

February 2012 Mineral of the Month: Muscovite

This month we are featuring muscovite from a recently discovered California source. Although muscovite is a common mica mineral, our specimens show a rare association with purple fluorite. Our write-up explains the unusual crystal structure of muscovite, its occurrence in granite pegmatites, and its many interesting uses.

OVERVIEW

PHYSICAL PROPERTIES

Chemistry: $KAl_2AlSi_3O_{10}(OH)_2$ Basic Potassium Aluminum Aluminosilicate (Basic Potassium Aluminosilicate, Basic Potassium Aluminum Silicate), often containing small amounts of iron, chromium, and fluorine.

Class: Silicates

Subclass: Phyllosilicates

Group: Three-layer Silicates

Subgroup: Muscovite

Crystal System: Monoclinic

Crystal Habits: Micaceous, as thin, tough, elastic, sheet-like, tabular crystals aligned parallel to the cleavage; pseudo-hexagonal, with crystals sometimes showing hexagonal outlines; often foliated; also as scattered grains, scales, and scaly masses. Aggregates of muscovite crystals are called "mica books." Prism faces usually tapered at the edges. Well-formed crystals are common.

Color: White, gray, silvery, or colorless to pale hues of yellow, green, pink, or brown; sometimes multicolored.

Luster: Vitreous to pearly

Transparency: Transparent to translucent

Streak: Colorless

Refractive Index: 1.552-1.616

Cleavage: Perfect in one direction, splitting easily into thin, tough, elastic sheets

Fracture: Uneven

Hardness: 2.0-2.5

Specific Gravity: Varies with composition from 2.7 to 3.0; average about 2.8.

Luminescence: None

Distinctive Features and Tests: Pronounced elasticity of thin, easily separated flakes; occurrence as well-formed crystals in granite, especially in pegmatites in association with quartz, beryl, tourmaline group minerals, and potash-feldspar group minerals. Muscovite is similar in structure to the biotite-mica group of basic potassium magnesium iron aluminosilicates, but is much lighter in color. Muscovite does not react with most acids.

Dana Classification Number: 71.2.2a.1

NAME The name "muscovite," pronounced MUSS-coh-vite, is derived from the Russian principality of Muscovia (Moscow), where the mineral was once widely used as a glass substitute. Muscovite's alternative names include "isenglas," "white mica," "moscovite," "moscovito," "amphylogite," "ammochrysol," "oncosine," "antonite," "didymite," "muscovy plate," "muscovy glass," and "Moscow glass." In European mineralogical literature, muscovite appears as *muscovita*, *moscovit* and *Muskovit*. "Fuchsite" is a green, chromium-rich variety; "mariposite" is a pink, chromium-rich variety. A twinned variety with five points is called "star muscovite."

COMPOSITION: Muscovite is a member of the silicates, the largest and most abundant class of minerals. More than 2,000 silicate minerals collectively make up three-quarters of the weight of the Earth's crust.

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Muscovite is one of the 40 members of the mica group of three-layer phyllosilicates or sheet silicates. As an allochromatic (other-colored) mineral, muscovite's colors are due to color-causing impurities called chromophores within its crystal lattice, or to other minerals that form between its thin, sheet-like crystals. When nearly pure, muscovite is colorless, white, silvery, or gray. But trace impurities, mainly of iron, manganese, and chromium, create pale hues of yellow, green, pink, or brown. As an abundant, rock-forming mineral, muscovite is an essential component of many igneous, metamorphic, and sedimentary rocks. It is also an accessory mineral in many rocks. Large, collectible specimens of muscovite usually occur only in granite pegmatites.

COLLECTING LOCALITIES: Notable muscovite localities are found in California, South Dakota, New Mexico, Maine, Vermont, North Carolina, Colorado, Connecticut, Idaho, Nevada, Massachusetts, and Virginia. Specimens are also collected in Namibia, Madagascar, Malawi, Zambia, Zimbabwe, Brazil, Austria, France, Germany, Pakistan, Sri Lanka, China, and Australia.

