April 2009 Mineral of the Month: Uralite

This month's mineral, collected at a Colorado iron mine, is unusual because it is not an individual mineral species, but a mix of amphibole group minerals that are pseudomorphs after pyroxene group minerals. Our write-up explains how pseudomorphs form and the importance of amphiboles as rock-forming minerals. The information under "Physical Properties" applies to the Amphibole group in general.

OVERVIEW

PHYSICAL PROPERTIES (Amphibole Group)

Chemistry: General formula $(XY)_2Z_5(Si,Al,Ti)Si_8O_{22}(OH)_2$ A group of complex basic silicates in which "X," "Y," and "Z" can represent sodium, potassium, calcium, iron, lithium, manganese, aluminum, magnesium, zinc, nickel, cobalt and chromium.
Class: Silicates
Subclass: Inosilicates (double-chain silicates)
Group: Amphiboles
Crystal System: Most amphiboles are monoclinic; a few are orthorhombic.
Crystal Habits: Usually as long, bladed, prismatic crystals with diamond-shaped cross sections; also in fibrous, radiating, massive, and granular forms.
Color: Green, dark-green, grayish-green, greenish-black, black, grayish-white, gray, blue, and brown
Luster: Vitreous to dull, silky in fibrous forms, sometimes submetallic
Transparency: Usually opaque to translucent, occasionally transparent
Streak: Usually colorless or white, sometimes gray or brown
Cleavage: Good to perfect in two directions
Fracture: Uneven and splintery to conchoidal
Hardness: 5.0-6.0
Specific Gravity: 2.8-3.5
Luminescence: None
Refractive Index: 1.619-1.644
Distinctive Features and Tests: The best field-identification marks of the amphiboles are grayish-green to dark-green colors, predominant occurrence in metamorphic environments, and cleavage plane angles of 56 degrees and 124 degrees. Laboratory methods are usually needed to distinguish individual species.
Dana Classification Numbers: 66.1.1-3c .1

NAME The name "uralite" (no longer an approved mineral name) is pronounced YOU-rahl-ite and derives from the Ural Mountains of Russia, where the first described specimens were collected. The name "amphibole," pronounced AM-fah-bowl, stems from the Greek *amphibolos*, meaning "ambiguous." Rock consisting primarily of amphibole minerals is called "amphibolite." The amphibole minerals are sometimes still referred to by the traditional term "hornblende."

COMPOSITION: Uralite is a pseudomorphic variety of the amphibole group and consists of a mix of amphibole minerals. The amphiboles are one of the "rock-forming" minerals and, as the name implies, they occur as essential or accessory minerals in a wide range of igneous and metamorphic rocks. Amphiboles form in both intrusive and extrusive igneous environments directly from the crystallization of certain components of magma in the presence of water. Amphiboles also form in metamorphic environments, most often as alteration products of the pyroxene-group minerals.

Amphiboles are double-chain inosilicates with the general formula $(XY)_2Z_5(Si,Al,Ti)_8O_{22}(OH)_2$, in which "X" can be vacant or occupied by sodium (Na) or potassium (K); "Y" can represent sodium, calcium (Ca),

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ferrous iron (Fe^{2+}), lithium (Li), manganese (Mn^{2+}), aluminum (Al), magnesium (Mg), zinc (Zn), nickel (Ni), or cobalt (Co); and "Z" can represent ferric iron (Fe^{3+}), manganese (Mn^{3+}), aluminum, chromium (Cr), titanium (Ti), and lithium. Because the number of possible combinations of elements is quite large, 120 amphibole minerals are now accepted as valid mineral species.

COLLECTING LOCALITIES: The most notable uralite localities are found in areas of heavily metamorphosed rock. In the United States, prime collecting sites are located in Chaffee County, Colorado; Prince of Wales Island, Alaska; St. Lawrence County, New York; and Avery County, North Carolina. Uralite also occurs in Guatemala in Verapaz Department, and in Canada in Ontario's Sudbury mining district. Other notable sources are in Russia at Mostovoya and Kaminskaya in the Urals Region; in Spain at the Monchi Mine at Burquillos del Cerro, Badajoz, Extremadura; in Norway at the Skjaerpemyr Mine at Grau near Lunnar in Oppland; in Italy at Caesana Torinese in the Susa Valley in Torino Province, Piemonte; and in Slovakia at Poprad in the High Tatra Mountains in the Prešov Region.

