

June 2013 Mineral of the Month: Fluorite

This month we are featuring fluorite from England's Rogerley Mine, the only specimen mine in the United Kingdom. Our write-up recounts the region's long mining history and explains why fluorite has more colors than any other mineral.

OVERVIEW

PHYSICAL PROPERTIES

Chemistry: Calcium Fluoride CaF_2

Class: Halides

Group: Fluorite

Crystal System: Isometric (Cubic)

Crystal Habits: Usually cubic, often as penetration twins; less frequently octahedral; rarely dodecahedral; also occurs in botryoidal, granular, massive, columnar, and earthy forms, and as cleavage masses.

Color: White, colorless, violet, purple, lilac, blue, green, yellow, brown, amber, bluish-black, pink, and rose-red.

Luster: Vitreous

Transparency: Transparent and translucent to nearly opaque

Streak: White

Cleavage: Perfect in four directions, forming octahedrons.

Fracture: Uneven, brittle.

Hardness: 4.0

Specific Gravity: 3.0-3.2

Luminescence: Often fluorescent and phosphorescent, sometimes thermoluminescent and triboluminescent.

Refractive Index: 1.433

Distinctive Features and Tests: Best field indicators are cubic crystal form and excellent crystal development; perfect, four-directional cleavage; relative softness; and occurrence in fluorine-rich mineral environments.

Dana Classification Number: 9.2.1.1

NAME: The name "fluorite," pronounced FLOR-ite, is derived from the Latin *fluere*, meaning "to flow," alluding to fluorite's ability to reduce the melting temperatures of metals in smelting processes. Fluorite's many alternative names include "androdamant," "bruiachite," "Derbyshire spar," "fluor," "fluores," "fluoride of calcium," "fluoride of lime," "fluorspar," "fluorspath," "flusse," "flusspat," "liparite," "murrhina," and "spath vitreux." In European mineralogical literature, fluorite appears as *fluorit*, *fluorita*, and *fluorin*. Variety names based on color include "false emerald," "false amethyst," "false ruby," and "fluorite rose." "Chlorophane" refers to a thermoluminescent variety. The "blue john" variety, found only in England, has alternating yellow, blue, and purple bands; "rainbow fluorite" is multicolored.

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COMPOSITION: As indicated by the chemical formula CaF_2 , fluorite contains calcium (Ca) and fluorine (F). Calcium accounts for 51.33 percent of fluorite's molecular weight, fluorine for 48.67 percent. The fluorite molecule and crystal lattice are held together entirely by ionic bonding. Because ionic bonding is inherently weak, fluorite has perfect, four-directional cleavage to form octahedrons and is relatively soft at Mohs 4.0. Fluorite has the broadest color range of all minerals. Its colors are caused by traces of non-essential elements called chromophores or by lattice defects called "color centers" that are created by abnormal crystal growth, exposure to natural geophysical radiation, or displacement of free fluorine ions. Fluorite is relatively abundant and forms in several mineralogical environments. In epithermal (low-temperature) veins, it is associated with calcite, rhodochrosite, and chalcedony. Fluorite also occurs with albite and pyrite in carbonatites, with calcite and spinel in the hornfels of contact metamorphic rocks, and occasionally with albite in granite pegmatites. In hydrothermal replacement deposits, it occurs with galena, pyrite, sphalerite, and barite and is a common gangue mineral with many lead, zinc, and silver ores.

COLLECTING LOCALITIES: Fluorite specimens are collected in England, China, Russia, Pakistan, Namibia, Morocco, South Africa, Zimbabwe, Norway, Sweden, Spain, Germany, Italy, Peru, Bolivia, Australia, Hungary, Canada, and Mexico. In the United States, notable sources are located in Illinois, Kentucky, Oklahoma, Ohio, New Hampshire, Colorado, New Mexico, and Tennessee.

