

Mineral of the Month Club December 2014

CREEDITE

Our featured mineral for December is creedite, an uncommon, chemically complex fluorosulfate from Colorado's Henderson molybdenum mine. Our write-up explains creedite's unusual mineralogy and chemistry, and discusses the history and mission of the United States Geological Survey.

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 Hydrus Calcium Aluminum Fluorosulfate
(Hydrus 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 may be slightly curved; crystals are often acicular in radiating, spherical groups; also granular, massive, and drusy.

Color: Colorless and white to purple, violet, lavender, pink, and reddish-orange; color is frequently zoned; color intensity decreases 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: Best field marks are occurrence in oxidized, fluorine-rich mineralogical environments; prominent zoning in colored crystals; asymmetrical termination faces; and decreased color intensity in transmitted light. Creedite can be confused with purple adamite [basic zinc arsenate, $\text{Zn}_2(\text{AsO}_4)(\text{OH})$], which is more lustrous and lacks asymmetrical termination faces.

Dana Classification Number: 12.1.4.1

NAME: Creedite, pronounced CREED-ite, is named for the United States Geological Survey's Creede (Colorado) map quadrangle, which covers the area where creedite 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 chemically complex mineral creedite is made up of 24.47 percent calcium, 10.98 percent aluminum, 6.54 percent sulfur, 29.00 percent fluorine,

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27.68 percent oxygen, and 1.33 percent hydrogen. Creedite occurs in oxidized zones of sulfur- and fluorine-rich mineralization, especially in fluorite and fluorite-barite deposits. It is a secondary mineral that forms at low temperature and pressure as a precipitate of acidic, hydrothermal solutions that are rich in calcium, aluminum, sulfur, and fluorine ions. Creedite is an allochromatic (other-colored) mineral, meaning that its colors are caused by traces of nonessential elements called chromophores. Pure creedite is colorless or white, but traces of manganese and iron create purple, violet, lavender, pink, and reddish-orange colors. 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 along the direction of the single, long axis. When space is not available for crystal development, creedite occurs in massive or granular forms. When space is available, as is often the case in the altered rock of oxidation environments, creedite forms well-developed crystals.

COLLECTING LOCALITIES: Creedite specimens are collected in the United States (Colorado, California, New Mexico, Arizona, Nevada), Mexico, Bolivia, France, Italy, Greece, Tajikistan, Kazakhstan, China, and South Africa.

HISTORY, LORE, & USES: Mineralogists identified creedite as a new mineral species in 1916 after studying specimens collected at the Colorado Fluorspar Mine near the silver-mining town of Creede in Mineral County, Colorado. Creedite's basic atomic structure was determined by X-ray diffraction in 1926; mineralogists defined the details of its structure and atomic-bonding arrangements in 1965. Until new sources were discovered in the 1950s, creedite was 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 large, nicely colored crystals are occasionally wire-wrapped as pendants. Mineral collectors value creedite specimens for their rarity, color, unusual chemistry, and distinctive crystal forms. Creedite is occasionally cut into collector's gems that, because of small crystal size, are always less than two carats in weight. Metaphysical practitioners believe that creedite aids in the understanding of others, helps heal emotional trauma, improves overall psychic abilities, and promotes clarity of expression in psychic realms. 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 of purple creedite were collected at the Henderson Mine in Clear Creek County, Colorado. The Henderson Mine, a major source of molybdenum, is 47 miles west of Denver. The mine is located at an elevation of 10,300 feet in the Front Range of the Rocky Mountains immediately east of the Continental Divide. The regional geology is linked to the Laramide Orogeny, the mountain-building episode that created the Rocky Mountains some 65 million years ago. When a second phase of crustal disruption occurred about 40 million years ago, surges of magma emplaced intrusions of rhyolitic porphyry. As these intrusions cooled, they contracted and fractured, enabling molybdenum-rich, hydrothermal solutions to migrate upward and precipitate molybdenite [molybdenum disulfide, MoS_2] in the networks of thin veins that make up the Henderson ore deposit. Creedite formed later as a secondary mineral when decreasing temperature and pressure caused acidic hydrothermal solutions that were rich in calcium, aluminum, sulfur, and fluorine ions to

