

September 2007 Mineral of the Month: Actinolite

This month's featured mineral has many interesting and unusual varieties: While our specimens have well-developed prismatic crystals, which is unusual for actinolite, a fibrous variety is a former ore of asbestos, and a microcrystalline variety is one of the two types of the gemstone jade. Read on!

PHYSICAL PROPERTIES

Chemistry: $\square\text{Ca}_2(\text{Mg},\text{Fe}^{2+})_5\text{Si}_8\text{O}_{22}(\text{OH})_2$ Basic Calcium Magnesium Iron Silicate (Calcium Magnesium Iron Silicate Hydroxide)

Class: Silicates

Subclass: Inosilicates (Double-Chain Silicates)

Group: Tremolite (Amphibole Group)

Crystal System: Monoclinic

Crystal Habits: Usually long prismatic with diamond-shaped cross section; also bladed, columnar, acicular, divergent, fibrous (asbestiform), and radiating. A compact, microcrystalline form is known as nephrite jade.

Color: Bright-to-dark green, grayish-green, and greenish-black.

Luster: Vitreous; silky and pearly on cleavage surfaces.

Transparency: Transparent to translucent

Streak: Colorless to white

Cleavage: Perfect in two directions lengthwise with intersecting cleavage planes.

Fracture: Splintery, uneven; fibrous forms are flexible.

Hardness: 5.0-6.0, nephrite variety is 6.5.

Specific Gravity: 3.0-3.5

Luminescence: None

Refractive Index: 1.63-1.66

Distinctive Features and Tests: Best field marks are the prismatic, often-radiating crystal habit and narrow cleavage-intersection angle. Can be confused with wollastonite, which is fluorescent; the tourmaline-group minerals, which lack cleavage; and epidote, which has a broader cleavage angle. Laboratory methods are necessary to differentiate actinolite from tremolite and ferro-actinolite, as explained in the box on Page 3.

Dana Classification Number: 66.1.3a.2

NAME

The name "actinolite," pronounced ack-TIH-no-lite, derives from the Greek *aktino*, meaning "ray," a reference to the common radiate habit of its prismatic crystals. In Europe, actinolite appears in mineralogical literature as "actinolit," "actinolota," and "actinolita." Alternative names include "actinote," "stibolit," "strahlstein," "strahlite," and "zillertite." Fibrous forms of actinolite are known as "amianthus," "asbestos," "asbestos amphibole," "asbestiform actinolite," "mountain leather," "mountain wood," and "mountain cork." Compact masses of interlocked actinolite microcrystals, once called "greenstone" or "byssolite," are properly known as "nephrite" or "nephrite jade." The name "nephrite" stems from the ancient belief that polished jade pebbles shaped like kidneys could cure kidney ailments. The Latin name for this "kidney stone," *lapis nephriticus*, eventually became anglicized to "nephrite." "Smaragdite" refers to a chromium-rich, emerald-green variety of nephrite.

COMPOSITION

In May 2002, we sent our 300 or so Club members attractive specimens of actinolite from locality at Wrightwood, San Bernardino County, California, east of Los Angeles, where the actinolite forms as

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radiating sprays and masses, typical of actinolite. We had featured Jade in July 2000, sending our roughly 220 Club members polished pieces from Jade Cove, Monterey County, California, and the write-up described both minerals that are called jade. The Jade Cove jade is of the nephrite variety, so technically it too is actinolite, so in a way, this month is the third time we have featured this important mineral.

The chemical formula $\square\text{Ca}_2(\text{Mg},\text{Fe}^{2+})_5\text{Si}_8\text{O}_{22}(\text{OH})_2$ indicates that actinolite contains six elements: calcium (Ca), magnesium (Mg), iron (Fe), silicon (Si), oxygen (O), and hydrogen (H). The “□” in the formula indicates a vacant crystallographic site. The molecular weight of actinolite is made up of 6.16 percent calcium, 8.33 percent magnesium, 12.76 percent iron, 25.66 percent silicon, 43.86 percent oxygen, and 0.23 percent hydrogen. In the actinolite formula, iron carries a +2 charge annotation because, like other transition elements, it has two or more oxidation or valence states. Iron can react chemically by giving up either two or three of its electrons to form the ferrous ion Fe^{2+} or the ferric ion Fe^{3+} .