HISTORY, LORE, & USES: In the 1600s, German miners referred to shiny minerals that contained no valuable metals as "*Hornblende,*" a name thought to have stemmed from the color of horn and *blenden*, the latter meaning "to dazzle." In 1801, when the number of "hornblende" minerals had grown to about a dozen, French mineralogist and crystallographer René Just Haüy (1743-1822) renamed the group "amphibole" from the Greek *amphibolos*, meaning "ambiguous," a reference to the similar appearance but different chemical compositions of the minerals. German mineralogist Gustav Rose (1798-1873) first described the uralite variety in 1822 from specimens collected in Russia.

The nephrite form of jade, a mixture of the amphibole minerals actinolite and tremolite, has served as a gemstone since antiquity. We featured nephrite jade from Jade Cove in Big Sur, Monterey County, California, in July 2000. Collecting is allowed there, but it is a treacherous path down to the beach. The best time to collect is after a large storm passes through, when the churning waves might toss a few pieces onto the beach. Most jade from this site, which was featured on the Travel Channel's "Cash & Treasures," is recovered by scuba divers from the ocean floor.

Five other amphibole-group members are a source of asbestos, a collective term for mineral fibers with many industrial uses.

ABOUT OUR SPECIMENS: Our uralite specimens were collected at the Calumet iron mine in the Turret Mining District near Salida in Chaffee County in central Colorado. This mine opened in 1882 to exploit a deposit of high-grade magnetite [iron oxide, $Fe^{2+}Fe_{3+}O_4$] ore and ranked as Colorado's largest source of iron ore for nearly 20 years. The Calumet deposit formed when a concentration of magnetite within a magmatic intrusion was subjected to contact metamorphism. Today, the Calumet mine is a popular collecting site for uralite and such minerals as corundum [sapphire, aluminum oxide, Al_2O_3] and epidote [basic calcium aluminum iron silicate, $Ca_2Al_2(Fe,Al)Si_3O_{12}(OH)$].

10 YEARS AGO IN OUR CLUB: Chrysocolla, Asarco Mine, Casa Grande, Pinal County, Arizona. This mine has also been known as the Sacaton mine, the Casa Grande mine, the Ray mine, and the Ray pit. The chrysocolla was of a bright blue color, due to its copper content. Ten years ago, the mining company was working through a zone of oxidized copper minerals, and they were smart enough to recover and sell the material, resulting in large quantities of lovely chrysocolla saturating the market. The mine is still in operation, but because a copper sulfide zone is now being exploited, no more chrysocolla is coming out. In April 1999, we were looking for a new place to live in Cambria. We had been renting a lovely home here since 1995, (only $850 month for a 3-bedroom home with a distant ocean view), but the owners were relocating from Orange County (the OC) to Cambria. We moved a few months later into our current home.

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COMPREHENSIVE WRITE-UP

COMPOSITION

If our parents had started the Mineral of the Month back in the 1970's, they could have featured uralite as an approved mineral, as could their parents, their parents, and so on, going way back into the 1800's. Perhaps the Filers, who ran the first version of the Mineral of the Month Club in the 1970's, did feature it. They probably did feature hornblende when it was still an officially approved mineral–now all we have are the amphibole group members ferrohornblende and magnesiohornblende. We probably won't ever feature either of them, nor are we likely to feature other amphibole group members like sodic-ferri-clinoferroholmquisite or protomangano-ferro-anthophyllite–the names wouldn't fit on our mineral labels!

All kidding aside, we welcome this opportunity to feature uralite, as we get to discuss in the write-up the amphibole and pyroxene mineral groups. We have only featured one amphibole–actinolite in May 2002 and in September 2007–and have never featured a pyroxene group mineral, though we love the pyroxenes jadeite, diopside, and spodumene. We have never had enough pieces at one time of any of these. This will change this year, though, as we plan on featuring aegerine later in the year.

Uralite is now known to be a pseudomorphic variety of the amphibole group that is composed of a mix of amphibole minerals. The amphiboles are one of the "rock-forming" minerals, a term referring to minerals that are essential components of many rocks (see "The Rock-Forming Minerals"). The amphiboles are members of the silicates, the largest mineral class, in which silicon and oxygen are combined with one or more metals. The basic silicate structural unit is the silica tetrahedron $(SiO_4)^{4-}$, in which a silicon ion is surrounded by four equally spaced oxygen ions positioned at the four corners of a tetrahedron (a four-faced polyhedron). In the silicates, silica anions and metal cations join together in repeating chains to form seven types of structures: independent tetrahedral silicates (nesosilicates); double tetrahedral silicates (sorosilicates); ring silicates (cyclosilicates); sheet silicates (phyllosilicates); framework silicates (tectosilicates); and both single- and double-chain silicates (inosilicates).