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crystallize. Our creedite specimens were collected in 2007, when miners working on the lowest of the three mine levels encountered fissures and vugs filled with drusy creedite. Although the Henderson Mine produces fine examples of molybdenite, pyrite, barite, and fluorite, it is not recognized as an important source of specimens because miners work on a tight, 24-7 production schedule and management discourages specimen collecting. Nevertheless, because the 2007 find was in a developmental section of the mine that was not scheduled for immediate production, miners were able to collect specimens. Local collectors purchased many of these specimens directly from Henderson miners; others were acquired by a Denver-based mineral dealer. The Henderson creedite specimens were introduced at the Denver Gem & Mineral Show in September 2007. Despite prices that were unusually high for creedite, the specimens sold out quickly. The value of these specimens has since increased, as no further creedite occurrences have been found at the Henderson Mine. The Mineral of the Month Club was fortunate to have had the opportunity to acquire several lots of these specimens when they recently reappeared on the market.

COMPREHENSIVE WRITE-UP

COMPOSITION & STRUCTURE

We previously featured creedite as our Mineral of the Month in October 2009, when our specimens—spherical, radiating clusters of crystals called “starbursts”—came from the Navidad Mine at El Rodeo, Durango, Mexico. This month’s creedite specimens are from a Colorado locality and exhibit a completely different color and crystal habit. Creedite is an excellent example of how mineral species from different localities can vary radically in color and crystal habit.

The 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 creedite contains calcium (Ca), aluminum (Al), sulfur (S), fluorine (F), oxygen (O), and hydrogen (H). Its molecular weight is made up 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 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 8F^{1-} that collectively provide a -12 anionic charge. Creedite’s compound cation consists of three calcium ions 3Ca^{2+} and two aluminum ions 2Al^{3+} with a collective cationic charge of +12. The balance of cationic and anionic charges provides the creedite molecule with electrical stability.

The “ $\cdot 2\text{H}_2\text{O}$ ” in creedite’s chemical formula indicates 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 (2H^{1+}) grouped closely together on one side of a large oxygen ion (O^{2-}). These grouped hydrogen ions retain a small positive charge, while the opposite side of the molecule, dominated by the large

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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.”

Because of its chemical complexity, creedite is 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 8F^{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, all of which are 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. Accordingly, creedite has been variously classified as a sulfate and as a halide (a mineral compound containing the halogen elements chlorine, bromine, fluorine, or iodine). The New Dana Mineral Classification System, the standard reference 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 creedite is classified as a compound halide, its 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 ions positioned at the four corners of a tetrahedron. Each of the four oxygen ions has a -2 charge, while the sulfur ion has a +6 charge to create 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, including halogen ions and hydroxyl radicals, as well as attached water molecules.

The best way to visualize the creedite crystal lattice is to construct 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 $[\text{Ca}_3\text{Al}_2(\text{SO}_4)]^{10+}$. The structure of this radical 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 “sub-molecule” $\text{Ca}_3\text{Al}_2(\text{SO}_4)(\text{OH})_2\text{F}_8$. Although this sub-molecule is electrically balanced, its uneven distribution of charges enables two dipolar water molecules to attach 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 is weak, however, and accounts for creedite’s perfect, one-directional cleavage, its brittleness, and its minimal hardness of Mohs 4.0. As in all halides, predominant, weak ionic bonding makes creedite moderately soluble in water. Although creedite has fairly close atomic packing, its relatively light constituent elements account for its low

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specific gravity of 2.7, which is only slightly more than that of quartz [silicon dioxide, SiO₂]. 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 is an allochromatic (other-colored) mineral, meaning that its colors are caused by small amounts of nonessential elements called chromophores. Pure creedite is colorless or white, but impurities such as manganese and iron can distort the crystal lattice to alter the manner in which creedite absorbs and reflects light. Small amounts of divalent manganese (Mn²⁺) substituting for calcium ions within the creedite lattice create pink, purple, lavender, and violet hues. The substitution of divalent iron (ferrous, Fe²⁺) imparts reddish-orange colors. Creedite is unusual in that its color intensity varies in reflected and transmitted light. The color of creedite crystals is most intense in reflected light; the same crystals can appear nearly colorless when viewed with transmitted light. This is because reflected white light is absorbed and reemitted by the crystal lattice within specific band wavelengths. But transmitted light is not absorbed and reemitted; instead, it passes directly through the lattice to emerge with its original wavelengths.