The complex actinolite molecule has two cations (positively charged ions) and two anions (negatively charged ions). Its compound cation consists of two calcium ions (2Ca^{2+}) and five magnesium-iron substitution units $(\text{Mg},\text{Fe}^{2+})_5$. In substitution units, elements freely substitute for each other. In actinolite, the interchangeable ions are magnesium (Mg^{2+}) and iron (ferrous, Fe^{2+}). Thus, the actinolite cation, with the +4 charge of its two calcium ions and the +10 charge of its five magnesium-iron substitution units, has a collective +14 charge. Actinolite's compound anion contains two radicals (groups of atoms that act as an entity in chemical reactions). The silicate radical $(\text{Si}_8\text{O}_{22})^{12-}$ contains 8 silicon ions (8Si^{4+}) and 22 oxygen ions (22O^{2-}) and has a net -12 charge. The other anionic radical is the double hydroxyl ion $(2\text{OH})^{1-}$, each of which contain a single hydrogen ion $[\text{H}^{1+}]$ and two oxygen ions $[2\text{O}^{2-}]$ for a net -2 charge. This collective -14 anionic charge balances the +14 cationic charge to provide electrical stability within the molecule.

Actinolite is a member of the silicates, the largest and most abundant class of minerals. Silicates are combinations of silicon and oxygen with one or more metals. The fundamental silicate structural unit is the silica tetrahedron $(\text{SiO}_4)^{4-}$, in which a silicon ion is surrounded by four equally spaced oxygen ions positioned at the corners of a tetrahedron (a four-faced polyhedron). In all silicate minerals, silica anions and metal cations join together like polymers (repeating chains) to form seven types of structures: independent tetrahedral silicates (nesosilicates); framework silicates (tectosilicates); single- and double-chain silicates (inosilicates); ring silicates (cyclosilicates); sheet silicates (phyllosilicates); and double tetrahedral silicates (sorosilicates).

Actinolite is a double-chain inosilicate with a structure consisting of two single chains bound together covalently by shared oxygen ions among the silica tetrahedra. This covalent bonding creates a residual positive charge on the apices of the bonded tetrahedra and along their unshared edges. Each of the hexagonal holes between the two linked single chains is occupied by an ionically bound hydroxyl ion $(\text{OH})^{1-}$. This creates the basic silicate radical $[\text{Si}_4\text{O}_{11}(\text{OH})]^{7-}$, which must then be balanced by ionically bonding to positive metal ions. In actinolite, calcium, magnesium, and iron ions position themselves between two basic silicate radicals to create the complete actinolite molecular unit $\text{Ca}_2(\text{Mg},\text{Fe}^{2+})_5\text{Si}_8\text{O}_{22}(\text{OH})_2$. Because different metal ions can bond together in numerous combinations, many double-chain silicate minerals exist. In the rigid actinolite crystal lattice, covalent oxygen-oxygen bonding between tetrahedra in the linked chains predominates, but because the lattice is not particularly compact, the bonding is somewhat weakened. This explains actinolite's moderate hardness of Mohs 5.0-6.0 (low for most silicates), its splintery fracture, and its perfect, two-directional cleavage. Because the lattice is built of long double chains, actinolite tends to form long, slender prisms and thin, flexible fibers.

The inosilicates consist of two important groups of rock-forming minerals: amphiboles and pyroxenes. Amphiboles, which are all double-chain silicates with hydroxyl ions, include such minerals as actinolite, tremolite, glaucophane [basic sodium magnesium aluminum silicate, $\text{Na}_2(\text{Mg}_3\text{Al}_2)\text{Si}_8\text{O}_{22}(\text{OH})_2$], riebeckite

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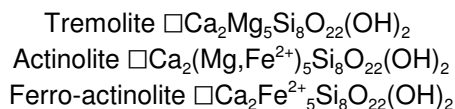
[basic sodium iron silicate, $\text{Na}_2(\text{Fe}^{2+3}\text{Fe}^{3+2})\text{Si}_8\text{O}_{22}(\text{OH})_2$], and the hornblende-group minerals [complex basic silicates of sodium, potassium, calcium, magnesium, iron, and aluminum]. The pyroxenes, which are all single-chain minerals, include wollastonite [calcium silicate, CaSiO_3], augite [calcium sodium magnesium iron aluminum titanium silicate, $(\text{Ca},\text{Na})(\text{Mg},\text{Fe}^{2+},\text{Al},\text{Ti})(\text{Si}_2,\text{Al})_2\text{O}$], jadeite [sodium aluminum iron silicate, $\text{Na}(\text{Al},\text{Fe}^{3+})\text{Si}_2\text{O}_6$], and spodumene [lithium aluminum silicate, $\text{LiAlSi}_2\text{O}_6$].