HISTORY, LORE & USES: Fluorite, which has served as a decorative stone since ancient times, is fashioned into spheres, dishes, figurines, vases, and other ornamental objects. Although fluorite's softness limits its use in jewelry, it is often faceted into collectors' gems. Fluorite has been used as a smelting flux since about 600 B.C. and continues to serve in metallurgical processes today. Fluorite is mined extensively as the primary source of fluorine for the manufacture of hydrofluoric acid, an important feedstock for the chemical and pharmaceutical industries. It is also converted into uranium hexafluoride (UF_6) for use in the gas-diffusion concentration of the uranium-235 isotope for nuclear fuel rods and nuclear weapons. Considerable amounts of fluorite are processed into aluminum fluoride (AlF_3) and synthetic cryolite [sodium aluminum fluoride, Na_3AlF_6] for use as a flux in aluminum-smelting processes. According to metaphysical belief, fluorite calms the spirit and mind when preparing for meditation, clarifies the decision-making process, and enhances objectivity and concentration.

ABOUT OUR SPECIMENS: Our fluorite specimens were collected at the Rogerley Mine near the village of Frosterly in the Weardale district, North Pennines County, Durham, England. This site in northern England is 22 miles southwest of Newcastle upon Tyne and 35 miles south of the Scottish border. The Rogerley Mine is located in an old limestone quarry in the Weardale lead-mining district, a part of the highly mineralized, 600-square-mile North Pennine Orefield. The Rogerley limestone quarry opened in the mid-1800s and closed in the 1950s. A British group began mining fluorite specimens in the quarry in the 1970s. An American group, operating as UK Mining Ventures, acquired the lease in 1996. The Rogerley Mine, the only specimen mine in the entire United Kingdom, is worked each summer and is a major source of fine fluorite specimens for international specimen markets. Mineralization within the Rogerley Quarry was emplaced when dioritic magma intruded formations of limestone, and associated, mineral-rich solutions formed lead-fluorite deposits in the form of nearly vertical, hydrothermal veins and

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horizontal, metasomatic sills. Today, specimen miners drive small tunnels and crosscuts to intersect the horizontal, metasomatic sills that they call “flats.” Pockets within these fluorite-rich flats contain well-developed, green-and-purple fluorite crystals. Miners use hydraulically powered, diamond-edged chain saws to cut the tough, altered host rock in order to recover undamaged matrix specimens of fluorite.

COMPREHENSIVE WRITE-UP

COMPOSITION

Fluorite consists of the elements calcium (Ca) and fluorine (F), which respectively make up 51.33 percent and 48.67 percent of its molecular weight. The fluorite molecule consists of a single cation (positively charged ion) and a single anion (negatively charged ion) that are held together entirely by ionic bonding. Ionic bonding is the attractive force that joins the positively charged ions of metallic elements to the negatively charged ions of nonmetallic elements. In fluorite, the calcium ion Ca^{2+} with its +2 charge is attracted to (opposite charges attract), and ionically bonds with, two fluorine ions 2F^{1-} with their collective -2 charge. The balance of anionic and cationic charges provides the fluorite molecule with electrical stability.

In the fluorite crystal lattice, eight fluorine ions surround each positively charged calcium ion, while four calcium ions surround each negatively charged fluorine ion. This forms alternating rows of calcium ions and fluorine ions that are arranged in four axial directions to create a cubic structure with calcium ions at the eight corners of each cube and at the centers of its six faces. Because of the inherent weakness of ionic bonding, fluorite exhibits perfect, four-directional cleavage and cleaves easily into octahedrons. It is also relatively soft at Mohs 4.0. Fluorite has a higher-than-expected density (specific gravity 3.0-3.2). The atomic weights of its essential elements calcium (40.08) and fluorine (19.00) would indicate a lesser density of about 2.8. But very close atomic packing of its calcium and fluorine ions within a rigid, well-organized cubic structure gives fluorite a significantly higher density.

Fluorite is often luminescent, with many specimens exhibiting fluorescence, phosphorescence, thermoluminescence, and triboluminescence. Luminescence occurs when certain minerals absorb electromagnetic, mechanical, thermal, and radiation energy. This energy excites certain electrons, boosting them from normal-energy, inner orbits to high-energy outer orbits. To return to their normal orbits, they release excess energy as visible light. In fluorescence, electromagnetic energy in the form of ultraviolet light energizes certain electrons, which then release excess energy by emitting visible light, usually in the blue wavelengths. The term “fluorescence” is actually derived from fluorite, which was the first mineral used to study this phenomenon. In phosphorescence, certain minerals continue to emit visible light even after the input energy source, such as ultraviolet light, has been removed. Triboluminescent minerals emit light when subjected to mechanical stress; thermoluminescent minerals emit light when heated.

