

January 2010 Mineral of the Month: Fluorite

For this month's mineral, we are featuring beautiful, lilac-colored fluorite in a rare botryoidal form. Our specimens were collected in China and our write-up explains the unusual origins of their color and crystal habit, and why China's days as a leading source of mineral specimens may be ending.

OVERVIEW

PHYSICAL PROPERTIES

Chemistry: CaF₂ Calcium Fluoride

Class: Halides

Group: Fluorite

Crystal System: Isometric (Cubic)

Crystal Habits: Usually cubic, often as penetration twins; less frequently octahedral; rarely dodecahedral; also 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 an octahedron

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, excellent crystal development, perfect four-directional cleavage, relative softness, and occurrence in fluorine-rich mineral environments.

Dana Classification Number: 9.2.1.1.1

NAME The name "fluorite," pronounced FLOR-ite, is derived from the Latin *fluere*, "to flow," a reference to its ability to reduce the melting temperatures of metals in smelting processes. Through long use as a decorative stone and metallurgical flux, fluorite has acquired such alternative names as "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." Fluorite also has several variety names based on color: "False emerald" is green, "false amethyst" is purple, "false ruby" is red, "fluorite rose" is pink, "rainbow fluorite" is multi-colored, and "blue john" has alternating yellow, blue, and purple bands. A thermoluminescent variety is known as "chlorophane."

COMPOSITION: Fluorite's chemical formula CaF₂ identifies its elemental constituents as calcium (Ca) and fluorine (F). Calcium makes up 51.33 percent of fluorite's molecular weight; fluorine contributes 48.67 percent. The fluorite molecule and crystal lattice are held together almost entirely by ionic bonding. Because of the inherent weakness of ionic bonding, fluorite exhibits perfect, four-directional cleavage and is relatively soft at Mohs 4.0. Fluorite's broad range of colors can have three causes: traces of non-essential elements called chromophores; lattice defects called "color centers" created either by abnormal crystal growth or exposure to natural geophysical radiation; or the presence of free fluorine ions. Fluorite is relatively abundant and forms in several mineralogical environments. In epithermal (low-temperature)

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veins, it is associated with calcite, rhodochrosite, and chalcedony. In hydrothermal replacement deposits, it occurs with galena, pyrite, sphalerite, and barite and is a common gangue mineral with lead, zinc, and silver ores. 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.

COLLECTING LOCALITIES: China is currently the world's largest source of fluorite specimens, with important localities in Henan and Hunan provinces. Russia has two important sources in its Siberian region. Pakistan has several fluorite localities in its Northern Areas. African fluorite is found in Namibia, Morocco, South Africa, and Zimbabwe. In Europe, fluorite is collected in Norway, Sweden, Spain, Germany, Italy, and England. Specimens also come from Peru, Bolivia, Australia, and Mexico. The leading fluorite locality in the United States is the Illinois-Kentucky Fluorspar District; specimens are also collected in Colorado, New Mexico, Oklahoma, and New Hampshire.

HISTORY, LORE, & USES: Fluorite has served as a decorative stone since antiquity. Today, massive fluorite is fashioned into spheres, dishes, figurines, vases, and other ornamental objects. Because of its softness, fluorite has limited use in jewelry, but is faceted into collector gems. Fluorite has been used as a smelting flux since 600 B.C. and remains vital to modern metallurgical processes. Fluorite is the primary source of fluorine for the manufacture of hydrofluoric acid, a feedstock for the chemical and pharmaceutical industries and for the industrial preparation of uranium hexafluoride (UF_6) needed in the gas-diffusion concentration of the uranium-235 isotope for nuclear fuel rods and nuclear weapons. Fluorite is also processed into aluminum fluoride [AlF_3] and synthetic cryolite [sodium aluminum fluoride, Na_3AlF_6] needed to smelt aluminum. Metaphysical practitioners believe that fluorite calms the spirit and mind when preparing for meditation, increases objectivity and concentration, and clarifies the decision-making process.