SOLID-SOLUTION SERIES

Minerals are often thought of in terms of fixed chemical composition, but their chemical formulas are usually "ideal," that is, they express approximations rather than exact compositions. The compositions of most minerals vary considerably within established limits. This variation is referred to as "solid solution," and actinolite is a textbook example of a solid-solution-series mineral.

Within a crystal lattice, elements occupy particular positions depending upon their electrical charge, the radii of their ions, and the type of atomic bonding involved. Many elements form ions (atoms that are electrically charged through the loss or gain of one or more electrons) that are sometimes very similar to those of other elements. This is the case with magnesium and iron, which both form ions with +2 charges and very similar ionic radii, and have the ability to bond covalently or ionically. Magnesium ions (Mg^{2+}) can easily replace ferrous ions (Fe^{2+}) in many iron minerals, and ferrous ions can replace magnesium ions in many magnesium minerals. Some magnesium is present in most iron minerals, and vice versa. Furthermore, their similar ionic radii enable iron and magnesium to replace each other without disrupting crystal-lattice structures.

Most solid-solution series consist only of two end members. But actinolite is part of a solid-solution series involving two other minerals—tremolite and ferro-actinolite. The nature of ionic substitution can be seen by comparing their chemical formulas:



In this unusual three-member solid-solution series, tremolite is the magnesium-rich end member, ferro-actinolite is the iron-rich end member, and actinolite is the intermediate-phase member. Predictably, iron-rich ferro-actinolite has the greatest density, while tremolite has the least density. Ferro-actinolite is blackish in color, actinolite is green, and tremolite is white to gray. All three minerals are considered isomorphous, meaning they have differing chemical compositions but identical crystal structures (monoclinic).

Ferro-actinolite forms when iron predominates in the crystallization environment, tremolite forms when magnesium predominates, and actinolite forms when magnesium and iron are both present in generally similar amounts. The intermediate phase is technically classified as actinolite when iron makes up 10 to 50 percent of the total magnesium-iron weight.

Actinolite occurs in small amounts as an accessory mineral in certain igneous rocks. However, it is found primarily in the contact and regional metamorphic zones of calcium-rich sedimentary rocks such as limestone and dolomite, and in the contact metamorphic zones of mafic (magnesium- and iron-rich) and

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ultramafic igneous rocks. Actinolite typically forms from low-grade metamorphism (low temperatures and moderate pressures). It is often associated in regional metamorphic rocks with albite [sodium aluminum silicate, $\text{NaAlSi}_3\text{O}_8$], epidote [basic calcium aluminum iron silicate, $\text{Ca}_2\text{Al}_2(\text{Fe}^{3+},\text{Al})\text{Si}_3\text{O}_{12}(\text{OH})$], and chlorite minerals [basic iron magnesium aluminum silicates], and in contact metamorphic rocks with albite and muscovite [basic potassium aluminum silicate, $\text{KAl}_2\text{AlSi}_3\text{O}_{10}(\text{OH})_2$]. Actinolite also forms through the alteration of pyroxenes; pseudomorphs of actinolite after hornblende minerals are known as “uralite.”

The Dana classification number 66.1.3a.2 identifies actinolite as a double-chain inosilicate (66). The subclassification (1) next defines it as a monoclinic amphibole that contains magnesium, iron, manganese, or lithium. Actinolite is then assigned to the calcic-amphiboles (calcium-containing amphiboles), also called the tremolite group, (3a), as the second (2) of 33 members.

As an idiochromatic or self-colored mineral, actinolite's basic green color is due to the presence of iron, one of its essential elemental components. Because the amount of iron varies considerably, actinolite's color ranges from green and grayish-green to greenish-black, with the darker colors indicating higher amounts of iron. Variations in the amount of iron present also account for actinolite's broad specific-gravity range (3.0 to 3.5).