As double-chain inosilicates, amphiboles have an infinite, double-chain structure composed of two single chains in which the silica tetrahedra of each chain share some of their oxygen ions. This arrangement imparts a residual positive charge to the apices and the unshared edges of the modified tetrahedra. The linking of two single chains into a double chain creates hexagonal holes between the joined chains that are occupied by hydroxyl ions $(OH)^{1-}$ that bond ionically to the residual positive charges to form the modified basic silica unit $(Si_4O_{11}OH)^{7-}$. In the formation of the double chain, two of these $(Si_4O_{11}OH)^{7-}$ units bond together covalently to form the $[Si_8O_{22}(OH)_2]^{14-}$ anion that is characteristic of all amphibole minerals. To complete the amphibole structure, the remaining negative charges are balanced by positively charged metal ions that bond ionically within the spaces between the double silica chains.

All molecules are composed of positively charged cations and negatively charged anions. In the amphibole molecule, which is represented by the general formula $(XY)_2Z_5(Si,Al,Ti)Si_8O_{22}(OH)_2$, the compound cation is $[(XY)_2Z_5]^{14+}$, while the compound anion is $[(Si_8O_{22})(OH)_2]^{14-}$. In the amphibole anion, the silica radical (a group of ions of different atoms that act as a single entity in chemical reactions) is $(Si_8O_{22})^{12-}$. This silica configuration is simply a chain-type, extended configuration of the basic $(SiO_4)^{4-}$ silica tetrahedron. It derives its -12 charge through 8 silicon ions $8Si^{4-}$ that are bonded covalently with 22 oxygen ions $22O^{2-}$. The compound amphibole anion also contains two hydroxyl ions $2(OH)^{1-}$, each composed of one oxygen ion O^{2-} and one hydrogen ion H^{1+}. In a few amphibole minerals, the fluorine ion F^{1-} substitutes for hydroxyl ion. Together, the silica ion and two hydroxyl ions provide a collective -14 anionic charge.

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Amphibole's compound cation is even more complex because of ready substitution by an array of divalent and trivalent metal ions. In the general formula for the compound amphibole cation $[(XY)_2Z_5]^{14+}$, "X" can be vacant or occupied by sodium (Na^{1+}) or potassium (K^{1+}); "Y" can represent sodium, calcium (Ca^{2+}), ferrous iron (Fe^{2+}), lithium (Li^{2+}), manganese (Mn^{2+}), aluminum (Al^{3+}), magnesium (Mg^{2+}), zinc (Zn^{2+}), nickel (Ni^{2+}), or cobalt (Co^{2+}); and "Z" can represent ferric iron (Fe^{3+}), manganese (Mn^{3+}), aluminum, chromium (Cr^{3+}), titanium (Ti^{3+}), and lithium. The possible number of elemental combinations within this cation is quite large, and mineralogists now recognize 120 amphiboles as valid mineral species. But whatever the elemental composition of amphibole's compound cation, its collective cationic charge must be +14 in order to balance the -14 anionic charge and thus provide the amphibole molecules with electrical stability.

The Dana classification numbers 66.1.1-3c first identify the amphibole minerals as inosilicates (66) with double chains (1). The amphiboles are then further classified into five subdivisions:

66.1.1 magnesium-iron-manganese-lithium amphiboles (monoclinic)
66.1.2 magnesium-iron-manganese-lithium amphiboles (orthorhombic)
66.1.3a calcic amphiboles
66.1.3b sodic-calcic amphiboles
66.1.3c sodic amphiboles

The following list compares the chemistries of a representative mineral from each of the five amphibole subdivisions. Notice how all their formulas are consistent with the general amphibole formula $(XY)_2Z_5(Si,Al,Ti)Si_8O_{22}(OH)_2$. Cationic substitution is common and produces many partial or complete solid-solution series. Because of subtle differences in chemistry and physical properties, positive differentiation of the closely related amphibole species usually requires laboratory analysis.