Fluorite’s extraordinary color range, the broadest of all minerals, is attributed to three causes: elemental impurities, defects in the crystal lattice, and unbound fluorine ions. As an allochromatic or “other-colored” mineral, fluorite’s colors are most often caused by traces of

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nonessential elements called chromophores (color-causing agents). When pure, fluorite is colorless or white, but traces of iron and the rare-earth elements yttrium and cerium can substitute for calcium, altering the light-absorption and light-reflection properties of the lattice. Iron imparts green and yellow colors to fluorite, traces of yttrium and cerium impart pink and rose colors, and lanthanum imparts green colors. Purple, blue, and violet colors, however, are usually due to lattice defects called “color centers,” which are created by abnormal crystal growth or exposure to natural geophysical radiation. In fluorite, color centers form when fluorine ions are displaced from their normal lattice positions to create voids which then trap electrons. White light boosts these trapped electrons to higher energy levels; when returning to normal levels, they release this excess energy as purple, blue, or violet light. Fluorite is often color-zoned, color-banded, or multicolored, depending upon conditions at the time of crystallization. Fluorite that formed through single-phase precipitation is usually mono-colored with minimal color-zoning. But changes in the chemistry of hydrothermal solutions during slow or multiple-phase precipitation create banding or multicoloration.

As a relatively common mineral, fluorite forms in several mineralogical environments. In epithermal (low-temperature) veins, it is associated with calcite [calcium carbonate, CaCO_3], rhodochrosite [manganese carbonate, MnCO_3], and chalcedony [microcrystalline quartz, silicon dioxide, SiO_2]. In hydrothermal replacement deposits, it occurs with galena [lead sulfide, PbS], pyrite [iron disulfide, FeS_2], sphalerite [zinc sulfide, ZnS], and barite [barium sulfate, BaSO_4]. Fluorite is a common gangue mineral associated with many lead, zinc, and silver ores. It also occurs with albite [sodium aluminum silicate, $\text{NaAlSi}_3\text{O}_8$] and pyrite in carbonatites (calcium-rich igneous rocks); with calcite and spinel [magnesium aluminum oxide, MgAl_2O_4] in the hornfels (fine-grained, altered silicate rocks) in contact metamorphic zones; and occasionally with albite in granite pegmatites.

Fluorite’s Dana classification number 9.2.1.1 first identifies it as a halide mineral (9). It is subclassified (2) as an anhydrous halide with the general formula AX_2 , in which “A” can be calcium, barium, or the rare-earth element yttrium, and “X” is any halogen element. Fluorite then falls into the fluorite group (1) as the first (1) of three members. The other two members are the physically similar minerals frankdicksonite [barium fluoride, BaF_2] and tveitite-Y [calcium yttrium fluoride, $\text{Ca}_{14}\text{Y}_5\text{F}_{43}$].

Although elemental fluorine is extremely poisonous and corrosive, fluorite specimens are stable, safe, and require no special handling or storage. However, never attempt to treat fluorite specimens with any acid that might release hazardous fluorine gas.

COLLECTING LOCALITIES

As a relatively abundant, widely distributed mineral, fluorite has numerous collecting localities. Our specimens are from the Rogerley Mine in the Weardale district near Frosterly, North Pennines County, Durham, England. Other English sources include the historic Blue John and Old Tor mines and Treak Cliff Cavern at Castleton, Derbyshire, Cornwall. Among Europe’s localities are the Lassedalen fluorite deposit and the Kongsberg silver mines near Kongsberg, Buskerud, Norway; the Manhem, Kåravet, and Finnbo mines at Falun, Dalarna, Sweden; the La

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Florina and Gloria mines at Hornachuelos near Córdoba, Andalusia, Spain; the Bella mine at Pákozd in the Velencei Mountains of Fejér County, Hungary; the Badenweiler lead-mining district in the Black Forest region of Baden-Württemberg, Germany; and the Carrara marble quarries in the Apuan Alps of Massa-Carrara Province, Tuscany, Italy.