HISTORY, LORE, & GEMSTONE/TECHNOLOGICAL USES: As the most abundant form of mica, muscovite has been known since antiquity and was used by prehistoric cultures as a whitening agent in paints. The name "muscovite" was formally assigned in 1850. The International Mineralogical Association revised the nomenclature and classification of the mica-group minerals in 1999 and now recognizes 40 species. In the form of large, thin, semitransparent sheets called "isinglass," muscovite has served as windowpanes and oven glass since the 16th century. Because it easily cleaves into thin, semi-transparent sheets of considerable size and has a low coefficient of friction between individual sheets, a low coefficient of thermal expansion, resistance to heat, general inertness, and excellent electrical- and heat-insulating properties, muscovite has many industrial, consumer, and scientific uses, ranging from lubricants and electronic components to optical filters, additives to gypsum wallboard and oil-well drilling muds, inert fillers in rubber and plastics, "glitter" agents in paints and cosmetics, and a substitute for asbestos in automotive brake components. Nearly 400,000 metric tons of mica are mined worldwide each year. Modern metaphysical practitioners believe that muscovite aids problem-solving, stimulates quick-wittedness, and alleviates anger, stress, and self-doubt.

ABOUT OUR SPECIMENS: Our muscovite specimens were collected in the White Mountains in Inyo County, California. The White Mountains are a 60-mile-long, 20-mile-wide, north-south-trending, fault-block mountain range with two peaks above 14,000 feet and six peaks above 13,000 feet. Some 500 million years ago during the Paleozoic Era, the ancient sea that covered this region deposited thick layers of sediments that later lithified into sandstone, dolomite, and other sedimentary rocks. Crustal stresses generated from distant tectonic collisions then slowly, but dramatically, uplifted sections of the crust to create geologically complex mountains. Our muscovite specimens formed during the uplift of the White Mountains when granitic magma intruded country rock. This magma cooled slowly and solidified into large bodies of granite that retained a central core of residual magma enriched with such unusual elements as fluorine. This residual magma forced its way into surrounding fissures and cracks to form pegmatite veins with muscovite in an unusual combination with purple fluorite.

10 YEARS AGO IN OUR CLUB: Malachite, Mulungwishi and Lwisha Mines, Katanga Copper Crescent, Katanga (Shaba), Democratic Republic of Congo (Zaire). The intense green of the finest malachite specimens is unmatched in the mineral world! And the specimens we sent ten years ago certainly had this color. A few years ago, malachite with a gorgeous fibrous crystal habit started coming out of Zaire, and we still see small amounts of it here and there, but never in the amount we need to feature it. Political and economic problems in this war-torn country prevent the organized exporting of significant quantities of malachite and the other exceptional minerals that are so abundant there—what a pity! But we remain on the lookout, and if we find a large lot, you'll be the first to know!

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COMPREHENSIVE WRITE-UP

COMPOSITION

This is the second time now that we have featured muscovite, the first being in September 1997, when we sent pieces with an unusual star-shaped twinned habit, rightly called “Star Mica,” to about 150 or so members. We still remember digging through 55-gallon drums from Brazil in the warehouse of a large mineral importer to find just the right pieces. We should have bought it all, but we couldn’t afford it.

The chemical formula $KAl_2AlSi_3O_{10}(OH)_2$ shows that muscovite contains potassium (K), aluminum (Al), silicon (Si), oxygen (O), hydrogen (H). The molecular weight of muscovite consists of 9.81 percent potassium, 20.30 percent aluminum, 21.13 percent silicon, 48.20 percent oxygen, and 0.56 percent hydrogen.

As a silicate, muscovite is a member of the largest and most abundant class of minerals. More than 2,000 silicate minerals collectively make up three-quarters of the weight of the Earth’s crust. Silicates are combinations of silicon and oxygen with one or more metals or semimetals. The basic building block of all silicate minerals is the silica tetrahedron $(SiO_4)^{4-}$, in which four equally spaced oxygen ions ($4O^{2-}$) surround a silicon ion (Si^{4+}). The oxygen ions occupy the four corners of the tetrahedron (a four-faced polyhedron) with the silicon ion at the center. Silicate minerals consist of silica anions (negatively charged ions) and metal or semimetal cations (positively charged ions) linked together like polymers to form seven distinct structures: independent tetrahedral silicates (nesosilicates), double tetrahedral silicates (sorosilicates), framework silicates (tectosilicates), single-chain and double-chain silicates (inosilicates), ring silicates (cyclosilicates), and sheet silicates (phyllosilicates).