66.1.1.2 cummingtonite [basic magnesium silicate, $Mg_7Si_8O_{22}(OH)_2$ (monoclinic)]
66.1.2.2 anthophyllite [basic magnesium silicate, $Mg_7Si_8O_{22}(OH)_2$ (orthorhombic)]
66.1.3a.2 actinolite [basic calcium magnesium iron silicate, $Ca_2(Mg,Fe^{2+})_5Si_8O_{22}(OH)_2$]
66.1.3b.9 richterite [basic sodium calcium magnesium silicate, $Na(CaNa)Mg_5Si_8O_{22}(OH)_2$]
66.1.3c.1 glaucophane [basic sodium magnesium silicate, $Na_2(Mg_3Al_2)Si_8O_{22}(OH)_2$]

The relatively weak, ionic, metal-silica bonding that predominates between the long double chains in the amphibole minerals explains their good-to-perfect cleavage in two directions. The strong covalent bonding between the extended silica tetrahedra accounts for the relatively high amphibole hardness of Mohs 5.0-6.0. Amphibole minerals are usually, but not always, some shade of green, which varies with the chemical composition of each species. This basic green color is due primarily to widely varying amounts of iron and magnesium, two elements that are usually present in all amphiboles, whether or not they are essential in any particular species.

Amphibole minerals occur both as essential and accessory minerals in virtually all igneous and metamorphic rocks. Amphiboles form directly from the crystallization of certain components of magma in both intrusive and extrusive igneous rocks. As cooling magma solidifies, pyroxenes and amphiboles crystallize in a definite sequence. Pyroxene minerals crystallize first in higher temperatures and in the absence of water. Amphibole minerals then crystallize at lower temperatures, but only if water is present to provide the oxygen and hydrogen necessary for their essential hydroxyl ions.

Most amphiboles form through metamorphism, usually as alteration products of pyroxene-group minerals that are present in igneous rocks. Because pyroxenes are neither basic nor hydrated (containing neither hydroxyl ions nor water molecules), groundwater must be present during metamorphism to provide the hydroxyl ions necessary for amphibole formation. Pseudomorphs of amphibole-after-pyroxene are known as "uralite" (see "About Our Specimens"). Amphiboles can also form through contact metamorphism of

dolomite rock (rock containing at least 50 percent dolomite [calcium magnesium carbonate, $CaMg(CO_3)_2$]. Rocks containing more than 50 percent amphibole minerals are known as amphibolites and are the product of the alteration of pyroxene-rich basalts.

THE ROCK-FORMING MINERALS

The amphiboles, along with the closely-related pyroxenes and certain other mineral groups, are often referred to as "rock-forming minerals," a term referring to those minerals and mineral groups that make up most of the rocks in the Earth's crust. The amphiboles are essential minerals in many common rocks, including such intrusive igneous rocks as granite, syenite, diorite, gabbro, and peridotite; the extrusive (volcanic) igneous rocks basalt, dacite, rhyolite, and andesite; and the metamorphic rocks gneiss and amphibolite, the latter an altered form of basalt that consists primarily of amphibole minerals. Rock-forming minerals are mostly silicates, but also include some oxides, carbonates, sulfates, and sulfides. The rock-forming silicate minerals are loosely categorized into eight main groups that are listed below in order of decreasing abundance.

***Silica (Quartz)**: Silica or quartz [silicon dioxide, SiO_2] crystallizes as a framework silicate (tectosilicate). In its various macro- and microcrystalline forms, it is the most abundant mineral in the Earth's crust and the most abundant of the rock-forming minerals. Because silica constitutes from 40 to 70 percent of all rock-forming silicate minerals, its importance in rocks cannot be overstated. The manner in which these silicates are formed, emplaced, and altered is a key to understanding the basic nature of the Earth's crust.*

***Feldspars**: The large feldspar group of minerals consists mostly of aluminosilicates of potassium, sodium, and/or calcium that crystallize in the monoclinc or triclinic systems as framework silicates (tectosilicates). They include such familiar and abundant minerals as orthoclase and its dimorphic form microcline [both $KAlSi_3O_8$], sanidine [$(K,Na)AlSi_3O_8$], and albite [$NaAlSi_3O_8$]. The associated feldspathoid mineral group of silica-poor feldspars includes such minerals as nepheline [$(Na,K)AlSiO_4$].*

***Micas**: Micas are basic aluminosilicates of potassium, sodium, calcium, iron and/or magnesium that crystallize in the monoclinic system as sheet silicates (phyllosilicates). The most abundant mica is light-colored muscovite [$KAl_2AlSi_3O_{10}(OH)_2$]. The iron- and magnesium-rich biotite-group micas include such dark-colored minerals as phlogopite [$KMg_3AlSi_3O_{10}(OH)_2$].*

***Pyroxenes**: These are silicates of primarily iron, magnesium, sodium, calcium, potassium, lithium and/or aluminum that crystallize as single-chain silicates (inosilicates) in the orthorhombic or monoclinic systems. The most abundant pyroxene mineral is augite [$(Ca,Na)(Mg,Fe,Al,Ti)(SiAl)_2O_6$].*