Fluorite is collected in China at the Tongbai fluorite mine in Tongbai County, Gaoxin District, Nanyang Prefecture, Henan Province; and the Huangshaping, Yaogangxian, Dongpo, Xianghualing, Chashan, and Xianghuapu lead-zinc mines in Chenzou Prefecture, Hunan Province. Russian specimens come from the Pouvya and Dodo mines at Tyumenskaya Oblast' in the Polar Urals of the Western-Siberian Region, and the Aunik rare metals deposit at Buriatia in Transbaikalia in the Eastern-Siberian Region. In the Northern Areas of Pakistan, specimens come from the Nagir and Chumar Bakhoor area of the Hunga Valley in the Gilgit District, and the Baha and Apo Ali Gun areas near Baltistan.

Fluorite is collected at the Huaron Mining District at Cerro del Pasco in Pasco Department, and the Pasto Buena Mining District in Ancash Department, both in Peru; and the Mururata and Chojilla mines in Sud Yungas Province, La Paz Department, Bolivia. In Australia, fluorite occurs at the Sandy Creek fluorite deposit at Walwa in Victoria, the Cannington silver-lead-zinc deposit in the Mt. Isa-Cloncurry area of Queensland, and the Gulf Fluorite Mine at The Gulf in New South Wales. Other localities include the El Hammam Mine at Meknès, Meknès-Tafilalet Region, Morocco; the Okoruso Mine in the Otjiwarongo District and the Kombat Mine in the Grootfontein District, both in the Otjozondjupa Region, Namibia; the Hwange lead-zinc district in Matabeleland, North District, Zimbabwe; and the Aladdin Fluorite Mine at Sinkwazi in KwaZulu-Natal Province, and the Marico Fluorspar Mine in the Marico district in Northwest Province, both in South Africa.

Mexican sources include the Navidad Mine near El Rodeo, and the China, Ojuela, and Reina mines at Mapimí, both in Durango; and the Cantera and Asturiana mines, Mun. de Zacatecas, Zacatecas. Canadian specimens are collected at the Rogers Fluorspar Mine at Madoc in Huntingdon Township, Hastings County, Ontario; the Poudrett, Uni-Mix, and Desourdy quarries at Mont Saint-Hilaire, Rouville County, Québec; and the Penobsquis potash mines, Kings County, New Brunswick.

In the United States, fluorite occurs throughout the Illinois-Kentucky Fluorspar District, notably in the Cave-in-Rock and Ozark-Mahoning subdistricts of Hardin County, Illinois, and the Babb, Commodore, Tabb, and Dike-Eaton subdistricts of Crittenden and Caldwell counties, Kentucky. The Elmwood Mine at Carthage in Smith County, Tennessee, has yielded exceptional specimens. Colorado's localities include the Sweet Home Mine at Alma, Park County; the Barstow Mine near Ouray, Ouray County; and the Browns Canyon Fluorspar District, Chaffee County. In New Mexico, fluorite occurs at Fluorite Ridge, Luna County, the Hansonburg district near Bingham in Socorro County, and Pine Canyon near Tyrone in Grant County. Fluorite is also collected at the Capital and Ten-Acre quarries, Johnston County, Oklahoma; the Kelly Island Stone Quarry at Clay Center, Ottawa County, Ohio; and the William Wise Mine in Westmoreland, Cheshire County, New Hampshire.

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JEWELRY & DECORATIVE USES

Cleaved fluorite octahedrons have been worn as gemstones since Biblical times. Faceted fluorite gems were popular in Europe in the 1600s when color varieties known as “false emerald,” “false ruby,” and “false amethyst” were used to imitate more valuable gems. Among fluorite’s many excellent gemological properties are good transparency, a broad range of pleasing colors, a vitreous luster, and crystals suitable for cutting large gems. Unfortunately, its low refractive index of 1.433 compromises brilliance. Fluorite is also too soft for everyday jewelry wear, and its perfect, four-directional cleavage makes cutting difficult. Nevertheless, fluorite cabochons and faceted gems are occasionally mounted in pendants and brooches. Collectors’ gems in sizes exceeding 100 carats are popular for both display and study purposes. The Smithsonian Institution in Washington D.C. exhibits several spectacular fluorite gems, the largest weighing 492.1 carats. As a decorative stone, large quantities of fluorite are carved into spheres, dishes, figurines, and vases.