Creedite usually occurs in oxidized zones of sulfur- and fluorine-rich mineralization, most often in fluorite [calcium fluoride, CaF₂] deposits and fluorite-rich barite [barium sulfate, BaSO₄] deposits. As a secondary mineral, creedite forms at low temperatures 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 with space for growth, which is often available in altered, oxidized environments, creedite can form well-developed crystals.

COLLECTING LOCALITIES

Although uncommon, creedite is widely distributed. Few localities produce collectible specimens, however. Our specimens are from the Henderson molybdenum mine in Clear Creek County, Colorado. Other Colorado creedite localities are the Cresson open-pit gold mine at Cripple Creek in Teller County; and the creedite type locality at the Colorado Fluorspar Mine at Wagon Wheel Gap near the former silver-mining town of Creede in Mineral County.

Other sources in the United States are the Mex-Tex and Blanchard mines at Bingham in the Hansonburg district, Socorro County, New Mexico; the Defiance Mine in the Darwin district, Inyo County, California; and the Grand Reef and Iron Cap mines in the Aravaipa district, Graham County, Arizona. Nevada's sources include the La Plata Mine in the Mountain Wells district, Churchill County; the Boulder Hill Mine in the Wellington district, Douglas County; the Rock Hill and Broken Toe mines in the Rock Hill district, Esmeralda County; the Silver Coin Mine in the Iron Point district, Humboldt County; and the Cyprus-Tonopah Mine in the Lodi district, Nye County.

Mexican sources include the Navidad Mine at El Rodeo, Durango; and the Condesa, El Potosí, Inglaterra, and San Antonio mines in the Santa Eulalia district near Aquiles Serdán, Chihuahua.

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Creedite is also collected in Bolivia at the Colquiri Mine at Colquiri, 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, Nuro Province, Sardinia; in Greece at the Laurium district mines at Laurium, Attikí; in Tajikistan at the Dzhaambai fluorite deposit in the Pamir Mountains near Viloyati Mukhtori, Gomo-Badakhshan; in Kazakhstan at the Aqshatau Mine at Aqshatau, Qaraghandy Oblasy; in China at the Qinglong antimony-gold deposit in Qinglong County, Qianxi'nan Prefecture, Guizhou Province; and in South Africa at the N'Chwaning I and II mines in the Kalahari manganese fields, Northern Cape Province.

JEWELRY & DECORATIVE USES

Creedite has very limited use as a gemstone because of its rarity, softness, and small crystal size. Single creedite crystals are occasionally wire-wrapped as pendants. Large, transparent creedite crystals with intense purple colors (which are rare) are occasionally cut into collector's gems. Because of the small size of the rough creedite crystals, these gems are not more than two carats in weight and very costly. Mineral collectors value creedite for its rarity, color, unusual chemistry, and distinctive crystal forms.

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, CaF_2], in 1900. The mine was developed in 1912 to provide fluorite flux for the steel mills in Pueblo, Colorado, 240 railroad miles to the east. When United States Geological Survey 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 more detailed laboratory analysis study revealed a different index of refraction. When qualitative analysis later detected sulfur in the second specimen, Larsen realized that he had discovered a new mineral—one of the very few minerals that contain both sulfate and fluoride anions as essential constituents. When the National Academy of Sciences accepted his published conclusions in 1916, Larsen named the new mineral “creedite” after the place of its discovery near the center of the United States Geological Survey's Creede map quadrangle.

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

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Metaphysical practitioners believe that creedite enhances the understanding of others, helps heal emotional trauma, improves overall psychic abilities, and promotes clarity of expression in psychic realms.

