

December 2013 Mineral of the Month

APOPHYLLITE-(KF)

Apophyllite-(KF) is a complex mineral with the unusual tendency to “leaf apart” when heated. It is a favorite among collectors because of its extraordinary transparency, bright luster, well-developed crystal habits, and occurrence in composite specimens with various zeolite minerals.

OVERVIEW

PHYSICAL PROPERTIES

Chemistry: $\text{KCa}_4\text{Si}_8\text{O}_{20}(\text{F},\text{OH})\cdot 8\text{H}_2\text{O}$ Basic Hydrated Potassium Calcium Fluorosilicate (Basic Potassium Calcium Silicate Fluoride Hydrate), often containing some sodium and trace amounts of iron and nickel.

Class: Silicates

Subclass: Phyllosilicates (Sheet Silicates)

Group: Apophyllite

Crystal System: Tetragonal

Crystal Habits: Usually well-formed, cube-like or tabular crystals with rectangular, longitudinally striated prisms, square cross sections, and steep, diamond-shaped, pyramidal termination faces; pseudo-cubic prisms usually have flat terminations with beveled, distinctly triangular corners; also granular, lamellar, and compact.

Color: Usually colorless or white; sometimes pale shades of green; occasionally pale shades of yellow, red, blue, or violet.

Luster: Vitreous to pearly on crystal faces, pearly on cleavage surfaces with occasional iridescence.

Transparency: Transparent to translucent

Streak: White

Cleavage: Perfect in one direction

Fracture: Uneven, brittle.

Hardness: 4.5-5.0

Specific Gravity: 2.3-2.4

Luminescence: Often fluoresces pale yellow-green.

Refractive Index: 1.535-1.537

Distinctive Features and Tests: Pseudo-cubic crystals with pearly luster on cleavage surfaces; longitudinal striations; and occurrence as a secondary mineral in association with various zeolite minerals. Laboratory analysis is necessary to differentiate apophyllite-(KF) from closely-related apophyllite-(KOH). Can be confused with such zeolite minerals as stilbite-Ca [hydrated calcium sodium potassium aluminum silicate, $\text{Ca}_{0.5}\text{K}_2\text{Na}_3(\text{Al}_9\text{Si}_{27}\text{O}_{72})\cdot 28\text{H}_2\text{O}$], which forms tabular, wheat-sheaf-like, monoclinic crystals.

Dana Classification Number: 72.3.1.1

NAME: The name “apophyllite,” pronounced ah-PAH-fih-lite, stems from the Greek *apo*, meaning “detached” or “off,” and *phylon* or “leaf,” literally meaning “to leaf apart,” in allusion

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to its tendency when heated to separate along cleavage planes into thin sheets. The “KF” suffix is pronounced phonetically as “kay-eff.” Apophyllite-(KF) is also known by its original names “apophyllite” and “fluorapophyllite,” both of which remain in common usage. Other names are “fluorine apophyllite” and “fish-eye stone.” In European mineralogical literature, apophyllite-(KF) appears as *fluorapophyllit*-(KF) and *fluorapophyllita*-(KF).

COMPOSITION: Apophyllite-(KF) consists of 4.87 percent potassium, 21.08 percent calcium, 29.50 percent silicon, 42.29 percent oxygen, 2.25 percent fluorine, and 0.01 percent hydrogen. It is a member of the silicates, the largest mineral group, in which oxygen and silicon are combined with one or more metals. The structural and chemical foundation of all silicate minerals is the silica tetrahedron (SiO_4)⁴⁻, in which four equally spaced oxygen atoms surround a silicon atom. Apophyllite-(KF) is a phyllosilicate or sheet silicate, specifically a two-layer sheet silicate consisting of alternating sheets of silica tetrahedra and metal cations. Weak ionic bonding between the sheets explains its perfect, one-directional cleavage. A diagnostic tendency to “leaf apart” when heated is due to the parting of the hydrogen bonds of its attached water molecules. Apophyllite-(KF) is an allochromatic (other-colored) mineral, meaning its colors are caused by traces of nonessential elements. It is colorless or white when pure or nearly pure, but trace impurities impart a range of pale colors. Most apophyllite-(KF) is colorless. Pale-green hues are caused by traces of iron or nickel that substitute for calcium in the crystal lattice. Iron also creates pale-yellow hues, while traces of manganese create pale shades of pink. Apophyllite-(KF) is among the most transparent of all minerals. As a secondary mineral, it forms primarily at low temperatures in vesicular cavities of basaltic rocks in association with quartz, calcite, prehnite, and various zeolite minerals. Apophyllite-(KF) also occurs to a lesser extent in cavities within metamorphic-contact zones where igneous rock has intruded limestone.