As both individual and composite specimens, fluorite is among the most collectible of all minerals because of its large crystal size, excellent crystal development, availability and affordability, and broad range of colors. In composite specimens, fluorite is often associated with galena, rhodochrosite, and quartz. Colorful, well-developed, cubic or octahedral fluorite crystals can greatly enhance both the value and visual appeal of composite mineral specimens.

HISTORY & LORE

Archaeologists have recovered amulets carved from massive fluorite from 4,000-year-old Egyptian tombs. By 600 B.C., Greek metalworkers were using fluorite as a smelting flux to remove impurities from, and lower the melting temperature of, silver. Later, the Romans mined fluorite in Spain and England as a smelting flux for lead, silver, and copper ores. Romans also made exquisite carvings from the distinctive, blue-purple-and-yellow-banded “blue john” fluorite (named from the French *bleu et jaune* meaning “blue-and-yellow”) that they mined in England. The Roman ruins at Pompeii have yielded many “blue john” fluorite vases. By 1500 A.D., when the Chinese were carving beautiful, jade-like figurines from massive, blue-and-green fluorite, European metallurgists had begun using fluorite, which they called *flusse* or *flusspat*, as a standard smelting flux. In his classic *De re Metallica*, German scholar Georgius Agricola (Georg Bauer, 1494-1555) described the use of *flusspat*, which he called “*lapides igni liquiscentes*,” literally “stones that become liquid in fire.” Agricola also renamed *flusspat* using the Latin word *fluere*, “to flow,” a word later anglicized to “fluor” and “fluorspar.” By 1670, German glassworkers were treating *flusspat* with sulfuric acid to produce another acid called *flusspatäure* (“acid of *flusspat*”) that could etch glass, thus greatly advancing the art of glassmaking.

By 1800, chemists realized that fluorite contained an extraordinarily reactive, but unknown element. In 1813, French physicist André Marie Ampère (1775-1836) named this mysterious element *phlor* (Greek for “destructive”). The influential English chemist Sir Humphry Davy (1778-1829), however, preferred the word “fluorine” as a derivative of the traditional “fluorspar.” In 1826, researchers coined the words “fluoride” for fluorine-containing minerals

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and “hydrofluoric acid” (HF) for *flusspatäure*. Fluorite wasn’t formally assigned its name until 1868. By then, the hazardous nature of fluorine had become quite apparent. Chemists who had lost their health or their lives by inhaling or contacting fluorine-based acids and vapors became known as “fluorine martyrs.” Finally, in 1886, French chemist Ferdinand Frederick Henri Moissan (1852-1907) isolated pure fluorine by electrolytically reducing hydrofluoric acid and potassium fluoride (KF). Moissan’s experiments demonstrated that fluorine was the most chemically reactive of all elements. Moissan’s work to reveal the chemical nature of fluorine earned him the 1906 Nobel Prize for chemistry, but also caused his premature death a year later at age 55.

Fluorite is the official state mineral of Illinois and has appeared on Switzerland’s 10-centime stamp of 1961, Namibia’s 2-cent stamp of 1991, Kyrgyzstan’s 80-tyiyn stamp of 1994, Kenya’s 80-cent stamp of 1977, France’s 5-franc stamp of 1986, and Algeria’s 2.40-dinar stamp of 1983.

Medieval physicians prescribed the ingestion of powdered fluorite to treat kidney disease and also placed fluorite crystals against joints to alleviate arthritic pain. Modern metaphysical practitioners believe that fluorite calms the spirit and mind when preparing for meditation, enhances objectivity and concentration, and clarifies the decision-making process. Metaphysical healers assign specific powers to individual fluorite colors: White is thought to help access the spiritual world, green to energize the heart and mind, blue to provide inner peace, purple to focus the mind, and yellow to facilitate group communication.

THE INTERNATIONAL MINERALOGICAL ASSOCIATION

In our write-ups, we sometimes generally refer to the number of recognized mineral species as “about 4,500” or “nearly 4,700.” Several Mineral of the Month Club members have recently asked us for the *exact* number of recognized mineral species. As of March 2013, the number provided by the International Mineralogical Association (IMA), the organization that approves and lists mineral species, was 4,782. However, by the time you read this, that number may have exceeded 4,800. This is because the IMA, which represents the national mineral societies of 38 nations, is currently recognizing new species at the rate of about one every three or four days.