***Amphiboles**: The amphiboles are a group of basic silicates of iron, magnesium, sodium, calcium, potassium, lithium, aluminum, chromium, manganese, zinc, nickel, and/or cobalt that crystallize in the orthorhombic or monoclinic systems as double-chain silicates (inosilicates). The most abundant amphiboles are actinolite and tremolite.*

***Miscellaneous Silicates**: Some other silicates that are classified as rock-forming minerals are the olivine group of iron, magnesium, calcium, and/or iron silicates that crystallize in the orthorhombic system as independent tetrahedral silicates (nesosilicates). The olivine group includes forsterite [Mg_2SiO_4] and fayalite [Fe_2SiO_4], whose gem variety is peridot. Other rock-forming silicate groups are the garnet-group*

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minerals of iron magnesium aluminum calcium silicates; the talc group of basic aluminum and magnesium silicates that includes talc [$Mg_3Si_4O_{10}(OH)_2$]; and the clay minerals of basic silicates and aluminosilicates that include montmorillonite [$(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}(OH)_2 \cdot nH_2O$].

***Carbonates**: The main carbonate rock-forming minerals are calcite [$CaCO_3$] and dolomite [$CaMg(CO_3)_2$], which are the primary components, respectively, of the marine sedimentary rocks limestone and dolomite.*

***Oxides, Sulfates, and Sulfides**: Other rock-forming minerals include the abundant iron oxides hematite [Fe_2O_3] and magnetite [Fe_3O_4]; gypsum [$CaSO_4 \cdot 2H_2O$]; and pyrite [Fe_2S], the latter the most abundant and widely distributed of the sulfide minerals.*

COLLECTING LOCALITIES

Although amphibole minerals are relatively abundant, the pseudomorphic uralite variety is rather rare. And while uralite is widely distributed, sources of fine specimens are few. Our uralite specimens were collected at the Calumet iron mine near Salida in the Turret Mining District in Chaffee County in central Colorado. Other sources in the western United States include the Crestmore quarries at Crestmore in Riverside County, California; the Green Monster Mine at Copper Mountain on Prince of Wales Island in Prince of Wales-Outer Ketchikan Borough, Alaska; the Milholland Creek area in the Eureka district of Yavapai County, Arizona; the Scarfield Mine in the Butte District of Silver Bow County, Montana; and the Oasis Divide area in the Silver Peaks district of Esmeralda County, Nevada. In the eastern United States, the uralite variety of amphibole occurs in New York at Power's Farm near Pierrepont in St. Lawrence County; in North Carolina at the Cranberry magnetite deposit in Avery County; in Maine at Sanford Hill near Sanford in York County; in Pennsylvania at the Williams Quarry at Chestnut Hill near Easton in Northampton County and the French Creek mines at St. Peters in Chester County; and in Virginia in quarries near Amelia in Amelia County.

In Europe, uralite is found in Spain at the Monchi Mine at Burquillos del Cerro, Badajoz, Extremadura; in Norway at the Skjaerpemyr Mine at Grau near Lunnar in Oppland; in Italy at Caesana Torinese in the Susa Valley in Torino Province, Piemonte, and the Sissone Valley in Sundrio Province in Lombardy; and in Slovakia at Poprad in the High Tatra Mountains in the Prešov Region. Russian specimens come from Mostovoya near Ekaterinburg and Kaminskaya near Miask in the Urals Region, and from the Pouyva Mine at Tyumenskaya Oblast' in the Western-Siberian Region. In China, uralite is collected at Zuomiban in Dejing County in Shangrao Prefecture, Jiangxi Province, and at the Yangliuping nickel-copper-platinum deposit at Baishiquan in Hami County in Garzç Prefecture in Sichuan Province. Uralite also occurs in New Zealand at Waikato on North Island; in southern New Caledonia in French Polynesia in the southwestern Pacific Ocean; in Guatemala at the Oxec Mine in Verapaz Department; and in Canada in the Sudbury mining district near Sudbury, Ontario.