COLLECTING LOCALITIES: Apophyllite-(KF) is collected in the basalt quarries of several districts in Maharashtra, India. Other sources are located in Brazil, China, South Africa, Morocco, Namibia, Germany, Japan, Russia, Australia, Chile, Italy, Madagascar, Norway, Switzerland, Northern Ireland, Canada, and Mexico. In the United States, apophyllite-(KF) is collected in New Jersey, Virginia, Pennsylvania, Colorado, Arizona, New York, and Michigan.

HISTORY, LORE & USES: Apophyllite-(KF) was identified as a mineral species in 1806 and assigned the name “apophyllite” in 1810. Apophyllite was considered to be a single mineral until the 1970s, when spectrographic analyses revealed that specimens often contained varying amounts of fluorine and sodium. Apophyllite was subsequently renamed “fluorapophyllite” in 1978. Following nomenclatural revision by the International Mineralogical Association in 1997, fluorapophyllite was assigned its current name of “apophyllite-(KF).” Many mineralogists believe that further research will result in the recognition of additional members of the apophyllite group. Apophyllite-(KF) has no technological uses and only limited use in jewelry. Small quantities of apophyllite-(KF) are tumbled and drilled into beads for use in necklaces; crystals are occasionally wire-wrapped and worn as pendants, usually for metaphysical purposes. Metaphysical practitioners believe that apophyllite-(KF) helps reduce fears and feelings of apprehension; suppresses anxieties, worries, and uncertainties; and enables one to take control of emotions and situations. It is also thought to aid in astral travel by facilitating spiritual connections with the physical body.

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ABOUT OUR SPECIMENS: Our apophyllite-(KF) specimens were collected from basalt quarries near the city of Mumbai in the Mumbai District, Maharashtra state, Republic of India. Maharashtra is entirely within the Deccan Traps, a huge volcanic province that covers much of west-central India. The Deccan Traps were created by massive, prolonged volcanic eruptions that began some 68 million years ago. In the Deccan Traps, collectible minerals occur in cavities or vesicles within the basalt that formed from gas bubbles when the original magma solidified. These vesicles, which range from less than an inch to many feet in size, were initially devoid of secondary mineralization. Fissures and fractures later enabled alkaline, mineral-rich groundwater to circulate through the basalt to precipitate apophyllite-(KF) and other minerals. The Mumbai District quarries have provided many fine crystals of apophyllite-(KF), okenite, prehnite, calcite, quartz, gyrolite, and pseudomorphs of prehnite-after-laumonite. At the Mumbai quarries, commercial collectors contract with quarry managers for permission to collect specimens that are exposed by quarrying operations. Because of continuing population growth and development in the Mumbai area, many basalt quarries are being closed and will no longer be sources of mineral specimens.

COMPREHENSIVE WRITE-UP

COMPOSITION

Before discussing apophyllite-(KF), it is helpful to clarify the apophyllite nomenclature. “Apophyllite” and “fluorapophyllite” are no longer valid mineral-species names. As our write-up explains, the word “apophyllite” now correctly refers to a group of four closely related minerals.

Apophyllite-(KF)’s chemical formula $\text{KCa}_4\text{Si}_8\text{O}_{20}(\text{F},\text{OH})\cdot 8\text{H}_2\text{O}$ identifies its elemental components as potassium (K), calcium (Ca), silicon (Si), oxygen (O), fluorine (F), and hydrogen (H). Its molecular weight is made up of 4.87 percent potassium, 21.08 percent calcium, 29.50 percent silicon, 42.29 percent oxygen, 2.25 percent fluorine, and 0.01 percent hydrogen. Despite its lengthy formula, the chemistry of apophyllite-(KF), which is usually verbalized as “basic hydrous potassium calcium fluorosilicate,” is easy to understand by remembering that all molecules are composed of positively charged cations and negatively charged anions. The double cation of apophyllite-(KF) consists of one potassium ion and four calcium ions. Apophyllite-(KF)’s double anion is made up of a silicate radical (a group of atoms of different elements that are bound together and act as a chemical entity) and a fluorohydroxyl radical, which is indicated by the term “basic.” The apophyllite molecule also has attached molecules of water, as indicated by the term “hydrous.”

Molecular stability depends upon an electrical balance between cationic and anionic charges. Apophyllite-(KF)’s two cations include a single potassium ion K^{1+} and four calcium ions 4Ca^{2+} , which provide a collective +9 charge. On the anionic side of the formula, the silicate radical $(\text{Si}_8\text{O}_{20})^{8-}$ consists of eight silicon ions 8Si^{4+} and 20 oxygen ions 20O^{2-} that provide a collective -8 charge. An additional -1 charge is provided by a fluorine ion F^{1-} or a hydroxyl ion $(\text{OH})^{1-}$ in the substitution radical $(\text{F},\text{OH})^{1-}$ to provide a collective -9 anionic charge. The comma within this radical indicates continuous partial or complete substitution so that it always retains a -1 charge.