ABOUT OUR SPECIMENS: Our fluorite specimens were collected at the Tongbai fluorite mine in Tongbai County, Gaoxin District, Nanyang Prefecture, Henan Province, in the Peoples Republic of China. The Tongbai deposit was emplaced when fluorine-rich hydrothermal solutions permeated porous sandstone to precipitate fluorite. This deposit was discovered in the 1950s when prospectors noticed purple fluorite in outcropped ridges of brown sandstone. The Tongbai mine was developed in the early 1980s to produce fluorite as a flux for steel-making. The fluorspar ore occurs in a thick stratum of fluorite-impregnated sandstone trending along a major geological fault which had served as a conduit for the fluorine-rich hydrothermal solutions that emplaced the deposit. The Tongbai deposit is a half-mile long and cylindrically shaped, with the richest grades of fluorspar near the center. The Tongbai mine is a highly mechanized operation that extracts and crushes fluorspar ore, then concentrates the fluorite by flotation separation. Tongbai fluorite is very unusual because of its botryoidal habit, which is the result of its very slow precipitation in a confined environment with insufficient space for normal crystal development. The lilac color of our specimens is caused by the effect of natural geophysical radiation emitted by particles of uranium- or thorium-bearing minerals within the host sandstone which altered the light-reflection properties of the fluorite crystal lattice.

10 YEARS AGO IN OUR CLUB: Lepidolite, unknown locality, Minas Gerais, Brazil. We sent Club members flat "books" of this lilac to purple lithium-containing mica, whose name derives from the Greek *lepidos*, meaning "scale," in reference to its common habit of scale-shaped crystals. The name was given by German chemist and mineralogist Martin Heinrich Klaproth (1743-1817), the discoverer of eight elements, whose collection now resides in the National History Museum in Paris. The write-up highlighted how gem miners are excited when finding lepidolite or other mica group minerals as it usually means they are zeroing in on gem-bearing pockets! The element lithium imparts characteristic pink to purple color to lepidolite, and pink colors to tourmaline and to beryl. Hard to believe it was ten years ago!

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COMPREHENSIVE WRITE-UP

COMPOSITION

This is the fourth time we have featured fluorite as our Mineral of the Month, each time from a different locality and in a variety of colors. In June 1996, we featured purple fluorite cubes from the Elmwood Mine at Carthage in Smith County, Tennessee, now recognized as a classic American locality; in March 2002, our specimens were fluorescent, green cubic crystals from the Rogerley Mine at Weardale, Durham County, England; and in October 2007 we presented transparent, green, cubic crystals from the Huangshaping lead-zinc mine at Huangshaping in Chenzou Prefecture, Hunan Province, China. This month's specimens are from a new source in China and are unusual because of their rare botryoidal form.

Fluorite has only two elemental components: calcium (Ca) and fluorine (F), which respectively make up 51.33 percent and 48.67 percent of fluorite's molecular weight. The fluorite molecule consists of a single cation (positively charged ion) and a single anion (negatively charged ion). The atomic bonding within the fluorite molecule and the crystal lattice is almost entirely ionic. Ionic bonding is the attractive force that joins the positively charged ions of distinctly metallic elements with the negatively charged ions of distinctly 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 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 ionic bonding is weak, fluorite exhibits perfect, four-directional cleavage and is easily cleaved into octahedrons. It is also relatively soft at Mohs 4.0. Fluorite has a higher-than-expected density (specific gravity 3.0-3.2). Fluorite's nearly equal proportions of calcium (atomic weight 40.08) and fluorine (atomic weight 19.00) would indicate a density of only about 2.8. But its significantly higher density is due to the close packing of its calcium and fluorine ions within its cubic structure.

Fluorite is often luminescent, a term that refers to fluorescence, phosphorescence, thermoluminescence, and triboluminescence. Because its crystal lattice contains unbound fluorine ions, fluorite is also one of the few minerals that can exhibit all four types of luminescence. Luminescence occurs at ambient temperatures 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 their excess energy as visible light. In fluorescent fluorite, electromagnetic energy in the form of ultraviolet light energizes certain electrons, which then release this excess energy in visible colors, most often blue. The term "fluorescence" derives from "fluorite," which was the first mineral used to study this phenomenon.