JEWELRY & DECORATIVE USES

The most familiar and valuable amphibole gemstone is jade. Jade occurs in two different forms: the pyroxene mineral jadeite [sodium aluminum iron silicate, $Na(Al,Fe^{3+})Si_2O_6$] and nephrite, which is a mixture of the amphibole minerals actinolite and tremolite. Nephrite is the more abundant and affordable form of jade. Its colors range from white to gray, greenish-gray ("mutton-fat" jade), light-to-dark green, and brown, and are often mottled. Nephrite is the product of a sequence of chemical and mechanical action. In the chemical phase, actinolite and tremolite form from the alteration of pyroxene minerals. Nephrite then forms 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 and enables the actinolite and tremolite crystals to reconstitute. The heat and pressure of shearing then partially melts the reconstituted actinolite-tremolite which, upon cooling, recrystallizes as nephrite in small, lens-shaped bodies of tightly interlocked microcrystals. Unlike the more abundant fibrous forms of actinolite and tremolite, nephrite is very tough and considerably harder at about Mohs 6.5. In prehistory, nephrite was fashioned into sharp, durable projectile points and tools and later served both as a gemstone and a decorative stone. Today, nephrite is fashioned into beads for necklaces, bracelets, and earrings; cabochons for pendants and brooches; rings; and spheres and other carved, decorative objects.

Transparent actinolite crystals in various shades of green are sometimes faceted into collectors' gems as large as four or five carats. "Cat's-eye (or catseye) actinolite," a fibrous, chatoyant form of actinolite, is occasionally fashioned into cabochons. "Angel quartz," also called "amphibole quartz," is a "phantom" variety of quartz that is used in pendants and decorative objects. Angel quartz contains delicate, white, feathery inclusions of amphibole minerals that produce interesting and pleasing visual effects.

Mineral collectors value well-developed crystals of the uralite variety of amphibole for their pseudomorphic interest and relative rarity.

HISTORY & LORE

For thousands of years, the only known amphibole minerals were jade and several types of asbestos. In the 1600s, German miners found new amphibole minerals that they collectively referred to as *Hornblende,* a name that is thought to have stemmed from the color of horn and *blenden*, the latter word meaning "to dazzle." *Hornblende* became the miners' general term for shiny minerals that contained no valuable metals. In 1801, when the number of recognized "hornblende" minerals had grown to about a dozen, French mineralogist and crystallographer René Just Haüy (1743-1822) renamed the group "amphibole" from the Greek *amphibolos*, meaning "ambiguous," a reference to the minerals' similar appearances but different chemical compositions.

German mineralogist Gustav Rose (1798-1873) first described the uralite variety of amphibole in 1822 after studying specimens of a green porphyritic rock (an igneous rock with distinct, large crystals within a fine-grained matrix) that had been collected at Mostovoya near Ekaterinburg and at Kaminskaya near Miask in the Urals Region of Russia. Based on chemical analysis and close measurement of cleavage-plane angles, Rose correctly identified uralite as a pseudomorph of amphibole-after-pyroxene and coined the word "uralitization" for the metamorphic process in which pyroxenes alter into amphiboles. At the time, uralite was thought to be a distinct mineral species. In 1892, American geologist and mineralogist James Dwight Dana (1813-1895) studied uralite and made observations about the origin of the pseudomorph that are still considered valid today. Writing in the sixth edition of his *System of Mineralogy*, Dana noted: "The crystals, when distinct, retain the form of the original mineral, but have the cleavage of amphibole. The change usually commences on the surface, transforming the outer layer into an aggregation of slender amphibole prisms, parallel in position to each other and to the parent pyroxene. When the change is complete the entire crystal is made up of a bundle of amphibole needles or fibers."

Mineralogists' understanding of the amphibole minerals remained rudimentary until the introduction in the 1920s of X-ray diffraction to define crystallographic structure, and the advancement in the 1950s of spectroscopic-analysis methods to accurately determine even subtle differences in chemical composition. As the list of amphibole minerals grew over the decades, so, too, did confusion about their names and nomenclature. In 1978, the International Mineralogical Association's Commission on New Minerals and Mineral Names appointed a Subcommittee on Amphiboles to clarify the matter. Dozens of ambiguous and

erroneous names were then discredited, including that of uralite. As the list of amphibole names and species continued nevertheless to grow, the Subcommittee on Amphiboles convened again in 1990 to reorganize the amphibole group, publishing a revised amphibole list in 1996. Today, mineralogists recognize 120 amphibole minerals as distinct species.

Medieval physicians administered elixirs of finely powdered amphiboles, mainly actinolite, to aid in physical, emotional, and spiritual healing, and to ward off unwanted thoughts. Modern metaphysical practitioners believe that the benefits of green actinolite are similar to those of green jade and bring emotions into harmony and balance. “Angel quartz,” with its feathery amphibole inclusions of amphibole minerals, is said to promote lucid dreaming.

The amphibole variety of nephrite is the state gemstone of Wyoming. In 1982, nephrite was featured on the 1-cent postage stamp of New Zealand and the 30-franc stamp of New Caledonia.