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Thus, the cationic +9 charge balances the anionic -9 charge to impart electrical stability to the apophyllite-(KF) molecule.

As indicated by its formula $\text{KCa}_4\text{Si}_8\text{O}_{20}(\text{F},\text{OH})\cdot 8\text{H}_2\text{O}$, the apophyllite-(KF) molecule has eight attached water molecules ($8\text{H}_2\text{O}$) that are known collectively as “water of hydration.” Water of hydration is bound to the parent molecule as integral water molecules that retain their characteristic composition and structure. Because these attached water molecules are electrically neutral, they function neither as cations nor anions, and thus have no effect on the electrical balance of the molecule. In water molecules, each oxygen ion O^{2-} is bound covalently by shared electrons to two hydrogen ions 2H^{1+} . The two small hydrogen ions group together on one side of the large oxygen ion atom. This creates a dipolar effect, with the two grouped hydrogen ions retaining a small positive charge and the opposite side of the molecule, dominated by the large oxygen ion, retaining a small negative charge. Water of hydration is attached to the parent molecule by hydrogen bonding (also called “polar bonding”), in which the water molecules’ faintly positive poles are attracted to negative charges.

Apophyllite-(KF) is a member of the silicates, the largest of all mineral groups, in which oxygen and silicon are combined with one or more metals. The structural and chemical foundation of all silicate minerals is the silica tetrahedron $(\text{SiO}_4)^{4-}$, in which four equally spaced oxygen atoms surround a silicon atom. Silicate minerals consist of silica anions bound to metal cations in repeating structural units that form seven general groups: independent tetrahedral silicates (nesosilicates); double tetrahedral silicates (sorosilicates); framework silicates (tectosilicates); single- and double-chain silicates (inosilicates); ring silicates (cyclosilicates); and sheet silicates (phyllosilicates).

The phyllosilicates, which include apophyllite-(KF), are also known as “sheet silicates,” a term that aptly describes their crystal structure. In phyllosilicates, each silica tetrahedron shares three oxygen ions with adjacent tetrahedra. This inter-molecular arrangement forms very thin, sheet-like structures that extend indefinitely in two directions. Within these flat sheets, the silica tetrahedra are arranged in three-, four-, five-, six-, or eight-membered rings. Apophyllite-(KF) has alternating four- and eight-membered rings. To visualize this arrangement, think of the silica layers as “chicken-wire” patterns with alternating octagonal and square holes. Both octagons and squares have four-fold symmetry, which is reflected in apophyllite-(KF)’s basic tetragonal or pseudo-cubic crystal form, and in the multiples of four in the $(\text{Si}_8\text{O}_{20})^{4-}$ silicate radical. The tetragonal system includes crystals with three mutually perpendicular axes, two of which are of equal length.

Sheet silicates are subclassified structurally into two-layer and three-layer groups. As a two-layer sheet silicate, apophyllite-(KF) consists of alternating sheets of silica tetrahedra and metal cations. Within the silica sheets, the charges of the three shared oxygen ions of the tetrahedra are neutralized, but the remaining, unshared oxygen ion on the tetrahedral apex still carries a -1 charge. Negatively charged fluorine (or hydroxyl) ions occupy the hexagonal holes between the apices of the sheet’s tetrahedra. Adjacent to the silica sheets are sheets of attached water molecules and positively charged potassium and calcium ions. Ionic bonding holds these alternating silica and metal-cation sheets together. The apophyllite-(KF) lattice thus has three

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distinct types of atomic bonds: covalent bonds within the silica tetrahedra; ionic bonds between the metal-cation sheets and silica sheets; and hydrogen bonds that attach the water of hydration.

Strong covalent bonding within the silica tetrahedra gives apophyllite-(KF) a moderate Mohs hardness of 4.5-5.0. Weak ionic bonding between the sheets explains its perfect, one-directional cleavage. One of apophyllite-(KF)'s diagnostic properties is its tendency to "leaf apart" when heated, a phenomenon caused by the parting of the hydrogen bonds of its attached water molecules. Hydrogen bonds are very heat-labile and are parted by even moderate heat. The resulting displacement of water molecules disrupts the spacing between the sheets in the apophyllite-(KF) crystal lattice, parting the weak ionic bonds and separating the sheets along the plane of perfect, one-directional cleavage. Higher levels of heat will break all the hydrogen bonds, dehydrating the crystal completely, disrupting all of its ionic bonding, and causing it to deteriorate into amorphous particles.