Fluorite's broad range of colors and color intensities is attributable 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 non-essential 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 manner in which the lattice absorbs and reflects the wavelengths of white light. Iron imparts green and yellow colors to fluorite, while traces of yttrium and cerium impart pink and rose colors. Purple, blue, and violet colors, however, are usually due to lattice defects called "color centers," which are created either by abnormal crystal growth or exposure to natural

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geophysical radiation. Fluorite color centers form when fluorine ions are displaced from their normal lattice positions to create voids which trap electrons. White light boosts these trapped electrons to higher energy levels; when returning to their normal levels, they release this excess energy as purple, blue, or violet light. Unbound fluorine ions can also contribute to fluorite color. Fluorite frequently exhibits color zoning, color banding, and multi-coloration, depending upon the conditions existing during the crystallization process. Precipitation of fluorite can occur in either single or multiple phases, and over varying periods of time. Fluorite formed in single-phase precipitation usually has a single color with minimal zoning. But changes in the chemistry of the hydrothermal solutions during slow or multiple-phase precipitation can create banding with two or more colors.

The Dana classification number 9.2.1.1 identifies fluorite 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, which share similar physical properties, are frankdicksonite [barium fluoride, BaF_2] and tveitite-Y [calcium yttrium fluoride, $Ca_{14}Y_5F_{43}$].

Fluorite is a relatively abundant mineral that 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, $BaSO_4$]. It is a common gangue mineral with many lead, zinc, and silver ores. Fluorite also occurs with albite [sodium aluminum silicate, $NaAlSi_3O_8$] 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.

COLLECTING LOCALITIES

Fluorite is a relatively abundant, widely distributed mineral with numerous occurrences. Our specimens were collected at the Tongbai fluorite mine in Tongbai County, Gaoxin District, Nanyang Prefecture, Henan Province, in the Peoples Republic of China. Other Chinese localities include the Huangshaping, Yaogangxian, Dongpo, Xianghualing, Chashan, and Xianghuapu lead-zinc mines in Chenzou Prefecture, Hunan Province. Russian specimens come from the Pouvyia and Dodo mines at Tyumenskaya Oblast' in the Polar Urals of the Western-Siberian Region, and the Aunik fluorite-rare metals deposit at Buriatia in Transbaikalia in the Eastern-Siberian Region. In Pakistan, specimens come from the Nagir and Chumar Bakhooor area of the Hunga Valley in the Gilgit District, and the Baha and Apo Ali Gun areas near Baltistan, both in the Northern Areas.

African specimens are collected in Morocco at the El Hammam Mine at Meknès in the Meknès-Tafilalet Region; in Namibia at the Okoruso Mine in the Otjiwarongo District and the Kombat Mine in the Grootfontein District, both in the Otjozondjupa Region; in Zimbabwe in the Hwange lead-zinc district in Matabeleland North District; and in South Africa at the Aladdin Fluorite Mine at Sinkwazi in KwaZulu-Natal Province, and the Marico Fluorspar Mine in the Marico Mining District in Northwest Province.

European localities include 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 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. English localities include the Rogerley and Hollywell mines at Weardale

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in North Pennines, and the historic Blue John and Old Tor mines and the Treak Cliff Cavern at Castleton, Derbyshire, all in Durham County, Cornwall.

In South America, specimens are collected in Peru at the Huaron Mining District at Cerro del Pasco in Pasco Department, and the Pasto Buena Mining District in Ancash Department. Bolivian localities include the Mururata and Chojilla mines in Sud Yungas Province of La Paz Department. 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.

North America has numerous fluorite localities. 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 near Mun. de Zacatecas in 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 potash mines at Penobsquis, Kings County, New Brunswick. The leading fluorite locality in the United States is the Illinois-Kentucky Fluorspar District, which includes the mines of the Cave-in-Rock and Ozark-Mahoning subdistricts of Hardin County, Illinois, and those of the Babb, Commodore, Tabb, and Dike-Eaton subdistricts of Crittenden and Caldwell counties, Kentucky. Notable Colorado localities include the Sweet Home Mine at Alma in Park County; the Barstow Mine near Ouray in Ouray County; and the Browns Canyon Fluorspar District in Chaffee County. Among New Mexico's localities are the Fluorite Ridge district in Luna County, the Hansonburg district near Bingham in Socorro County, and the Pine Canyon Deposit near Tyrone in Grant County. Among other localities are the Capital and Ten-Acre quarries in Johnston County, Oklahoma; the Kelly Island Stone Quarry at Clay Center in Ottawa County, Ohio; and the William Wise Mine in Westmoreland, Cheshire County, New Hampshire. The Elmwood Mine at Carthage in Smith County, Tennessee, has yielded exceptional fluorite specimens.