COLLECTING LOCALITIES

Because it is so common in many metamorphic rocks, actinolite has numerous collecting localities. Our actinolite specimens were obtained from one of the inactive, open-pit iron mines in the northern Buena Vista Hills of the Mineral Basin Mining District of Pershing County, Nevada. Other important localities in the western United States include the Rainy Creek Mine, a former commercial actinolite source, at Libby, Lincoln County, Montana. Other notable sources include the iron mines at Iron and Granite mountains in Iron County, Utah; the numerous nephrite claims and mines near Sweetwater Station and Christine Lake in Fremont County, Wyoming; the Green Monster Mine on Prince of Wales Island in the Prince of Wales-Outer Ketchikan Borough in Alaska; and the serpentine deposits near Hopland in Mendocino County and the talc deposits near Pleasanton in Alameda County, both in California. Sources in the eastern United States include the asbestos quarries at Lisbon and Lebanon in Grafton County, and the Actinolite Quarry at Jeffrey in Cheshire County, all in New Hampshire; the Ashe Mine and Woods magnetite prospect near Jefferson in Ashe County, North Carolina; and the asbestos mines at Lowell and Eden Mills in Lamoille and Orleans counties, and the American Soapstone Quarry at Chester in Windsor County, all in Vermont.

In Canada, actinolite specimens are collected at the Merry Widow Mine at Port McNeill on Vancouver Island and at the Vital Creek and Kiwanika Creek districts in British Columbia. In Ontario, actinolite occurs at the Actinolite Mine at Actinolite in Hastings County. In Québec, fine specimens are found at the Jeffrey Mine at Asbestos in Richmond County, and at the Poudrette and Uni-Mix quarries at Mont Sainte-Hilaire in Rouville County.

In Europe, actinolite is found in France at the serpentine deposits at Vieille-Brioude and Paulhac in the Brioude-Massiac area, Haute-Loire, Auvergne; in Germany at the Bastwald and Amphibolite quarries at Haslach in the Black Forest region of Baden-Württemberg; in Sweden at the Ludvika iron mines in Dalarna; in Spain at the La Judía and Nueve Vizcaya mines at Burquillos del Cerro, Badajoz, Extremadura; and in Italy at the Poggio San Vittore asbestos mine near Balangero in Piemonte.

Fine Russian actinolite specimens come from the Pouyva and Dodo mines in the Polar Urals of Tyumenskaya Oblast' in the Western-Siberian region. In China, nephrite is collected in Liaoning Province (Manchuria) at the Xiuyan Jade Mine at Xiuyan in Anshan Prefecture and at the Nanfen and Waitoushan

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iron deposits at Benxi in Benxi Prefecture. Actinolite occurs in many mines of the Skardu district in the Shigar Valley at Baltistan in Pakistan's Northern Areas. In Africa, fine specimens come from the Kombat Mine at Kombat in the Grootfontein district in Namibia's Otjozondjupa Region. South American specimens are collected near Sete Lagoas, Itabira, and Conselheiro Lafaiete in Minas Gerais, Brazil. Australia's finest specimens are found at the Wallaroo Mine at Kadina and the Moonta Mine at Moonta on the Yorke Peninsula in South Australia. Nice specimens also occur at the San Antonio Mine at Aquiles Serdán in Chihuahua, Mexico.

JEWELRY & DECORATIVE USES

Nephrite, the massive, microcrystalline form of actinolite that is one of the two types of jade, is widely used in jewelry and decorative objects. Jade is a general term for two silicate minerals, jadeite and nephrite:

Jadeite [sodium aluminum iron silicate, $\text{Na}(\text{Al}, \text{Fe}^{3+})\text{Si}_2\text{O}_6$], a pyroxene mineral, is granular in structure and very hard (Mohs 6.5-7.0). Pure jadeite is white, while iron-bearing varieties are green; other chromophoric (color-causing) elements create pink, yellow, and lavender hues. Jadeite forms when sections of the continental crust are drawn downward into tectonic subduction zones and metamorphosed by high levels of heat and pressure. Some jadeite-bearing rock then returns to the surface in major faulting events. The finest quality, most valuable jadeite jade comes from Myanmar, formerly Burma. Recently, Guatemala has become a notable source for this prized gemstone.