Apophyllite-(KF) is often erroneously assumed to be a zeolite mineral. Zeolites are hydrous aluminosilicates that are structurally classified as tectosilicates (framework silicates). Zeolites have the unusual ability to lose and regain water of hydration without altering their crystal structure. Although apophyllite-(KF) is a phyllosilicate, it does have certain zeolitic properties and can lose *some* of its water of hydration without altering its crystal structure. However, unlike zeolites, apophyllite-(KF) cannot *completely* regain its water of hydration. Further confusion arises from apophyllite-(KF)'s close mineralogical association with zeolite minerals in basaltic environments.

Apophyllite-(KF) is an allochromatic (other-colored) mineral, meaning that its colors are caused by traces of nonessential elements. When pure or nearly pure it is colorless or white, but trace impurities impart a range of pale colors. Most apophyllite-(KF) is colorless. Pale-green hues are caused by traces of iron or nickel that substitute for calcium in the crystal lattice. Iron can also create pale-yellow hues, while traces of manganese sometimes create pale shades of pink. Apophyllite-(KF) is one of the most transparent of all minerals. Transparency is a measure of a crystal's ability to transmit light. Apophyllite-(KF) crystals, when nearly pure and free of inclusions and stress fractures, have a remarkable, "water-clear" transparency.

The Dana classification number 72.3.1.1 first identifies apophyllite-(KF) as a phyllosilicate with a two-dimensional, infinite sheet structure that consists of other than six-membered rings (72). The subclassification (3) defines it as a phyllosilicate with sheets consisting only of four- and eight-membered rings. Finally, apophyllite-(KF) is a member of the apophyllite group (1) and the first (1) of four members. The apophyllite-group minerals, all chemically related, hydrous silicates with similar properties, include:

72.3.1.1 apophyllite-(KF) [basic hydrous potassium calcium fluorosilicate, $\text{KCa}_4\text{Si}_8\text{O}_{20}(\text{F},\text{OH})\cdot 8\text{H}_2\text{O}$], tetragonal, formerly "fluorapophyllite"

72.3.1.2 apophyllite-(KOH) [basic hydrous potassium calcium fluorosilicate, $\text{KCa}_4\text{Si}_8\text{O}_{20}(\text{OH},\text{F})\cdot 8\text{H}_2\text{O}$], tetragonal, formerly "hydroxyapophyllite"

72.3.1.3 apophyllite-(NaF) [hydrous sodium calcium fluorosilicate, $\text{NaCa}_4\text{Si}_8\text{O}_{20}\text{F}\cdot 8\text{H}_2\text{O}$], orthorhombic, formerly "natroapophyllite"

72.3.1.4 carletonite [basic hydrous potassium sodium calcium carbofluorosilicate,

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$\text{KNa}_4\text{Ca}_4\text{Si}_8\text{O}_{20}(\text{CO}_3)_4(\text{OH},\text{F})\cdot\text{H}_2\text{O}$], tetragonal

These formulas show the cationic and anionic substitution among the apophyllite-group minerals. Although uncommon itself, apophyllite-(KF) is the most abundant of the apophyllite-group minerals, followed by apophyllite-(KOH). Both apophyllite-(NaF) and carletonite are rare. As end members of a complete solid-solution series, apophyllite-(KF) and apophyllite-(KOH) are differentiated by the predominance of either fluorine or hydroxyl ions. Because precise chemistries can be determined only by laboratory analysis, all apophyllite-group minerals are often referred to simply as “apophyllite.” However, most specimens that are labeled “apophyllite” are apophyllite-(KF).

Apophyllite-(KF) is a secondary mineral that primarily forms at low temperatures in vesicular (gas-formed) cavities of basaltic rock. When magma is extruded, gas bubbles form when pressure is reduced. As the magma cools and solidifies, these gas bubbles create vugs or cavities. Over time, the circulation of mineral-rich groundwater through the basalt partially or completely fills these vugs and precipitates such minerals as quartz [silicon dioxide, SiO_2]; calcite [calcium carbonate, CaCO_3]; zeolite minerals (a group of hydrous aluminosilicates); prehnite [basic calcium aluminum silicate, $\text{Ca}_2\text{Al}_2\text{Si}_3\text{O}_{10}(\text{OH})_2$]; and the apophyllite-group minerals. Apophyllite-KF also occurs to a lesser extent in cavities within metamorphic contact zones where igneous rock has intruded limestone.