JEWELRY & DECORATIVE USES

The Egyptians fashioned figurines from massive fluorite as early as 2000 B.C. The Romans later carved the blue-purple-yellow banded "blue john" (the name derives from the French *bleu et jaune* or "blue and yellow") fluorite mined in Cornwall, England. Archaeologists have recovered numerous blue john fluorite vases and urns from the ruins of Pompei, Italy. By 1500 A.D., the Chinese were carving figurines from massive, blue and green fluorite that resembled jade. Today, translucent, massive fluorite is carved into such ornamental objects as spheres, dishes, figurines, and vases. Cleaved, octahedral fluorite crystals have been used in jewelry since Biblical times, and faceted fluorite gems became popular in Europe in the 1600s when color varieties chosen to imitate more valuable gems were known as "false emerald," "false ruby," and "false amethyst."

Fluorite's outstanding gem attributes include good transparency, pleasing colors, a vitreous luster, and crystals that can be cut into large gems. Unfortunately, fluorite's low refractive index of 1.433 imparts little brilliance to these gems. It is also too soft for everyday wear, and its perfect, four-directional cleavage makes cutting difficult. Nevertheless, fluorite cabochons and faceted gems are occasionally mounted in pendants and brooches. Fluorite collector gems intended for display and study in weights ranging from only a few carats to more than 100 carats each are quite popular. The Smithsonian Institution in Washington, D.C. displays several spectacular fluorite gems, the largest weighing 492.1 carats.

From China comes a translucent form of massive fluorite with alternating bands of color in shades of green, purple, and occasionally blue, with colorless layers, too. Over the years, we have sold many hundreds of vases, bowls, cups, dishes, massage pieces, pendants, and carved shapes of this lovely

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material—and broken our fair share, too, due to fluorite’s four perfect cleavage planes and brittleness. Despite the breakage, we cannot resist the delicate beauty of the colors and patterns! Chinese geologists believe this fluorite formed directly from fluorine-rich vapor, the same way ice forms in a freezer.

Fluorite is an eminently collectible mineral because of its large crystal size and excellent crystal development, affordability, and range of colors. As both individual and composite specimens, fluorite is among the most widely collected of all minerals. In composite specimens with such minerals as galena [PbS], rhodochrosite [MnCO₃], and quartz [SiO₂], the presence of colorful, well-developed, cubic crystals of fluorite greatly enhances specimen value and visual appeal.

HISTORY & LORE

By 600 B.C., Greek metalworkers were employing 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. By 1500 A.D., European metallurgists had made fluorite, which they called *flusse* or *flusspat*, their 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* with the Latin word *fluere*, “to flow,” a word later anglicized to “fluor” and “fluorspar.” By 1670, German glassworkers had begun treating *flusspat* with sulfuric acid to produce another acid that they called *flusspatäure* (“acid of *flusspat*”). *Flusspatäure* could etch glass, which had previously been considered inert and impervious to all chemicals, imparting a new creativity to the art of glassmaking.

It became apparent that fluorite contained a very reactive, unknown element that had not yet been identified or isolated. French physicist André Marie Ampère (1775-1836) named this mysterious element *phlor* (Greek for “destructive”) in 1813. But English chemist Sir Humphry Davy (1778-1829) favored the word “fluorine” as a derivative of the traditional “fluorspar.” In 1826, researchers coined the words “fluoride” for fluorine-containing compounds and “hydrofluoric acid” (HF) for *flusspatäure*. When the mineral calcium fluoride received its current name—fluorite—in 1868, the term “fluorspar” was assigned specifically to fluorite ores. By then, the health hazards of fluorine had become obvious. Those who compromised their health or lost their lives by having inhaled or contacted various 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 the elements. His efforts to discover the nature of fluorine earned him the Nobel Prize for chemistry in 1906. Moissan’s premature death only a year later at age 55 was likely due to exposure to fluorine.