TECHNOLOGICAL USES

Five different amphibole minerals have served as ores of asbestos: actinolite; tremolite [basic calcium magnesium silicate, $Ca_2Mg_5Si_8O_{22}(OH)_2$]; anthrophyllite [basic magnesium silicate, $Mg_7Si_8O_{22}(OH)_2$]; riebeckite [basic sodium iron silicate, $Na_2(Fe^{2+3}Fe^{3+2})Si_8O_{22}(OH)_2$]; and grunerite [basic iron silicate, $Fe^{2+7}Si_8O_{22}(OH)_2$]. These minerals occur as bundles of fibers that separate easily from their matrix rock and cleave into thinner fibers that are incombustible, chemically inactive, and flexible enough to weave. With their poor electrical conductivity and great thermal stability, they are well-suited for use in building insulation, tar paper, food-processing filters, medical sutures, asbestos-cement pipes, brake linings, and flame-retardant panels and garments. But because of associated health hazards, the use of amphiboles for asbestiform materials has been largely phased out. Most asbestos now comes from clinochrysotile [basic magnesium silicate, $Mg_3Si_2O_5(OH)_4$], a much-less-toxic, serpentine-group mineral.

The study of the amphibole group of minerals and the manner in which they alter from pyroxenes is helping petrologists (scientists who study rocks) to better understand rock genesis and the nature of metamorphic processes.

ABOUT OUR SPECIMENS

Our uralite specimens were collected at the Calumet iron mine in the Turret Mining District near Salida in Chaffee County in central Colorado. Salida, a community of 6,000 residents, is located 110 air miles southwest of Denver and 90 highway miles west of Pueblo on U.S. Highway 50. The Calumet Mine, located eight miles north of Salida in pine-forested hills at an elevation of 9,400 feet, is accessible on graded county and U.S. Forest Service roads.

The Calumet Mine was opened in 1882 after prospectors discovered a large body of nearly pure magnetite [iron oxide, $Fe^{2+}Fe^{3+2}O_4$] ore and quickly became a major source of iron for the Colorado Fuel & Iron Company steel mill in Pueblo. During its first two years of production, teamsters used reinforced ore wagons pulled by mules to haul the heavy magnetite ore from the mine to the main rail line at Salida for shipment to the Pueblo steel mill. In 1884, the Denver & Rio Grande Railroad built a spur line connecting Salida with the mine to ship its increased daily production of 10 railcar loads of magnetite ore. This ore, some of the richest ever mined in the United States, contained nearly 70 percent metallic iron by weight. Miners worked the Calumet deposit as an open pit until 1885, then went underground to follow the steeply dipping magnetite vein. Although the Calumet was Colorado’s biggest source of iron, it was forced to close prematurely in 1900 following the collapse of its 600 level. But by then, prospectors had also discovered

modest deposits of gold, silver, and base metals several miles to the west and founded the town of Turret. Many former Calumet miners subsequently mined multi-metal ores in the small, underground mines at Turret until the district closed six years later.

The Calumet iron mine exploited a contact-metamorphic ore deposit in an area of extremely complex geology. The mine is situated on the east side of the Upper Arkansas River Valley, which is also the west side of the Rio Grande Rift. The Rio Grande Rift, a section of the Great American Rift that extends from Mexico to Canada, was created 40 million years ago when deep magmatic pressure uplifted the entire American Southwest some 4,000 feet. As the crust stretched, it separated along both sides of major fault systems, enabling the center sections, which ranged in width from 5 to 50 miles, to displace downward some 10,000 feet. This displacement created New Mexico's greater Rio Grande Valley and Colorado's San Luis and Upper Arkansas River valleys, along with new fault systems on both sides of the rift. Magma and associated mineral-rich, hydrothermal solutions later penetrated sections of these new faults to emplace many of New Mexico's and Colorado's economic metal deposits.

One of these magmatic intrusions emplaced the iron mineralization at the Calumet Mine. Geologists believe that the Calumet iron deposit originated when magnetite became separated by density and concentrated within a mass of magma that intruded existing country-rock formations of limestone and shale. Millions of years later, massive intrusions and extrusions of magma immediately to the east in what is now the Thirty-Nine-Mile Volcanic Field metamorphosed the iron deposit and its surroundings. The mass of magnetite then became further concentrated into a massive, near-vertical vein of nearly pure magnetite that cuts through tilted beds of limestone, marble, shale, slate, and schist.