COLLECTING LOCALITIES

Our apophyllite-(KF) specimens were collected at quarries in the Deccan Traps basalt formations near the city of Mumbai, Mumbai District, Maharashtra state, Republic of India. Other Maharashtra collecting localities include basalt quarries at Wagholi and Pashan in Pune District, Nashik and Shakur in Nashik District, Chalisgaon and Dharangaon Taluka in Jalgaon District, Aurangabad and Bidkin in Aurangabad District, and Rahuri and Gunjalin in Ahmadnagar District.

In Brazil, apophyllite-(KF) is collected at the Bortolon Quarry at Poços de Caldas in Minas Gerais, and at Das Antas Tunnel at Veranópolis in Rio Grande do Sul. Chinese specimens come from the Fengjiashan copper mine, Daye County, Huangshi Prefecture, Hubei Province; and the Xiaomeiling wollastonite mine in Liyang County, Changzhou Prefecture, Jiangsu Province. African localities include the Clairwood quarries at Umhlatuzana near Durban, KwaZulu-Natal Province, South Africa; El Hamman near Meknés, Meknés Prefecture, Meknés-Tifilalet Region, Morocco; and the Ariskop Quarry at Aris, Windhoek District, Khomas Region, Namibia. German specimens come from the Schneeberg, Schwarzenberg, and Freiburg districts near Erzgebirge in Saxony; and the St. Andreasburg and Bad Harzburg districts at Harz in Lower Saxony.

Other localities include the Sampo Mine at Takahashi, Okayama Prefecture, Chugoko Region, Honshu Island, Japan; the Bor, Danbury, and 1st Sovetskii mines at Dal’negorsk, Primorskiy Kray, Far-Eastern Region, Russia; the Zeehan, Upper Mersey Valley, and Roseberry districts in Tasmania, Australia; La Cotita Mine at Inca de Oro, Copiapó Province, Atacama Region, Chile;

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the Molinello Mine at Spoleto, Perugia Province, Liguria, Italy; the Ambariomiambana basalt quarry, Sambava District, Sava Region, Antsiranana Province, Madagascar; the Sulitjelma mines at Sulitjelma, Fauske, Nordland, Norway; the Arvigo gneiss quarries in the Calanca Valley, Grischun, Switzerland; the Scottstown quarry at Ballymena, County Antrim, Northern Ireland, United Kingdom; the Poudrette and Desourdy quarries at Mont Sainte-Hilaire, Montérégie, Québec, Canada; and the San Martín Mine at Sombrerete, Zacatecas, Mexico.

In the United States, apophyllite-(KF) specimens are collected at basalt quarries in Passaic, Bergen, Hudson, Morris, and Essex counties in northern New Jersey. Other notable localities are the diabase quarries near Centreville in Fairfax County and near Conklin and Leesburg in Loudon County, both in Virginia; the Dyer and Robeson quarries at Birdsboro, Berks County, Pennsylvania; North and South Table Mountain at Golden, Jefferson County, Colorado; the Christmas Mine in the Banner District, Gila County, Arizona; the Gouverneur talc quarry at Harrisville, Diana Township, Lewis County, New York; and the Keweenaw Peninsula copper deposits in Keweenaw and Houghton counties, northern Michigan.

JEWELRY & DECORATIVE USES

Apophyllite-(KF) has limited use in jewelry because it is colorless or pale in color and has only moderate hardness (Mohs 4.5-5.0). It is also difficult to cut because of its perfect, one-directional cleavage and its sensitivity to the heat generated by cutting and soldering processes. Small quantities of apophyllite-(KF) are tumbled and drilled for use in necklaces. Crystals are occasionally wire-wrapped and worn as pendants, usually for metaphysical purposes.

Exceptional crystals are cut into collectors' gems as large as 20 carats. Although apophyllite-(KF)'s index of refraction (1.535-1.537) is only slightly higher than that of quartz, its water-clear transparency makes for very attractive gems. Apophyllite-(KF) is also known as "fish-eye stone," because of the soft, gray-blue, mother-of-pearl-like luster on its facets and natural cleavage surfaces.

Apophyllite-(KF) is popular among mineral collectors because of its excellent transparency and well-developed crystals. It is especially popular in composite specimens with such minerals as prehnite [basic calcium aluminum silicate, $\text{Ca}_2\text{Al}_2\text{Si}_3\text{O}_{10}(\text{OH})_2$] and various zeolite minerals such as stilbite-Ca [hydrous calcium potassium sodium aluminum silicate, $(\text{Ca}_{0.5}\text{KNa})_9(\text{Al}_9\text{Si}_{27}\text{O}_{72}) \cdot 28\text{H}_2\text{O}$] that provide attractive and interesting contrasts in color, crystal form, and degrees of transparency.