The rate of recognition of new mineral species reflects the technological advancement of mineralogy. Prior to 1750, mineralogists recognized only about 30 minerals that qualified as distinct species because of their unique chemistries and structures. But the dawn of the age of scientific enlightenment in the late 1700s brought rapid advances in crystallography and quantitative chemical analysis that soon enabled mineralogists to recognize new species at the rate of about ten a year.

This rate remained relatively steady until the 1950s and the introduction of advanced X-ray diffractometers that could define a mineral’s most subtle crystallographic features and electron-microprobe instruments that produced accurate quantitative and qualitative results from even the tiniest mineral samples. With unprecedented abilities to distinguish minerals both chemically and physically, mineralogists then began to recognize about 40 new mineral species annually.

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These rapid advancements in mineral analysis and identification created confusion in the naming, nomenclature, and classification of the rapidly growing number of species. This led mineralogists from two dozen national mineral societies to establish the International Mineralogical Association in 1958. Foremost among its duties was to bring order to the classification and naming of new mineral species. Toward this end, the first committees formed within the IMA were the Committee on New Minerals and Mineral Names (CNMMN) and the Committee on Mineral Classification (CCM). These committees instituted the two-tier system of mineral recognition that is still used today. Proposed new minerals are first being accepted as valid *unnamed* species that are assigned codes and subjected to additional study. Once more complete data becomes available, these unnamed new minerals can then earn full recognition as *named* species. During the 1960s, mineralogists proposed or recognized about 60 new minerals each year. In the 1970s, the annual average increased to 80 new minerals. The annual average during the 1980s soared to 110 new minerals and has declined only slightly since that time.

In 2006, the CNMMN and CCM merged into a single unit, the Committee on New Minerals, Nomenclature and Classification (CNMNC). Today, this committee, the most active of all the IMA's committees, is the authority that recognizes new minerals, approves new mineral names and, if warranted, discredits previously named species or revalidates previously discredited species.

While most new species are previously unknown minerals, revised nomenclatural standards also increase the growing number. One example is the major revision of zeolite-mineral classification and nomenclature that took place during the 1990s and increased the number of zeolite species from 48 to 83. In March 2013, when the IMA listed 4,782 named species, it also listed more than 1,200 unnamed species. Many of these unnamed minerals will gain full recognition and be formally named in the future.

It is interesting to look at the origin of the names of, and the distribution of elements within, the 4,782 currently recognized species. About 45 percent of the fully recognized minerals are named for individuals, usually scientists who have in some way contributed to mineralogy. About 23 percent are named for discovery sites, such as towns, cities, counties, nations, and topographical features. Another 14 percent are named for their chemistry, usually a constituent element or ion, while 8 percent are named for such physical properties as color, density, or crystal characteristics. In terms of elemental distribution, oxygen is an essential element in 76 percent of all named species. Hydrogen is an essential element in 53 percent; iron in 32 percent; silicon in 31 percent; calcium in 27 percent; sulfur in 24 percent; and aluminum in 23 percent. Aluminum is therefore an essential element in about 1,100 of the fully recognized species.

Of all the minerals, only about 100 are considered generally collectible in terms of availability, abundance, affordability, and visual appeal. All the others are too rare, unavailable, or unaffordable, or they occur in such small sizes as to have little visual appeal or popular interest.

While most new mineral species have relatively complex chemistries, a few are very simple. One new mineral with a very simple chemistry is vanadium which, of course, consists only of that element. Although identified as an element in 1831, vanadium was not known to occur free in nature and therefore was never classified as a mineral. But after mineralogists recently

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discovered traces of elemental vanadium at Mexico's Colima Volcano in February 2013, the IMA officially recognized the element vanadium as a mineral.

The rapid evolution of the science of mineralogy is illustrated by the fact that nearly three-quarters of all the known mineral species have been recognized and named since 1955. When the Mineral of the Month Club mailed its first specimens in 1996, the IMA listed only 3,400 species. Today, in our Club's 17th year, the IMA lists 4,782 mineral species.