THE UNITED STATES GEOLOGICAL SURVEY: PAST AND PRESENT

Our write-ups often mention the United States Geological Survey (USGS) or cite some of its many publications. In this write-up, we note that USGS field surveyor Esper Signius Larsen discovered and named creedite after a USGS map quadrangle (see “History & Lore”). In our discussion of Colorado’s Henderson molybdenum mine and molybdenum-production statistics (see “About Our Specimens”), we cite a USGS open-file report and its *2012 Mineral Resources*. USGS publications are authoritative sources of current and historical information on the geology of mineral localities; the uses of mineral resources; and domestic and international data on prices, demand, and production.

For the past 145 years, USGS scientists have performed research and field investigations of mineral deposits and resources, presenting their results and conclusions in tens of thousands of reports, papers, and maps. Virtually all of these are available to the public free of charge or at nominal cost. Just how all this material was compiled—and continues to be compiled is an interesting story.

In the early decades of the 19th century, the federal government realized the need for coordinated geological surveys of the nation’s public lands. At that time, geological surveys were performed by individual states or by private groups and served only agricultural, transportation, and military interests. The California gold rush of 1849 generated the first serious national interest in mining and geology. Although the federal government had established the Department of the Interior that same year, geological surveys remained restricted to the U.S. Army’s topographical engineers who were concerned primarily with possible transcontinental railroad routes.

California conducted the first systematic, state geological survey in 1860 and demonstrated how such surveys could benefit state economies. With the gold rush over and rich placer gravels depleted, mining in California had become increasingly difficult and costly. So the California Geological Survey’s statewide exploration of mineral resources was specifically aimed at encouraging and reviving the private mining industry.

In 1867, the federal government authorized four geological surveys of the vast western public lands. The first survey of the proposed 40th-parallel route of the transcontinental railroad was conducted by the Army Corp of Engineers and headed by Clarence King, a 25-year-old geologist from Yale University who had worked with the California Geological Survey. The next survey was led by Ferdinand V. Hayden, M.D., an experienced state and military surveyor, who had orders to investigate the mineral resources and geological features of Nebraska. In 1869, John Wesley Powell, a Civil War veteran and professor of geology at Illinois State Normal University, began exploring the southwestern canyon lands and eventually completed a harrowing, wooden-boat journey through the Arizona’s Grand Canyon. Lt. George Wheeler, an U.S. Army engineer, led the fourth survey through Nevada and the adjacent Great Basin areas.

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All four surveys were successful, although a lack of coordination produced some competition and duplication of effort. In 1878, Congress proposed a master plan to explore and map the western territories through a single agency created within the U.S. Department of the Interior. Its mission was “the classification of the public lands, and the examination of the geological structure, mineral resources, and products of the national domain.” On March 3, 1879, President Rutherford B. Hayes signed a bill discontinuing all previous surveys and establishing the United States Geological Survey with Clarence King as its director.

When the USGS began work with 38 employees and an annual budget of \$106,000, many still believed that the government had no business involving itself in science. Nevertheless, the USGS went forward, focusing initially on topographical mapping and compiling, interpreting, and publishing mining and mineral-resource statistics. The first major USGS publication was its *1882 Mineral Resources*, an accounting of the nation’s known mineral deposits. Amid the sections on energy and construction resources, along with metal, and nonmetal mineral deposits, was a report on gemstone deposits written by George Frederick Kunz, America’s first gemologist.

John Wesley Powell succeeded Clarence King as USGS director in 1881. Powell, who allowed his geologists great freedom in their methods and goals, concentrated on creating a national geological map and standardizing geological taxonomy, especially regarding stratigraphic nomenclature and cartographic representation. Powell’s system of geological mapping gained immediate, worldwide acceptance.

The direction of the USGS was not always dictated by scientific needs, but sometimes by politics, economics, and natural events. After the severe drought of 1886, Congress ordered the USGS to investigate the nation’s water resources. When declining gold and silver production in the 1890s threatened the balance of coinage-metal and monetary-metal supplies, the Survey was tasked with finding precious-metal deposits. Around 1900, when the bonanza copper and lead ores of the frontier era began rapidly depleting, the USGS was directed to search for deposits of low-grade, base-metal ores.