HISTORY & LORE

French mineralogist and crystallographer René-Just Haüy (1743-1822) identified apophyllite-(KF) as a new mineral species in 1806. The name "apophyllite" was assigned in 1810 after blowpipe tests revealed the mineral's tendency when heated to exfoliate, or "leaf off," in thin sheets. In 1931, researchers used newly developed X-ray-diffraction techniques to reveal its crystal structure. Apophyllite was thought to be a single mineral until the 1970s, when

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spectrographic analyses revealed that many specimens contained varying amounts of fluorine and sodium. Mineralogists Pete J. Dunn, Roland C. Rouse, and Julie A. Norberg of the Minerals Section of the National Museum of Natural History (Smithsonian Institution) in Washington, D.C., in noting close association with fluorine-free zeolite minerals, suggested that a fluorine-free variety would likely exist. After a search of mineralogical literature revealed many apophyllite analyses with low fluorine contents, they searched for a pure variety in which hydroxyl ions substituted completely for fluorine ions. Using scanning electron microscopy, this research team identified a fluorine-free variety and concluded that the fluorine- and hydroxyl-rich varieties are independent end members of a solid-solution series and therefore distinct mineral species.

Dunn, Rouse, and Norberg published their results in 1978 in the *American Mineralogist* in an article titled “Hydroxyapophyllite, a New Mineral, and a Redefinition of the Apophyllite Group.” That same year, the International Mineralogical Association’s Commission on New Minerals and Mineral Names approved hydroxyapophyllite and fluorapophyllite as new species. Many mineralogists opposed these names because mineral glossaries listed entries alphabetically, thus the more appropriate names should have been “apophyllite-OH” and “apophyllite-F,” respectively. Their concern was that a search in the literature for “apophyllite,” the name used since 1810, would be confusing to amateur mineralogists and even to some earth-science professionals. This confusion was increased in 1981, when mineralogists discovered another member of the apophyllite group, the rare mineral natroapophyllite [hydrous sodium calcium fluorosilicate, $\text{NaCa}_4\text{Si}_8\text{O}_{20}\text{F} \cdot 8\text{H}_2\text{O}$], in which sodium substitutes completely for potassium, and hydroxyl ions are absent (see “Composition”). This confusion in names was largely corrected in 1997, when the International Mineralogical Association assigned fluorapophyllite, hydroxyapophyllite, and natroapophyllite their current names of apophyllite-(KF), apophyllite-(KOH), and apophyllite-(NaF). Many mineralogists believe that continued research will result in the recognition of additional members of the apophyllite group.

A composite specimen of apophyllite-(KF) and stilbite-Ca appeared on the 100-franc postage stamp of the Republic of Mali in 1998. Metaphysical practitioners believe that apophyllite-(KF) and other apophyllite-group minerals help reduce fears and feelings of apprehension; suppress anxieties, worries, and uncertainties; and enable one to establish control over emotions and situations. These minerals are also thought to aid in astral travel by facilitating a spiritual connection with the physical body. Metaphysical healers believe that apophyllite-(KF) alleviates respiratory and allergenic ailments and helps to regenerate the skin and mucous membranes.

TECHNOLOGICAL USES

Apophyllite-(KF) has no technological uses.

CRYSTAL SYSTEMS

In the “Physical Properties” section of our write-ups, we explain that each Mineral of the Month is assigned to a specific crystal system. Apophyllite-(KF), this month’s featured mineral,

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crystallizes in the tetragonal system which, as explained in “Composition,” is characterized by three mutually perpendicular axes, two of which are of equal length. It is easy to visualize how this axial arrangement produces the rectangular shape, square cross sections, and pseudo-cubic appearance of many apophyllite-(KF) crystals.

Mineral crystals might seem to occur in an infinite range of shapes. But behind the great diversity of crystal form is a strict order that is governed by rigid mathematical laws. By studying crystal geometry, mineralogists and crystallographers can assign any crystal to one of six basic crystal systems. These are the isometric (cubic), tetragonal, hexagonal (and trigonal), orthorhombic, monoclinic, and triclinic systems.

Isometric (Cubic) System: This system includes crystals with three mutually perpendicular axes of equal length. Isometric crystals are usually blocky or ball-like in appearance and have many similar, symmetrical faces. Isometric minerals also tend to have simple chemistries. Common isometric habits include 4-faced tetrahedrons, 6-faced cubes, 8-faced octahedrons, 12-faced dodecahedrons, and 24-faced trapezohedrons. Familiar minerals that crystallize in the isometric system are pyrite [iron disulfide, FeS_2], halite [sodium chloride, NaCl], and galena [lead sulfide, PbS].