Muscovite is a phyllosilicate, a term derived from the Greek *phyllon*, meaning “leaf,” a reference to its micaceous crystal structure of thin sheets. In phyllosilicates, each silica tetrahedron shares three oxygen ions with adjacent tetrahedra to create a thin sheet structure that extends indefinitely in two directions. Although the charges of the shared oxygen ions are neutralized, the unshared oxygen on the apex of each tetrahedron carries a net -1 charge. This attracts positive metal ions which satisfy the collective negative charges of the tetrahedra and bond the sheets together. Because this arrangement can accommodate metal ions of many types, ionic sizes, and charges, sheet silicates have a large range of chemical compositions and form many solid-solution series. Because the accumulation of metal ions produces a net positive charge, hydroxyl ions $(OH)^{-1}$ occupy the holes among the tetrahedra to electrically balance the molecule. In certain chemical environments, fluorine ions (F^{-1}) sometimes substitute for hydroxyl ions.

Sheet silicates are classified by structure as two-layer or three-layer. The three-layer sheet silicates, which include muscovite, fall into seven general groups based on the nature of their atomic bonds: talcs, micas, brittle micas, montmorillonites, chlorites, vermiculites, and sepiolites. Muscovite is one of 40 members of the mica group of three-layer sheet silicates. Micas are defined as sheet silicates with three-layer silicate sheet structures that contain aluminum ions (Al^{3+}) and have inter-sheet spaces occupied by potassium ions (K^{1+}), calcium ions (Ca^{2+}), or sodium ions (Na^{1+}). As a three-layer, sheet silicate, muscovite consists of two aluminosilicate tetrahedral layers, with the aluminosilicate tetrahedra arranged in flat sheets, each consisting of six-membered rings. The tetrahedral apices of each layer point toward each other and “sandwich” an octahedral layer of potassium and aluminum ions in a 2:1 structure (hence the term “three-layer”). The substitution of an aluminum ion (Al^{3+}) for a silicon ion (Si^{4+}) in each silica tetrahedra creates a net negative charge which attracts the large potassium and aluminum ions that attach between the three-layer sheets. Because the resulting ionic bonds between the three-layer sheets are weak, muscovite has perfect, one-directional cleavage, separates easily, and has a Mohs hardness of only 2.0-2.5.

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In muscovite's chemical formula $KAl_2AlSi_3O_{10}(OH)_2$, the aluminum ion (Al^{3+}) is notated twice. In a strictly quantitative formula, such as $KAl_3Si_3O_{10}(OH)_2$, aluminum is stated only once (Al_3). But in a quantitative-structural formula, the double notation expresses the double role of aluminum ions within the muscovite crystal lattice. In the formula $KAl_2AlSi_3O_{10}(OH)_2$, the first notation (Al_2) refers to aluminum ions that, along with potassium ions, are bonded ionically between the tetrahedral sheets. The second notation refers to single aluminum ion (Al) that covalently bonds to each silica tetrahedron to replace a silicon ion and become an integral part of the aluminosilicate structure ($AlSi_3O_{10}$)⁵⁻. Accordingly, muscovite is correctly described as a basic potassium aluminum aluminosilicate.

The muscovite molecule consists of a compound cation and a compound anion. The cation contains one potassium ion K^{1+} and two aluminum ions $2Al^{3+}$ with a total cationic charge of +7. The anion consists of two radicals (groups of ions of different elements that behave as an entity in chemical reactions): the aluminosilicate radical ($AlSi_3O_{10}$)⁵⁻ and two hydroxyl radicals $2(OH)^{1-}$. The aluminosilicate radical has a -5 charge, while the two hydroxyl radicals have a combined -2 charge. This total -7 anionic charge balances the total +7 cationic charge to provide the muscovite molecule with electrical stability.

Muscovite is an allochromatic (other-colored) mineral, meaning its colors are due to color-causing impurities called chromophores. When nearly pure, muscovite is colorless, white, silvery, or gray. But traces of impurities, mainly of iron (ferric, Fe^{3+}) which replaces aluminum in the crystal lattice, can create pale hues of yellow, green, and brown. Traces of manganese ions (Mn^{3+}) and chromium ions (Cr^{3+}) that also substitute for aluminum can respectively impart soft pinkish and greenish hues. Colors can also be caused by staining from minerals that form between the thin muscovite sheets. Muscovite is sometimes multicolored, with the same specimen exhibiting different color shades.

The Dana mineral classification number 71.2.2a.1 identifies muscovite as a phyllosilicate with silica sheets consisting of six-membered rings (71) and a 2:1 layered structure (2). Muscovite is then assigned to the muscovite subgroup (2a) of the mica group as the first (1) of 16 members. Muscovite is the most abundant and chemically simple mineral of this subgroup. Although all subgroup members have similar crystal shapes, their chemistries vary considerably. Because of their similar appearance, laboratory analysis is usually necessary to differentiate between individual species.