At the Calumet mine, magnetite is abundant and occurs both in a black, massive form and in well-developed gray, quarter-inch crystals. The mine is also Colorado's only notable occurrence of sapphire, the blue color variety of corundum [aluminum oxide, Al_2O_3]. The corundum crystals, few of which are gem quality, occur in a layer of green schist. The mine and its dumps are also known for fine epidote [basic calcium aluminum iron silicate, $Ca_2Al_2(Fe,Al)Si_3O_{12}(OH)$] crystals and nice specimens of the amphibole minerals tremolite and actinolite. Today, the Calumet mine is often visited by individual mineral collectors, members of gem-and-mineral clubs, and geology students participating in college and university field trips. Commercial collectors periodically work the site to collect specimens of epidote and uralite.

Our uralite specimens are pseudomorphs of amphibole-after-pyroxene. Pseudomorphs form when a new mineral replaces, alters, or coats a previously deposited mineral in a manner that retains the original mineral's external crystal shape. Derived from the Greek words *pseudos*, meaning "false," and *morph*, or "form," "pseudomorph" literally means "false form." Our uralite specimens consist of mixed amphibole minerals, mainly actinolite, that have replaced mixed pyroxene minerals, mainly augite [calcium sodium magnesium iron aluminum titanium oxysilicate, $(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al)_2O_6$].

Pseudomorphism is a process of chemical change in which an original mineral (or minerals, in the case of uralite) is replaced by a second mineral (or minerals) of different chemical composition. Pseudomorphism can occur by substitution, incrustation, or alteration. Pseudomorphism by substitution occurs when a new mineral completely replaces the original mineral on a molecule-by-molecule basis, changing both the chemistry and the internal crystal structure. Pseudomorphism by incrustation occurs when a new mineral coats an original mineral with a thin film in the precise shape of the original mineral.

Pseudomorphism by alteration—the manner in which our specimens were formed—occurs when a new mineral replaces the original mineral through chemical alteration and physical alteration of the internal crystal structure, while retaining the external shape of the original mineral. While the exact nature of the metamorphic process that alters pyroxene into the uralite variety of amphibole, called "uralitization,"

remains uncertain, researchers propose two general theories. One suggests that after pyroxenes have crystallized in cooling magma, they are immediately acted upon by the residual magma and alter quickly into amphiboles. The other focuses on later metamorphism that occurs when feldspar-rich magma intrudes into pyroxene-rich rock in the presence of groundwater.

Our specimens are amphiboles that exhibit the external crystal form of pyroxenes. In examining your uralite specimen, remember that uralite has the chemistry and crystal habits of amphibole, but the external form of the original pyroxene. Note first the external shapes—the short, stubby crystal form with square or rectangular cross sections that are typical of pyroxenes. Another feature that is characteristic of amphiboles is the diagnostic amphibole cleavage angles of 56 degrees or 124 degrees (pyroxene cleavage angles are about 90 degrees). To find cleavage surfaces (if present) and angles, study the crystals near the specimen's edge that may have cleaved during its preparation. Note also that the crystal faces have the fibrous (asbestiform) appearance and silky luster typical of amphiboles. Although radical color changes between the original and the secondary mineral are often apparent in pseudomorphs, this is not the case with our specimens. The grayish-green color of our specimens is very similar to the color of the original pyroxene. In both the original pyroxene and our amphibole pseudomorphs, this grayish-green color is due to the presence of essential iron and magnesium.

We're happy to have had this opportunity to delve into these important mineral groups, and hope you have enjoyed reading this write-up. It will be great to focus on the pyroxene group mineral aegerine later in the year, and those so inclined can reread this information in connection with the aegerine article, and hopefully come away with a good understanding.

We have just enough space for one rant, so here goes: there are no photos of the mine in this write-up because our supplier did not provide them in time! They just referred us to someone else, who did not respond in time to help us out, though we gave them two weeks notice. Are people just too busy? I know many mineral dealers are, especially full-time dealers like us, traveling to shows, field collecting, and of course dealing with problems of life as we all must–health problems, aging parents, raising children, financial stresses, etc. We try to arrange to obtain photos when we pick out the minerals and complete the purchase, and many of our suppliers are very accommodating, perhaps we have just hit a streak of those who aren't–one dealer supplied us with movies rather than photos, another promised photos and for one reason or another did not come through for us. Oh well, what can we do? We have our deadlines and pressures too, so we do as much and as best we can to fill each write-ups with lots of in-depth information and whenever possible . . . PHOTOS!

Thank you for reading and for understanding, thank you for being a member, and thank you for supporting us during these uncertain times. We hope the minerals and write-ups will continue to bring comfort and joy into your life!

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