Tetragonal System: Tetragonal crystals are characterized by three mutually perpendicular axes, two of which are of equal length. Crystals are often long and slender, and sometimes even needle-like. Characteristic forms are four-sided prisms, pyramids, and dipyrramids, which differ from the somewhat similar forms of the hexagonal system by having four prismatic faces rather than six. Minerals that crystallize in the tetragonal system include zircon [zirconium silicate, ZrSiO_4], wulfenite [lead molybdate, PbMoO_4], and vesuvianite [basic calcium aluminum magnesium iron oxyfluorosilicate, $\text{Ca}_{19}(\text{Al,Mg,Fe})_{13}\text{Si}_{18}\text{O}_{68}(\text{O,OH,F})_{10}$].

Hexagonal System: Hexagonal crystals have four axes, three of equal length and lying in a plane with angles of 120 degrees between them. The fourth axis, called the unique or hexagonal axis, is perpendicular to the plane of the other three and may be of any length. Only crystals in the hexagonal system have four axes. Hexagonal crystals are often prismatic or columnar, with rounded triangular or hexagonal cross sections. Typical habits are three- or six-sided prisms, pyramids, and rhombohedrons. Minerals that crystallize in the hexagonal system include beryl [beryllium aluminum silicate, $\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$], quartz [silicon dioxide, SiO_2], and corundum [aluminum oxide, Al_2O_3]. The trigonal system, which is now considered a subsystem of the hexagonal system, has the same axial arrangements as the hexagonal system, but has three-fold rather than six-fold symmetry.

Orthorhombic System: This system includes crystals with three mutually perpendicular axes of different lengths. Crystals vary widely in form, but are often short and stubby, with diamond-shaped or rectangular cross sections. Many compounds that are chemically complex or that have complex atomic-bonding arrangements crystallize in the orthorhombic system. Typical forms are pyramids, four-sided prisms, and pinacoids (open forms with two parallel faces). Minerals that crystallize in the orthorhombic system include celestine [strontium sulfate, SrSO_4], barite [barium sulfate, BaSO_4], and topaz [basic aluminum fluorosilicate, $\text{AlSiO}_4(\text{F,OH})_2$].

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Monoclinic System: Monoclinic crystals have three axes of different lengths, two of which are perpendicular. The third axis is not perpendicular to the plane of the other two, but makes an angle with one so that the crystals appear to be orthorhombic, with one-directional deformation. Orthorhombic crystals are usually stubby, with tilted, matching faces at opposite ends that resemble distorted triangles. Typical forms are pinacoids and prisms oriented in the direction of one axis. Minerals that are chemically complex or that have complex atomic-bonding arrangements often crystallize in the monoclinic system. Monoclinic minerals include gypsum [hydrous calcium sulfate, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$], azurite [basic copper carbonate, $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$], and orthoclase [potassium aluminum silicate, KAlSi_3O_8].

Triclinic System: This system includes crystals with three axes of different lengths, none perpendicular to the others. Triclinic structures can be difficult to determine and describe, and low symmetry mostly limits crystal forms to pinacoids. Triclinic crystals are usually flattened, with sharp edges and thin cross sections. As with the monoclinic and orthorhombic systems, many minerals that are chemically complex or that have complex atomic-bonding arrangements crystallize in the triclinic system. Among the minerals that crystallize in the triclinic system are turquoise [basic hydrous copper aluminum phosphate, $\text{CuAl}_6(\text{PO}_4)_4(\text{OH})_8 \cdot 4\text{H}_2\text{O}$], rhodonite [calcium manganese silicate, $\text{CaMn}_4\text{Si}_5\text{O}_{15}$], and okenite [hydrous calcium silicate, $\text{Ca}_5\text{Si}_9\text{O}_{23} \cdot 9\text{H}_2\text{O}$].

Minerals that crystallize in any of these systems can have many different habits. The term “habit” generally refers to the arrangement and proportions of crystal faces, which often bear little resemblance to the “ideal” shape of each crystal system. But of the countless different crystal shapes that can be assumed by the nearly 4,800 recognized mineral species, all fit into one of the six basic crystal systems.

ABOUT OUR SPECIMENS

Our apophyllite-(KF) specimens were collected from basalt quarries near the city of Mumbai in the Mumbai District, Maharashtra state, Republic of India. Covering 118,000 square miles, Maharashtra is roughly half the size of the state of Texas. The city of Mumbai (formerly Bombay), located in west-central India on the coast of the Arabian Sea, is India’s leading commercial and cultural center. Mumbai has 14 million residents and an excellent deepwater port. The Mumbai quarries are about 25 miles north of the center of Mumbai near the suburb city of Khandivali. These quarries were first mined in the 1860s as a source of basalt for building stone used in the construction of many prominent buildings in Bombay.