TECHNOLOGICAL USES

Fluorite is the primary component of fluor spar ore, the only commercial source of fluorine. Fluorite serves as a metallurgical flux and as a feedstock to manufacture hydrofluoric acid for use in the chemical and pharmaceutical industries. Fluorine's extreme chemical reactivity makes it an excellent metallurgical flux. In molten metals, fluorine readily combines with impurities to form volatile fluorides, which are removed as vapors, while fluorite's calcium component combines with silicate impurities to form easily removable slag. Large quantities of fluorite are also converted to aluminum fluoride (AlF_3) and synthetic cryolite [sodium aluminum fluoride, Na_3AlF_6] for use in smelting aluminum. Fluorite is also converted to uranium hexafluoride (UF_6), a vital intermediate chemical step in the gas-diffusion concentration of the uranium-235 isotope that is used in nuclear fuel rods and fission components for nuclear weapons. Flawless, transparent fluorite crystals were once cut into apochromatic lenses free of chromatic and spherical aberrations for infrared and ultraviolet optical uses. Today, synthetic fluorite serves this purpose. Synthetic fluorite doped with uranium and rare-earth elements is also used in certain lasers.

Some five million metric tons of fluor spar, worth about \$225 per metric ton, are mined worldwide each year. China is the leading producer, followed by Mexico, Mongolia, South Africa, and Russia.

ABOUT OUR SPECIMENS

Our fluorite specimens are from the Rogerley Mine in the Weardale district near the village of Frosterly, North Pennines County, Durham, in northern England. The Weardale district is 22 miles southwest of Newcastle upon Tyne, 35 miles south of the Scottish border, and not far from the ruins of Hadrian's Wall, the ancient stone wall that marked the northern limit of Roman Britain. The regional topography is characterized by the low mountains and hills of the Pennine Chain. The Rogerley Mine, located at an elevation of 1,500 feet, is surrounded by rolling, open moorlands with stone walls, scattered cottages, and small villages.

The Weardale lead-mining district is part of the highly mineralized, 600-square-mile North Pennine Orefield. The host rock at the Rogerley Mine is limestone that was laid down during the Carboniferous Period some 300 million years ago when shallow seas covered the region. Later, when dioritic magma intruded this limestone, associated mineral-rich, hydrothermal solutions emplaced scattered lead deposits in the form of nearly vertical, hydrothermal veins and

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horizontal, metasomatic sills or “flats.” In the metasomatic flats, hydrothermal solutions not only emplaced mineralization, but also altered the chemistry of the host rock. These metasomatic flats are the source of our fluorite specimens.

Lead was first mined in the North Pennine Orefield in the 12th century A.D., with mining reaching its peak in the 1800s with many small, underground mines and two dozen, small smelters. Some mines also worked deposits of ankerite [calcium iron magnesium manganese carbonate, $\text{Ca}(\text{Fe},\text{Mg},\text{Mn})(\text{CO}_3)_2$] and siderite [iron carbonate, FeCO_3] as sources of iron. When lead and iron mining declined after World War I, miners turned to fluorspar, which they had previously discarded as worthless, but which had since become valuable as a steelmaking flux. By the time fluorspar mining was finally discontinued in the 1990s, the Weardale district had produced more than one million tons of lead and two million tons of fluorspar. The district had also yielded many fine fluorite specimens.

The Rogerley Mine is located within the Rogerley Quarry, an old limestone quarry that opened in the mid-1800s to provide limestone as a flux for nearby iron foundries. The limestone contains mineralized veins of galena and fluorite that had not been large enough to mine in the past. Because the lead and fluorite “contaminated” the limestone, quarrymen left these vein sections in place. In 1972, a group of partners established the Cumbria Mining and Mineral Company to mine fluorite specimens commercially. At the time, this was a novel idea in England, and obtaining the necessary government permits was difficult. The partners also faced dangerously weak and collapsing rock on the sheer quarry walls and frequent visits by “high-graders” (thieves). Despite the difficulties, this part-time operation produced many excellent fluorite specimens for 20 years. In 1996, an American group, operating as UK Mining Ventures, picked up the quarry lease. The Rogerley Mine has since operated every summer and is the only specimen mine in the entire United Kingdom.

Miners drive small tunnels and crosscuts to intersect horizontal, metasomatic flats that are rich in fluorite and can contain pockets filled with well-developed fluorite crystals. Because the silicified limestone host rock is very tough and durable, removing these crystals intact is difficult. Most of the altered limestone that contacts the pockets has actually been replaced by hard silica and iron oxides. To recover intact, matrix specimens of fluorite, miners use hydraulically powered, diamond-edged chain saws to cut through the altered limestone.