Despite being perpetually underfunded, the USGS was at Cripple Creek, Colorado, during the huge gold strike of 1893. Its field geologists had already investigated gold occurrences in Alaska before the Klondike strike. They surveyed Michigan’s iron deposits and the oil fields of Texas before most Americans ever heard of either, and they studied Utah’s huge Bingham Canyon copper deposit before it became the site of one of the world’s greatest mines. USGS geologists worked side-by-side with miners, drillers, and speculators who were out to become millionaires, not to advance the earth sciences. Ultimately, it was the USGS that did the footwork for the subsequent great discoveries of the huge, low-grade, base-metal deposits that would become America’s true mineral treasure.

By 1929, the USGS had 1,000 employees, including 126 geologists. During World War II, many of these geologists were sent abroad to participate in the vital search for strategic minerals for the war effort. In the late 1950s, when the USGS had increased its staff to 7,000 employees, it again diversified its interests to encompass everything from photogeologic lunar mapping to the mitigation of such natural hazards as earthquakes, floods, volcanic eruptions, and tsunamis.

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Today, the USGS, which employs 10,000 employees and has a billion-dollar annual budget, is one of the few government agencies founded in the 1800s that has retained its original name and basic mission. That mission is “to serve the nation by providing reliable scientific information to describe and understand the Earth, minimize loss of life and property from natural disasters, and manage water, energy, biological, and mineral resources to enhance and protect the quality of life.”

The USGS also continues to have a direct impact on specimen mining and mineral collecting through its vast library of bulletins and professional papers. These include reports of investigations of countless mines, mining districts, mineral occurrences, placer and lode deposits, and geological features. All are filled with mineralogical and geological data, along with fascinating accounts of discoveries, exploration, and development. Most of the mineral localities mentioned in commercial field-collecting guides first appeared in USGS publications papers. These reports continue to be used regularly by mining historians, writers who specialize in mineralogy and gemology, commercial specimen miners and dealers, and serious collectors. And the USGS annual *Mineral Resources*, which first appeared in 1882, is still published today and is filled with current production statistics for domestic and foreign mineral resources. Anyone interested in minerals, geology, mining, and the earth sciences should visit the USGS website at www.usgs.gov, which contains a wealth of mineral-related information and educational resources.

TECHNOLOGICAL USES

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

ABOUT OUR SPECIMENS

Our specimens of purple creedite were collected at the Henderson Mine in Clear Creek County, Colorado. The Henderson Mine, a major source of molybdenum, is 47 miles west of Denver and can be reached by taking Interstate-70 west to the town of Empire, following U.S. Highway 40 west for 9 miles, then continuing north for 2 miles on Clear Creek County Road 202 (Henderson Mine Road). The mine is located immediately east of the Continental Divide at an elevation of 10,300 feet in the Front Range of the Rocky Mountains. The head frame and surface buildings are just below timberline in an area of pine forests and subalpine valleys.

The Henderson molybdenite deposit lies within the Colorado Mineral Belt, a 150-mile-long, northeast-southwest-trending, mineralized zone that stretches from northwest of Denver to Durango in southwest Colorado. Most of Colorado's metal-sulfide deposits fall within the Colorado Mineral Belt. The geology of the Henderson molybdenite deposit is linked to the Laramide Orogeny, the mountain-building episode that began some 65 million years ago when tectonic stresses uplifted huge blocks of basement rock to form the Rocky Mountains. At

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Henderson, a second phase of crustal disruption occurred about 40 million years ago, when surges of magma emplaced intrusions of rhyolitic porphyry within the granite and gneiss host rock. As these intrusions cooled, contracted, and fractured, molybdenum-rich, hydrothermal solutions migrated upward into fissures, precipitating massive amounts of molybdenite [molybdenum disulfide, MoS_2] in networks of thin veins.