Fluorite is the state mineral of Illinois. It 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. In testimony to its beauty and appeal to collectors, fluorite has been featured on the cover of *The Mineralogical Record* eight times.

In the 16th century, physicians prescribed powdered fluorite to relieve the symptoms of kidney disease and placed fluorite crystals against joints to alleviate the pain of arthritis and rheumatism. Today, metaphysical practitioners believe that fluorite crystals calms the spirit and mind when preparing for meditation, increases objectivity and concentration, and clarifies the decision-making process. Healers assign special powers to individual fluorite colors: green energizes the heart and mind, blue provides inner peace, purple focuses the mind, and yellow facilitates group communication.

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THE FUTURE OF CHINESE MINERAL SPECIMENS

This month's botryoidal fluorite specimens are another example of the many fine mineral specimens that have come from China over the past 25 years. During this time, China has gained recognition as, arguably, the world's greatest current source of mineral specimens in terms of quality, quantity, and variety. The reason is the booming Chinese mining industry that depends on the output of hundreds of small metal mines. But growing numbers of mining analysts and mineral-specimen dealers, citing the sweeping changes now underway in the Chinese mining industry, contend that China's reign as the leading specimen source may soon be ending.

China first gained recognition as an important source of mineral specimens in the late 1970s, soon after its government had introduced plans to modernize the nation and accelerate its economic progress. A key element of that plan was the rapid development of domestic coal, metal, and non-metal mineral resources. To expedite production and minimize cost, the government ordered the immediate expansion of existing mines and the development of new mines on previously discovered mineral deposits. By the early 1980s, China's mineral production had increased sharply through the combined output of hundreds of small, obsolescent mines that worked many different mineral deposits.

Smaller mines generally produce more mineral specimens than large mines for two reasons. First, large mines tend to exploit low-grade, disseminated mineralization that rarely contains good mineral specimens. On the other hand, small mines usually work higher-grade, vein-type mineral deposits that frequently yield superb specimens. Second, smaller mines are much more amenable to the concept of specimen collecting than are large mines which are highly mechanized and operate on tight schedules. By its nature, mechanized mining, which employs large-scale blasting, ore-loading, and haulage methods, usually destroys most mineral specimens. (How we hate to report this all-too common practice!) Managers of large mines are obligated to maintain high production levels and understandably rarely allow specimen collecting to interfere with operations. But in small mines, especially the labor-intensive, outdated operations that have typified Chinese mining for the past 25 years, miners and mine managers are able to visually inspect every bit of ore and waste rock. Because they earn low wages, they consider mineral specimens a welcome opportunity for personal profit. Hence, they are more than willing to temporarily halt production in return for a chance to earn some supplemental income.

Another factor in China's recent ability to supply large quantities of fine mineral specimens is a network of enterprising dealers who are well aware of the value of fine specimens on international markets. These Chinese dealers, who operate from cities near mining districts, act as middlemen between the mines and foreign buyers, paying mine managers for specimens, then contacting foreign dealers who purchase and export the specimens. With this combination of hundreds of small mines and an efficient network of dealers, it is little wonder that Chinese specimens have dominated the international specimen markets for the past 25 years.

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Another factor in the proliferation of Chinese minerals is their prices. Our experience over the years with Chinese dealers has shown us they prefer to sell in large quantities with low markups. Such a philosophy allows dealers like us to obtain and resell Chinese specimens at lower prices than similar pieces from other countries, an arrangement that benefits everyone.

However, this attitude seems to have changed the last few years, as we have noted many Chinese dealers at mineral shows with sky-high prices on some of their better material. We also hear that dealers in China are asking high prices from overseas buyers who come to China, prices similar to what the same Chinese minerals sell for at shows here!

In addition, economic and operational factors are bringing a sweeping transition to China's mining industry. The Chinese government, which tightly controls all industries, both nationalized and privatized, has long realized that its system of hundreds of small mines is notoriously inefficient. Even as late as the 1990s, some Chinese mines still used mules to haul ore and hammers and hand steels to drill blast holes. No less inefficient was the practice of trucking ores from numerous, remote mines over rough roads to distant mills and smelters. The government now contends—and international mining analysts agree—that the future of China's mineral production rests not in numerous small mines, but in a far lesser number of large, modern, highly mechanized operations that exploit massive, low-grade ore deposits and process ores on-site.