Along with fluorite, other minerals in the metasomatic flats include aragonite and calcite [both polymorphic forms of calcium carbonate, CaCO_3], galena [lead sulfide, PbS], quartz [silicon dioxide, SiO_2], hydrocerussite [basic lead carbonate, $\text{Pb}_3(\text{CO}_3)_2(\text{OH})_2$], smithsonite [zinc carbonate, ZnCO_3], and cerussite [lead carbonate, PbCO_3]. The pockets, however, contain only fluorite with smaller amounts of quartz, cerussite, and galena. Most fluorite occurs in the cubic habit, is dark emerald-green in color, and exhibits an unusual, subtle, blue-purple fluorescence in daylight. Under ultraviolet light, the fluorescence is a strong purplish-white. The largest fluorite cubic crystals measure about two inches on a side. The colors and unusual daylight fluorescence of Rogerley fluorite are attributed to traces of the rare-earth elements yttrium and lanthanum that create color by forming color centers (see “Composition”).

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When these pockets developed, quartz formed first as drusy coatings on the pocket walls. Fluorite and galena next formed simultaneously, with galena crystals sometimes embedded in the fluorite crystals. In some pockets, a second phase of quartz crystallization has deposited a drusy coating atop the fluorite crystals. The mineralogy varies significantly among pockets: While green is the dominant fluorite color throughout the mine, a few individual pockets yield purple fluorite crystals, some of which are multicolored with both purple and green.

As you examine your specimen of Rogerley Mine fluorite, note first its color, which can be described as dark emerald-green with a slight, bluish cast. The basic green color is due to traces of the rare-earth element lanthanum that forms color centers. The subtle bluish cast is due to an unusual daylight fluorescence in which the fluorite absorbs a portion of the incident light and reemits it as visible blue light. Under ultraviolet light, your specimen will exhibit a purplish-white fluorescence. Note also that the fluorite crystals range from translucent to transparent. Almost all the crystals in your specimen are cubic in habit with only slight dimensional modification. Some specimens may contain small numbers of octahedral crystals. Your specimen has a noticeable “heft” in the hand. This is due to its specific gravity of 3.0-3.2, which indicates about 15 percent greater density than a similar volume of quartz. The fluorite crystals rest atop a matrix of dark, silicified limestone, which is actually a section of the vein wall. Any orange-brown coloration is caused by the presence of hematite [iron oxide, Fe_2O_3]. Separating the altered limestone and fluorite is a thin, grayish-white layer of drusy quartz that, during the crystallization sequence, formed before the fluorite. Your specimen is a fine example of cubic fluorite and a mineral keepsake from the Rogerley Mine—the only specimen mine in the United Kingdom.

References: *Dana's New Mineralogy*, Eighth Edition; *Encyclopedia of Minerals*, Second Edition, Roberts, et al, Van Nostrand Reinhold Company; *2008 Glossary of Mineralogical Species*, J. A. Mandarino and Malcolm E. Back; *Mineralogy*, John Sinkankas, Van Nostrand Reinhold Company; *Gems and Jewelry*, Joel Arem, Geoscience Press; *Gemstones of the World*, Walter Schumann, Sterling Publishing Company; *The Complete Guide to Rock & Minerals*, John Farndon, Hermes House, 2006; *Fluorite: The Collector's Choice*, (editors) J. Fisher, M. Jarrat, et al, ExtraLapis English Series No. 9, Lithographie LLC, 2006; “The Fluorine Martyrs,” Steve Voynick, *Rock & Gem*, October 2008; “The Frugal Collector: Fluorite,” Bob Jones, *Rock & Gem*, April 2004; “Letters from Europe: The British Scene,” Michael P. Cooper, *The Mineralogical Record*, January-February 1994; “The Denver Show 1998,” Thomas P. Moore, *The Mineralogical Record*, January-February 1999; “The Denver Show 1999,” Wendell E. Wilson, *The Mineralogical Record*, January-February 2000; “The Springfield Show 2003,” Joe Polityka, *The Mineralogical Record*, March-April 2004; “The Tucson Show 2000,” Thomas P. Moore, *The Mineralogical Record*, May-June 2000; “Fluorspar,” M. Michael Miller, *2010 Minerals Yearbook*, United States Geological Survey.

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