Molybdenite, the most common molybdenum-bearing mineral, consists of 59.94 percent molybdenum and 40.06 percent sulfur. Molybdenum is a silvery-white metal that does not occur free in nature. With an atomic number of 42 and an atomic weight of 95.94, it is roughly as heavy as lead, but much harder and less abundant. Ranking 56th in crustal abundance, molybdenum is as common as tungsten. Molybdenum's extremely high melting point of 4,730° F. (2610° C.), is the fifth-highest among all elements and is roughly 2,000° F. (1093° C.) higher than that of most steels. Molybdenum has a strong chemical affinity for many metals, especially iron. Small amounts of molybdenum have a remarkable ability to toughen steel alloys, which is the primary use of the metal today. The United States ranks second behind China in molybdenum production, accounting for one-quarter of the current annual world output of 242,000 metric tons. The price of molybdenum is now about \$13 per pound.

Core-drill exploration revealed the Henderson molybdenite deposit in 1967 and the Henderson Mine began operations in 1974. An underground mine with 300 employees, Henderson employs a block-cave mining system in which tunnels undercut the ore body, enabling it to collapse and crush itself under its own weight. The crushed ore is then moved onto a conveyor-belt system that transports it beneath the Continental Divide to a mill 15 miles north where a flotation-separation system concentrates the molybdenite. Although the ore grades only 0.17 percent molybdenum, the size of the ore body makes Henderson a world-class source of the metal. Since production began in 1976, 200 million tons of ore have yielded 900 million pounds of molybdenum. Henderson currently produces about 38 million pounds of molybdenum per year and has sufficient ore reserves for at least 12 more years of mining.

Although the Henderson Mine has produced exceptional molybdenite specimens and fine examples of pyrite [iron disulfide, FeS_2], barite [barium sulfate, BaSO_4], and fluorite [calcium fluoride, CaF_2], it is not a major source of specimens. The reason is that the mine works on a tight, 24-7 production schedule and management discourages specimen collecting. Our credite specimens were collected in March 2007, when miners on the lowest of the mine's three levels encountered fissures and vugs filled with drusy credite. Because the find was made in a developmental section of the mine that was not scheduled for immediate production, miners were able to extract specimens. Local mineral collectors purchased many of these specimens directly from Henderson miners; other specimens were acquired by a Denver-based mineral dealer. When introduced at the Denver Gem & Mineral Show in September 2007, the specimens were widely acclaimed by collectors. Despite prices that were unusually high for credite, the specimens sold out quickly. Collectors believed that the high prices were justified because of the delicate, lavender color and unusual drusy crystal habit of the specimens. These specimens have subsequently increased in value, because no further credite occurrences have been found at the Henderson Mine. The Mineral of the Month Club was fortunate to have acquired several lots of these specimens when they recently reappeared on the market.

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Your specimen, which consists of a drusy coating of creedite on a brecciated matrix of altered, Precambrian gneiss, formed as a coating on fissure walls. Under an intense light source or using a loupe or magnifying glass, individual creedite crystals with the typical monoclinic form of four prism faces and four termination faces can be seen. When viewed longitudinally (through the long crystal axis), the distinctive and diagnostic, diamond-shaped cross section of the creedite prisms is apparent. Another diagnostic feature of creedite crystals is the termination, in which one face is elongated and steeply slanted in the direction of the long axis. Most of these specimens consist of drusy creedite coatings; in some specimens, the clusters of creedite crystals form hemispheric structures as large as one-quarter inch in diameter. Molybdenite can be seen on some specimens, appearing as amorphous, greasy, gray-blue particles and stains.

The creedite crystals in your specimen are transparent to translucent. Their delicate, pale-lavender color is caused by traces of divalent manganese Mn^{2+} , which alters the crystal lattice in a manner that causes it to absorb the green-yellow-red end of the visible spectrum, while reflecting the shorter-wavelength, blue-purple colors that we perceive as pale lavender. Another interesting feature of creedite is that its color is most intense in reflected light, with the intensity decreasing noticeably in transmitted light. Your specimen, which represents an unusual color and habit of creedite, is a keepsake from one of the world's most productive molybdenum mines.

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