The current international economic recession has provided China's government with a timely opportunity to modernize its mining industry. Citing the plummeting demand for metals, the government has already ordered the permanent closure of dozens of small metal mines and scheduled many more for closure over the next few years. The government is comfortable with this decision, because its long-range mineral-exploration program that began in the 1980s has paid off by delineating a number of large, low-grade mineral deposits that are suitable for mechanized, high-volume, open-pit mining. The closing of many of China's smaller mines is already impacting the supply of mineral specimens. As examples, the Chinese mines that provided our Mineral of the Month specimens of arsenopyrite and azurite for February 2008 and December 2008, respectively, have already closed. And the Chinese mine that provided our stibnite specimens for June 2009, will close within two years. In the future, China will certainly continue as one of the world's leading producers of metal and non-metal minerals. But its status as a source of fine mineral specimens promises to decline significantly.

Still, these factors will probably not affect the number of Chinese dealers commonly seen at large gem and jewelry shows at Tucson and elsewhere around the country, as the vast majority of beads and stone carvings sold at shows are now made in China. Numerous factories in China employ thousands of workers to meet the demands of the growing bead market.

TECHNOLOGICAL USES

Fluorspar, the ore of fluorite, is the primary source of fluorine. Some five million metric tons of fluorspar, worth \$225 per metric ton, is mined worldwide each year. China is the leading producer, followed by Mexico, Mongolia, South Africa, and Russia. Flawless, transparent fluorite crystals were once cut into

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apochromatic lenses free of chromatic and spherical aberrations for infrared and ultraviolet optical uses. Today, synthetic fluorite serves this purpose. Synthetic fluorite crystals doped with uranium and rare-earth elements are also used in certain lasers.

Fluorite's biggest uses are as a metallurgical flux and a feedstock for the manufacture of hydrofluoric acid. Fluorite is an effective flux because of fluorine's high chemical reactivity. In molten metal, fluorine readily combines with impurities to form volatile fluorides, which are driven off as vapors; fluorite's calcium component combines with silicates to form an easily removable slag. Large quantities of fluorite are converted to aluminum fluoride [AlF₃] and synthetic cryolite [sodium aluminum fluoride, Na₃AlF₆], compounds used in smelting aluminum. Fluorite is used to produce hydrofluoric acid, an important feedstock for the chemical and pharmaceutical industries. Hydrofluoric acid is also employed to convert uranium oxide to uranium hexafluoride (UF₆), an intermediate chemical step in the gas-diffusion concentration of the uranium-235 isotope needed for nuclear fuel rods and fission components for nuclear weapons.

Although fluorine is extremely poisonous and corrosive, fluorite specimens are stable and safe, and require no special handling or storage. However, never attempt to treat fluorite specimens with any type of acid to avoid the possibility of releasing hazardous fluorine gas.

ABOUT OUR SPECIMENS

Our fluorite specimens were collected at the Tongbai Mine in Tongbai County, Gaoxin District, Nanyang Prefecture, Henan Province, in the Peoples Republic of China. Located in east-central China, Henan is the nation's most populous province. Although roughly equal in area only to the state of Georgia, its population exceeds 100 million. The provincial capital, Zhengzhou, population eight million, has a rapidly growing, mixed economy based on agricultural processing, manufacturing, and service industries. Zhengzhou is 400 miles south of Beijing and 500 miles northwest of the port city of Shanghai. The Tongbai mine is located in Nanyang, Henan's southernmost prefecture, 140 miles southwest of Zhengzhou. Nanyang is an area of topographical transition between the Funiu Shan Mountains in the west and the East China Plain in the east.