As an abundant, rock-forming mineral, muscovite is an essential component of many rocks, including the igneous intrusive rocks granite, granodiorite, diorite, and monzonite; the igneous extrusive (volcanic) rocks dacite, andesite, and rhyolite; certain metamorphic rocks, notably micaceous schist; and sedimentary rocks, especially shales and clays. Muscovite is also present in small quantities as an accessory mineral in numerous other rocks. As flakes and small particles, muscovite is a common component of many soils and sediments. Large, collectible muscovite specimens are usually found only in granite pegmatites, which are bodies of very coarse-grained granite that form from the slow cooling of residual magma. In granite pegmatites, aggregates of muscovite crystals, called "books," can attain sizes of several feet and weigh more than one ton.

COLLECTING LOCALITIES

As an abundant, rock-forming mineral, muscovite is common worldwide. Our specimens were collected in the White Mountains in Inyo County, California. Other California localities are the Inyo beryl claims on Haystack Mountain near Lone Pine, Inyo County; and the Pala Chief and Elizabeth R. mines in the Pala district, and the Little Three and Hercules mines in the Ramona district, all in San Diego County.

Colorado specimens are collected in the greater Pikes Peak Batholith, notably the Crystal Peak area of Teller and Park counties; the Devil's Head and Pine Creek pegmatite areas in Douglas County; the

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Cheyenne, Pikes Peak, and Crystal Park areas of El Paso County; and Harris Park and Lake George in Park County. Colorado specimens are also found in the Mt. Antero and Mt. White summit areas of Chaffee County. Other localities in the United States include the Hewitt Gem Quarry at Haddam and the Strickland pegmatite at Portland, Middlesex County, Connecticut; the Bumpus Quarry near Albany, Oxford County, Maine; the Upper Cramer Lake pegmatites in the Sawtooth Batholith, Custer County, Idaho; the pegmatites of Pennington County, South Dakota; the Harding pegmatite mine in Taos County, New Mexico; the Zapot Pegmatite in the Fitting District, Mineral County, Nevada; the Rockport, Beverly, and Gloucester feldspar quarries, Essex County, Massachusetts; and the Amelia Mine at Amelia in Amelia County and the Burley Prospect at Roseland in Amherst County, both in Virginia.

African specimens come from the Erongo Mountains in the Usakos and Omaruru districts and the Tsaobismund pegmatite in Karibib District, both in Namibia's Erongo Region; the Sakavalana Mine at Ambatovita, Ambatofinadrahana District, Amoron'i Mani Region, Flanarantsoa Province, Madagascar; the Mangochi District, Southern Region, Malawi; the Kaplinkese Mine, Lukusuzi National Park, Eastern Province, Zambia; St. Anne's Mine at Mwami, Karoi District, Mashanoland West, Zimbabwe; the Ankazobe pegmatite field in the Antananarivo Province of Madagascar; and the Kakamas and Bushmanland feldspar quarries in Northern Cape Province, South Africa. In Brazil's Minas Gerais state, muscovite is found at the Batatal and Papamel mines at Marambaia in the Jequitinhonha Valley; the Ipé Mine at Governador Valadares in the Doce Valley; the Miguri Mine at Teófilo Otoni in the Mucuri Valley; the Santa Maria do Itabira and Ponte do Raiz mines at Santa Maria do Itabira; and the Santa Maria do Itabera Mine at Itabera and the Fazenda Mine at Ferros. Other Brazilian sources include the Ursina, Mimoso do Sul, and Concordia mines at Mimoso do Sul in Espírito Santo; and the Velha Mine at Tenente Ananias in Rio Grande do Norte.

In Europe, muscovite is collected in Austria at Gradischkogel Mountain near St. Vinzenz in Carinthia and the Pack pegmatite in the Packalpe Mountains in Styria; in France at Vizzalona Mountain, Vivario, Corsica; in Germany at the Ossling and Dubring quarries at Kamenz, Saxony; in Norway at the Landsverk feldspar quarry at Landsverk, Akershus; and Mourne Mountain in County Down, Northern Ireland, United Kingdom. Russian specimens come from the Danburitovaya and Etyka pegmatites in Chitinsilaya Oblast', the Tazheranskii Massif in Irkutskaya Oblast', and the Nerchinsk gem mines at Nerchinsk, Chitinskaya Oblast', all in the Eastern Siberian Region; and from Kanozero on the Kola Peninsula, Murmansk Oblast', Northern Region.