Maharashtra is entirely within the Deccan Traps, a huge volcanic province that covers much of west-central India. The Deccan Traps were created by massive, prolonged massive volcanic eruptions that began some 68 million years ago, lasted 8 million years, and extruded an estimated 300,000 cubic miles of basaltic magma in repeated lava floods that formed superposed layers of basalt from 3 to 400 feet thick. Even after substantial erosion, the Deccan basalt now covers 200,000 square miles to a depth of 6,000 feet. As an extrusive igneous rock, basalt forms from the solidification of magma. Volcanic rocks usually cool quickly and have smooth or aphanitic textures with no visible crystals. Some Deccan basalts have a porphyritic texture and exhibit

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very small crystals scattered through a dense matrix. Basalt is a low-silica rock in which large amounts of iron and magnesium minerals impart a dark color. Hard, durable, and dense, basalt is widely used throughout west-central India as a building stone and cement additive, and as ballast-fill material for roads, building foundations, and rail beds.

In the Deccan Traps, collectible minerals occur in cavities or vesicles within the basalt that formed from gas bubbles in the original magma when it solidified. These vesicles, which range from less than an inch to many feet in size, were initially devoid of mineralization. But as alkaline, mineral-rich groundwater circulated through fissures and fractures in the basalt, it filled many vesicles and precipitated such minerals as apophyllite-(KF), quartz [silicon dioxide, SiO_2], calcite [calcium carbonate, CaCO_3], prehnite [basic calcium aluminum silicate, $\text{Ca}_2\text{Al}_2\text{Si}_3\text{O}_{10}(\text{OH})_2$], and various zeolite-group minerals. Vesicles filled with these secondary minerals are called “amygdules.”

Commercial specimen collecting in India’s basalt quarries began in the 1960s. Since then, the Mumbai quarries have yielded countless fine specimens of apophyllite-(KF), okenite [hydrous calcium silicate, $\text{Ca}_5\text{Si}_9\text{O}_{23} \cdot 9\text{H}_2\text{O}$], prehnite, quartz, gyrolite [basic hydrous sodium calcium aluminosilicate, $(\text{NaCa})_2\text{Ca}_{14}(\text{Si}_{23}\text{Al})\text{O}_{60}(\text{OH})_8 \cdot (14+x)\text{H}_2\text{O}$], calcite, the zeolite mineral laumontite [hydrous calcium aluminum silicate, $\text{Ca}_2(\text{Al}_8\text{Si}_{16}\text{O}_{25}) \cdot 25\text{H}_2\text{O}$], and pseudomorphs of prehnite-after-laumontite. Commercial collectors contract with Mumbai quarry managers for permission to collect specimens that are exposed by quarrying operations, then sell them to buyers in Mumbai for export to world markets. Apophyllite-(KF) is frequently and erroneously thought be a zeolite mineral, not only because of its similar appearance and occurrence, but also because many Indian exporters have traditionally mislabeled apophyllite-(KF) as a zeolite. Because of continuing population growth and development in Mumbai’s northern suburbs, many quarries are closing and will no longer be a source of mineral specimens.

Notice that your specimen consists of three sections. The dark material is altered basalt that formed a vug wall. Atop the basalt is a thin, white layer of the zeolite mineral stilbite-Ca [hydrous calcium potassium sodium aluminum silicate, $(\text{Ca}_{0.5}\text{K},\text{Na})_9(\text{Si}_9\text{Si}_{27}\text{O}_{72}) \cdot 28\text{H}_2\text{O}$]. In some specimens, this stilbite-Ca layer is massive; in others it is crystalline. Atop the stilbite-Ca layer are well-developed, sub-transparent-to-transparent crystals of apophyllite-(KF). The transparent sections are exceptionally clear, which is typical of the species. The apophyllite-(KF) crystal faces have a bright, vitreous luster. Visible exterior cleavage surfaces (usually seen at the edges of the specimen) exhibit a pearly luster and occasional flashes of iridescence. Interior cleavage-plane separations appear as bright, silvery, mirror-like surfaces within the crystals. The crystals themselves are colorless or white which, in allochromatic minerals, indicates a high chemical purity. The apophyllite-(KF) crystals exhibit prominent, longitudinal striations. Their nearly square or rectangular cross sections are characteristic of the pseudo-cubic habit. Many of these crystals have flat terminations with the sharply beveled corners that form triangles—a diagnostic feature of apophyllite-(KF). Your apophyllite-(KF) specimen is a fine example of one of the collectible, non-zeolite minerals to come from India’s Deccan Traps.

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