aquiles Serdán, Chihuahua, yielded specimens that attracted collector attention. Navidad miners, alerted by mineral dealers, collected their first creedite specimens in the mid-1980s. These early specimens, which were transparent with a pale, reddish-orange color and about one inch long, attracted enough interest at the Nürnberg (Germany) gem-and-mineral show in 1988 to earn mention in *The Mineralogical Record* the following year. The Navidad Mine and Aquiles Serdán mines have since supplied the world's finest creedite specimens. The Navidad Mine last produced from 2002 through 2007, during which time our specimens were collected. Because its fluorspar reserves are near depletion, the mine is not expected to reopen, meaning supplies of excellent creedite specimens will dwindle in the years to come.

According to one digger who has collected at Mina Navidad, the creedite comes from a large vein of green fluorite with occasional minor creedite that runs through rhyolite prevalent in the area. This fluorite

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vein is at least three miles long, and ranges from eighteen inches to more than seven feet in thickness. This green fluorite is massive, sold only as cutting rough, or processed for ore as described earlier.

The Mineralogical Record describes these specimens as “spheres of divergent, well individualized spiky prisms . . . The luster is high and the overall aspect of the bristling, glittering specimens is extremely attractive.” No doubt you will agree with their description as you examine your specimen! Because of the creedite prisms that protrude outward from the surface, this unusual form is known as a “starburst.” Internally, the core consists of massive creedite with a distinct, radiating structure; externally, the sphere is completely covered with protruding, prismatic creedite crystals. These crystals developed within a void that was once filled with a mineral-rich, hydrothermal solution. In rotating your specimen, note that there is no apparent point where the core was attached to a void wall. This absence of a “contact point” indicates that these spheres developed as “floaters”—masses of crystals that formed without contact with the void wall. Instead, they are thought to have formed around a free particle—perhaps of oxidized iron—within the hydrothermal solution. The creedite first precipitated around the nucleus in radiating, massive form in a general spherical shape. Later, when conditions of temperature, pressure, and chemistry had changed, the creedite precipitated onto the surface of the sphere as well-developed, protruding prisms. These starbursts later settled to the void floors where they became covered with a coating of paste-like iron oxide and were eventually recovered by fluorspar miners.

Studying the creedite prisms closely, you will note that they are monoclinic crystals that most often show four prism faces and four termination faces. When viewed longitudinally, that is, from the top down through the long axis of the crystal, the diagnostic, distinctive, diamond-shaped cross section is apparent. Another diagnostic feature of creedite crystals is the termination, in which one termination face is elongated and steeply slanted in the direction of the long crystal axis.

The orange-brown color of your creedite specimen is caused primarily by ferrous iron ( $\text{Fe}^{2+}$ ) that substitutes for aluminum within the crystal lattice and alters its structure to cause it to absorb white light and to re-emit it in the yellow-orange wavelengths. This orange-brown color is also partially caused by inclusions of tiny particles of limonite (an indefinite mixture of hydrous iron hydroxides) that were suspended in the hydrothermal solution when the creedite crystals formed. A diagnostic property of creedite is its pronounced color zoning, which occurs when color is not evenly distributed throughout the crystal. This color zoning is readily apparent when your creedite crystals are viewed through both reflected and transmitted light. Certainly there is a lot to love about our featured mineral this month!

References: *Dana's New Mineralogy*, Eighth Edition; *Encyclopedia of Minerals*, Second Edition, Roberts, et al, Van Nostrand Reinhold Co.; *2004 Fleischer's Glossary of Mineral Species*, Joseph Mandarino and Malcolm Back, The Mineralogical Record Company; *Mineralogy*, John Sinkankas, Van Nostrand Reinhold Co.; *Manual of Mineralogy*, Cornelius Hurlbut and Cornelius Klein, Twenty-first Edition, John Wiley & Sons; *Minerals of Mexico*, William Panczer, Van Nostrand Reinhold Co., 1987; “The Mineral Industry of Mexico,” Alberto Alexander Perez, *2007 Minerals Yearbook*, United States Geological Survey; *Geology of Mexico*, Susana Alaniz-Alvaréz and Ángel Nieto-Samaniego (editors), Geological Society of America Special Paper 422, 2007; “Highlights of Mexican Minerals at Harvard University,” William Metropolis, *Rocks & Minerals*, January-February 1999; “What's New in Minerals: Denver Show 2003,” Thomas Moore, *The Mineralogical Record*, March-April 2004; “Refining the Crystal Structure of Creedite,” F. Brusentov, S. Borisov, and R. Klevtsova, *Journal of Structural Chemistry*, July 1965; “Some Minerals from the Fluorite-Barite Vein near Wagon Wheel Gap, Colorado,” Esper S. Larsen and Roger C. Wells, *Proceedings of the National Academy of Sciences*, Volume 2, 1916; “The Contact Zone,” Bob Jones, *Rocks and Minerals*, March 1970; “What's New in Minerals: Nürnberg Show 1988,” Thomas Moore, *The Mineralogical Record*, March-April 1989; “What's New in Minerals: Seventeenth Annual Rochester Academy of Science Mineralogical Symposium,” George Robinson and Vandall King, *The Mineralogical Record*, September-October 1997; “What's New in Minerals: Springfield Show 1997,” Thomas Moore, *The Mineralogical Record*, November-December 1997; “What's New in Minerals: Springfield Show 2003,” Joe Polityka, *The Mineralogical Record*, March-April 2003; “Connoisseur's Choice: Creedite from the Cresson Mine, Cripple Creek, Teller County, Colorado,” *Rocks & Minerals*, September-October 2008; “The Frugal Collector: More Sulfates,” Bob Jones, *Rock & Gem*, May 2006.