Nephrite, the more abundant and less expensive form of jade, is usually a mixture of the amphibole minerals actinolite and tremolite. Nephrite colors include white, gray, greenish-gray ("mutton-fat" jade), light-to-dark green, and brown, sometimes in mottled patterns. At Mohs 6.5, nephrite is a bit softer than jadeite, but tougher because of its unusual structure of interlocked microcrystals. Unlike the usual macro or fibrous crystal habits of actinolite, nephrite is created by a two-part sequence of chemical and mechanical action. In the chemical phase, actinolite (and tremolite) form mainly by metamorphic processes and the alteration of pyroxene minerals. The formation of the nephrite variety begins when rocks rich in disseminated actinolite and tremolite crystals are subjected to high-stress shearing in tectonic fault movements. This mechanical action breaks down the host rock to permit the reconstitution of the actinolite crystals. Heat and pressure then partially melt the actinolite which, upon cooling, recrystallizes as nephrite in small, lens-shaped bodies of tightly interlocked microcrystals.

Nephrite has served as a gemstone and decorative stone for more than 3,000 years. Occurring in many parts of the world, nephrite has been fashioned into ornaments, jewelry, and very durable tools and weapons. Today, nephrite is in great demand for the manufacture of beads for necklaces, bracelets, and earrings; cabochons for pendants and brooches; rings; spheres; and a wide array of elaborately carved decorative objects. Most nephrite used in jewelry today comes from British Columbia, Canada. Other nephrite-producing areas include China, Taiwan, Myanmar, Russia, New Zealand, Poland, and in the United States, Wyoming, Alaska, and California.

Transparent actinolite crystals in pleasing shades of green are occasionally faceted into collectors' gems as large as five carats, although very few have been cut to more than two carats. Actinolite is difficult to facet, tending to fray on the sharp edges. Great care must be taken not to cut and polish parallel with the cleavage planes. Tanzania yields small quantities of transparent, facet-grade actinolite that is cut into gems similar in color to that of dark peridot. Tremolite is also occasionally cut into gems, as is smaragdite, the chromium-rich, emerald-green variety of nephrite. Actinolite gems have a refractive index of 1.61, approaching that of beryl, but their Mohs hardness of 5.5-6 is too soft to stand up to use in rings. Due to its fibrous nature, actinolite cut into cabochons often shows the catseye effect, with a single reflected ray of

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light moving across stone as it is turned. Such chatoyant actinolite comes from Alaska, Russia, and Taiwan. Mineral collectors value actinolite specimens, in crystalline, fibrous, and nephritic forms, for study and display purposes.

HISTORY & LORE

Actinolite has been known since antiquity when it was confused with many other minerals. It is one of the asbestos minerals (see “Technological Uses”) that occur in fibrous crystal habits and separate easily into long, flexible fibers. The early Greeks wove asbestos fibers, including those of actinolite, into wicks for the “eternal” flames of the lamps of the Acropolis. (“Asbestos” derives from the Greek word for “inextinguishable.”) Medieval alchemists called various forms of asbestos “salamandra,” in the belief that they were the remains of the skin of salamanders that were immune to the effects of fire.

French mineralogist René Just Haüy (1743-1822), known as the “Father of Mineralogy,” noted the chemical and crystallographic similarities of actinolite and tremolite and assigned their names in the late 1790s. In 1820, Haüy classified actinolite, tremolite, and several hornblende-group minerals (complex basic silicates of sodium, potassium, calcium, magnesium, iron, and aluminum) into a group that he named the “amphiboles,” after the Greek *amphibolos*, meaning “ambiguous,” in reference to their confusing similarities. Today, this name refers to the entire group of double-chain silicates.

As the asbestos industry grew rapidly in the early 1900s, mineralogists closely studied the asbestos minerals and learned that actinolite, tremolite, and ferro-actinolite were members of the same solid-solution series (see “Solid-Solution Series”). But they did not agree on how to set the compositional limits for the three species. Because most solid-solution series have only two members, the compositional dividing point for solid-solution species was traditionally set at 50 percent by weight of the substituting elements. In the three-member tremolite/actinolite/ferro-actinolite series, the logical dividing point was 33.3 and 66.6 percent of the iron-magnesium weight. But metamorphic petrologists objected to this proposal because tremolite had long been used to identify and define metamorphic zones, and much petrological literature contained numerous mention of *green* actinolite and *white* or *gray* tremolite. Petrologists insisted that in any new compositional definition, tremolite retain its white or gray colors. The issue was finally settled until 1997, when the International Mineralogical Association, the organization that governs the naming of mineral species, formally established the compositional limits of the tremolite/actinolite/ferro-actinolite series. Tremolite now officially has 10 percent or less iron in its total iron-magnesium weight, actinolite has 10-to-50-percent iron, and ferro-actinolite has 50 percent or more iron. Accordingly, tremolite, in keeping with tradition, is always white or gray, and actinolite is always some shade of green.