The Tongbai fluorite deposit is hosted by a sandstone formation with a complex geological origin. Beginning some 200 million years ago, the regional crust was deformed by several orogenies or mountain-building episodes, most recently the Tertiary Himalayan Orogeny that took place about 40 million years ago. During this orogeny, tectonic stresses generated by the collision of the South China and North China cratons (stable sections of continental crust) uplifted sections of calcareous (calcite-rich) basement rock to form the Funiu Shan Mountains. Eventually water and wind erosion reduced these mountains, moving huge quantities of sand and silt to the East China Plain. The heat and pressure of deep burial lithified these sediments into formations of calcareous sandstone. Ongoing tectonic stresses then fractured these formations, enabling fluorine-rich, hydrothermal solutions associated with deep magmatic intrusions to penetrate the faulted sandstone. These solutions first dissolved calcite to form a maze of small cavities within the sandstone, then precipitated calcium and fluorine ions as fluorite that coated the cavity walls. Surface erosion later reduced the surface to expose the fluorite-rich sandstone.

Prospectors discovered the outcrops of purple fluorite overlying the Tongbai fluorite deposit in the 1950s. At that time, however, China's war-devastated steel-making industry had no need for fluorite as a smelting flux. But in 1980, when the nation's booming steel industry needed large quantities of fluorite, the Tongbai deposit was developed as an open-pit mine. The Tongbai fluorspar ore is a thick stratum of fluorite-impregnated sandstone that trends along a geological fault that had served as a conduit for the fluorine-rich hydrothermal solutions that emplaced the deposit. The half-mile-long ore body is cylindrically shaped,

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with the richest grades of fluor spar near the center. The mine is a mechanized operation that extracts, crushes, and concentrates fluor spar ore. Initially, the crushed ore was concentrated gravitationally by washing it with water to separate the fluorite (specific gravity 3.2) from the host sandstone (specific gravity about 2.7). But since 2000, the ore has been more efficiently concentrated by flotation separation. In this process, a crushed ore-water slurry is mixed with a foamy chemical reagent that selectively “floats” the fluorite particles away from the sandstone particles.

Tongbai fluorite is very unusual because of its botryoidal nature. Given sufficient room to develop, fluorite usually forms well-developed cubic crystals. But without room to grow, fluorite forms tightly interlocked microcrystals in massive or granular bodies. At Tongbai, fluorite precipitation occurred very slowly within restricted spaces. The fluorite could neither form cubic macrocrystals nor solidify quickly and “freeze” into massive or granular fluorite. Instead, the fluorite precipitated slowly in layers to create the unusual botryoidal crystal habit seen in our specimens.

When examining your specimen, note first the classic botryoidal form in which the surface consists of grape-like, spherical bulges. The term “botryoidal” actually derives from the Greek *botrys* meaning literally a “bunch of grapes.” Each spherical bulge consists of microcrystals that radiate outward from a central point. At the edge of the specimen, this radiating pattern is apparent in fracture surfaces. (Do not confuse fracture surfaces with the flat surfaces marked by parallel grooves; these surfaces have been cut during specimen preparation.) The fractured edges of the specimen may also reveal layers with subtle color variations that indicate changes in the chemical composition of the hydrothermal solution during crystal growth. Although our specimens are a soft lilac color, their original color when precipitated was probably white. The lilac color likely developed from the effects of natural geophysical radiation emitted by particles of uranium- or thorium-bearing minerals within the host sandstone. This radiation created color centers (see “Composition”), which caused the crystal lattice to reflect a lilac color. Our specimens are mildly fluorescent and glow pale whitish-blue under shortwave ultraviolet light. Finally, the yellow-brown, grainy material in parts of our specimens is the sandstone host rock. The grainy texture is typical of sandstone, and the yellow-brown stain is due to the presence of hydrous and anhydrous iron oxide minerals.

Tongbai botryoidal fluorite is now used as a decorative stone known as “Shu Fa,” utilized as large display pieces that are popular in the feng shui interior-decoration style, which adheres to the ancient Chinese feng shui system of aesthetics in which homes are arranged to harmonize with spiritual forces. The fluorite-coated sandstone from the Tongbai mine is laced with many small voids. When the fluorite-coated sandstone is cut into thin slabs, these voids closely resemble the brushstroke characters of Chinese calligraphy—with each “character” lined with lilac-colored, botryoidal fluorite.

We have now featured fluorite in different forms and colors in 1996, 2002, 2007, and 2010! We will probably feature it again, but odds are, it will not be from a mine in China!

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