In medieval times, physicians administered elixirs of finely ground actinolite to aid in physical, emotional, and spiritual healing, and to ward off unwanted thoughts. Modern metaphysicists believe that green actinolite provides similar benefits to those of green jade, bringing bodily functions and emotions into harmony and balance.

Nephrite is the official state gemstone of Wyoming and the inspiration for the Big Sur Jade Festival, which takes place annually on the Columbus-day weekend at Pacific Valley School in Big Sur. In 1982, nephrite was featured on the 30-franc postage stamp of New Caledonia and the 1-cent stamp of New Zealand.

TECHNOLOGICAL USES

Actinolite is a minor ore of asbestos, a generic term that refers to six types of naturally occurring mineral fibers with many industrial uses. These fibers belong to two mineral groups: serpentines and amphiboles.

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The serpentine group has only a single asbestiform mineral—clinocrysotile [basic magnesium silicate, $\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4$]. The five asbestiform amphibole minerals are actinolite, tremolite, anthrophyllite [basic magnesium silicate, $\text{Mg}_7\text{Si}_8\text{O}_{22}(\text{OH})_2$], grunerite [basic iron silicate, $\text{Fe}^{2+7}\text{Si}_8\text{O}_{22}(\text{OH})_2$], and riebeckite [basic sodium iron silicate, $\text{Na}_2(\text{Fe}^{2+3}\text{Fe}^{3+2})\text{Si}_8\text{O}_{22}(\text{OH})_2$]. All asbestos minerals occur in bundles of fibers that separate easily from their host matrix and cleave into thinner fibers that are flexible enough to be spun.

Asbestos minerals are incombustible and chemically unreactive. They also have poor electrical conductivity and great thermal stability, making them ideal for use in building insulation, tar paper, food-processing filters, medical sutures, asbestos-cement pipes, brake linings, and flame-retardant panels and garments. During the 20th century, the U.S. mined some 3.3 million tons of asbestos. Most came from clinocrysotile, but about five percent, or 165,000 metric tons, consisted of actinolite and tremolite.

The adverse health effects of asbestos mining, manufacturing, and installation were first noted around the turn of the nineteenth century. As often seems to happen, in the lust for a profitable bottom line, the health hazards were often ignored or worse yet, covered up. For decades, workers in asbestos mines, mills, and manufacturing plants who inhaled the tiny, airborne asbestos fibers had been known to contract asbestosis, the scarring of lung tissues which decreases normal oxygen transfer and can lead to lung infection and lung cancer. As early as 1930, for example, the Johns-Manville Company, which had been promoting asbestos as fire-resistant roofing material since the 1850's, produced an internal report on asbestos worker fatalities. An insurance company study in 1933 reported that 29% of workers in a Johns-Manville factory had asbestosis. Cheryl's Grandfather William Wavrenchuck, a Russian immigrant to America, was one of the victims. According to one source, asbestos litigation is the longest, most expensive mass tort in U.S. history, involving more than 6,000 defendants and 600,000 claimants!

In the late 1960s, after medical researchers had finally proved that inhalation of even low levels of asbestos fibers posed serious health hazards, asbestos mining and manufacturing industries began to decline. Today, most developed nations use only clinocrysotile asbestos, the least harmful type, and then only in approved applications. Worldwide mine production of asbestos is now just 2.4 million tons per year, with only about one percent coming from actinolite. All the negative publicity has made some people afraid of anything remotely connected to the word "Asbestos," yet the only health danger from it comes from inhalation of tiny, airborne fibers. Since our specimens consist of crystalline rather than fibrous actinolite, they pose no health hazard—although care in handling your specimen is called for, as some have crystals that splinter easily and could get lodged in your fingers.

ABOUT OUR SPECIMENS

As previously noted, our actinolite specimens were collected at the Metals Materials Mine, one of many inactive, open-pit iron mines in the northern Buena Vista Hills of the Mineral Basin Mining District of Pershing County. This area is located in west-central Nevada about 80 miles northwest of Reno. The Mineral Basin Mining District, which has a typical basin-and-range topography, straddles the border of Pershing and Churchill counties about 20 miles southeast of the Interstate-80 town of Lovelock. Within this district, elevations range from 3,500 feet on the valley floors to about 5,000 feet at the higher summits of the Buena Vista Hills, which are a western extension of the Stillwater Range. The climate is arid, with long, hot summers and cool, moist winters; the valleys are covered with sagebrush, while the higher elevations have thin growths of cedar, piñon, and some pine.

Prospectors discovered magnetite [$\text{Fe}^{2+}\text{Fe}^{3+}_2\text{O}_4$] deposits in the Mineral Basin Mining District in the 1880s, but mining was impractical because of the district's remoteness and isolation. In 1898, Lovelock businessman, mining engineer, prospector, and amateur archaeologist John T. Reid "rediscovered" the

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magnetite deposits and staked claims. Again, the need to ship the ore over long distances made mining uneconomical. But Reid's claims suddenly became valuable when World War I sent the demand for steel soaring. Mining companies quickly developed several shallow, open-pit magnetite mines in the northern Buena Vista Hills, hauling the ore 20 miles in mule-drawn wagons to the railroad at Lovelock for shipment to Utah steel mills. Production ended abruptly when steel demand plummeted with the Armistice of November 1918.

The iron ore in the Mineral Basin Mining District consists primarily of magnetite with lesser amounts of other iron minerals, notably hematite [Fe₂O₃]. Gangue minerals include actinolite, tremolite, calcite [CaCO₃], chlorapatite [Ca₅(PO₄)₃Cl], and titanite [CaTiSiO₅]. The iron deposits are metamorphic in origin and hosted in formations of andesite, an intermediate-silica volcanic rock, and diorite, an intermediate-silica intrusive rock of Jurassic age. Some 60 million years ago, Nevada's basin-and-range topography formed when tectonic stresses generated by the collision of the North American and Pacific plates caused extensive faulting and folding. The crustal fracturing enabled magma to intrude upward into the country rock. In the Mineral Basin Mining District, mineralization was created by contact metamorphism, not by direct magmatic intrusion, but rather by the movement of associated hydrothermal fluids through fractures and fissures in the host rock. These superheated, mineral-rich hydrothermal fluids caused a metasomatic metamorphic event by introducing elements not present in the original host rock. The result was complex vein systems of fine-grained magnetite with lesser amounts of hematite and gangue minerals. Subsequent erosion eventually reduced the surface to expose the magnetite in shallow deposits.

In 1942, when World War II generated an emergency need for iron, mining companies returned to the Mineral Basin Mining District to operate four open-pit mines for the duration of the war. The mines reopened again in 1951 in response to a critical shortage of steel in Japan, which was then rebuilding its war-devastated economy. The magnetite ore was trucked to Lovelock for rail shipment to ports in San Francisco Bay, where it was loaded as ballast on Japan-bound freighters and tankers. By 1955, iron mining in the Mineral Basin Mining District was booming with eight open pits shipping ore. The largest operations were the Buena Vista, Thomas, and Sergerstrom-Heizer mines. Business was so brisk that the Union Pacific Railroad planned to construct a rail spur to link Lovelock with the iron mines and to expand loading facilities at the California ports.

By the early 1960s, the Mineral Basin Mining District had produced more than four million tons of magnetite ore, most of which had been shipped to Japan. But by then, Japan had found cheaper sources of iron ore in Australia. In 1964, when the cost of shipping magnetite ore from the Mineral Basin Mining District became prohibitive, the mines closed and have been inactive ever since. However, they are still visited by mineral collectors who continue to make new finds, such as ours. Actinolite usually forms as masses of interlocking crystals, rather than the freestanding, prismatic crystals we sent this month, which makes ours unique. The white calcite matrix serves as a nice background—it could be etched with mild acid if you wanted to further expose the actinolite crystals, but be careful! And watch for splinters if you can't resist handling your fascinating specimen!

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