Muscovite is collected in Pakistan's Northern Areas, notably in the Skardu, Shigar, Braidu, and Basha valleys in the Skardu District; and the Haramosh Mountains and Hunza Valley in the Gilgit District. Other localities are the Nilaw-Kolum pegmatite field, Du Ab District, Nuristan Province, Afghanistan; the Karur District pegmatites in Tamil Nadu, India; the Delicias Mine at El Rodeo, Baja California Norte, Mexico; and the Ratnapura gem gravels in the Ratnapura District, Sabaragamuwa Province, Sri Lanka. Chinese localities include the Chengjawan pegmatite, Anyuan District, Pingxiang Prefecture, Jiangxi Province; and the Huya tungsten-tin-beryllium deposit at Mt. Xuebaoding, Mianyang Prefecture, Sichuan Province. Australian specimens come from the Cararra Mine in the Harts Range, Northern Territory, and the Pinnacles Mine at Broken Hill, New South Wales.

JEWELRY & DECORATIVE USES

Because of its softness (Mohs 2.0-2.5) and tendency to cleave easily into thin, flat sheets, muscovite has very limited use in jewelry. Compact aggregates of flat crystals are sometimes tumble-polished and drilled for use as beads. Until the introduction of synthetic materials in the 1960s, muscovite flakes served as Christmas-tree "snow" and decorative material to add glitter to retail window displays.

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Muscovite is found in many mineral collections, usually as composite specimens in association with such gemstone minerals as beryl [beryllium aluminum silicate $\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$], the tourmaline-group minerals of complex sodium magnesium aluminum borosilicates, the amazonite gem variety of microcline [potassium aluminum silicate, KAlSi_3O_8], and smoky quartz [silicon dioxide, SiO_2].

HISTORY & LORE

Mica was used as a whitening agent in the paints of Upper Paleolithic cave art. The Aztec Pyramid of the Sun at Teotihuacan (near present-day Mexico City) contained aggregates of mica one foot thick. The word “mica” stems from the Latin *micare*, meaning “to shine,” a reference to its glittering, reflective flakes. Mica was first described in India about 200 A.D. by the Buddhist monk and scholar Acharya Nagarjuna (ca 150-250 A.D.). Since about 1300 A.D., the Taos and Picuris Pueblo cultures of northern New Mexico have mixed muscovite particles into ceramic clays to impart a glittery, micaceous finish to pottery.

The word “muscovite” was first used in a mineralogical context in 1794 by German mineralogist Johann Gottfried Schmeisser (1767-1837) in his *System of Mineralogy*. Mineralogists initially assumed that the common mica-group minerals were a single species until the 1840s when they created two separate groups, “white mica” and “dark mica,” that were based largely on color and to a lesser extent on chemistry. In 1847, German mineralogist Johann F. L. Hausmann (1782-1859) recognized “dark mica” as an individual species, naming it “biotite” after the French physicist Jean Baptiste Biot (1774-1862). At the time, “white mica” was still known as “muscovy” after the Russian principality of Muscovia (Moscow), where it was used extensively as a substitute for window glass. In 1850, the American mineralogist James Dwight Dana (1813-1895) recognized “white mica” as a separate species and formally named it “muscovite,” borrowing the name first used by Johann Gottfried Schmeisser.

By the 1970s, mineralogists using advanced quantitative-analysis methods had identified more than two dozen mica-group minerals, many of which participated in partial or complete solid-solution series. In the 1980s, the International Mineralogical Association (IMA), which approves the names of mineral species, took steps to reclassify the growing number of mica-group minerals. To study the issue, the IMA’s Committee on New Minerals and Mineral Names appointed a Mica Subcommittee. In 1999, after years of study, the Mica Subcommittee recommended a sweeping revision of mica-group nomenclature and classification. The IMA now recognizes a muscovite subgroup (71.2.2a) with 16 members and a biotite subgroup (71.2.2b) with 24 members. In the muscovite subgroup, muscovite retains its status as an individual species. Biotite, however, has been discredited as a species because of its variable chemical composition. “Muscovite” remains a generic term for white micas, while “biotite” remains a generic term for dark micas.

Modern metaphysical practitioners believe that muscovite aids problem-solving, stimulates quick-wittedness, and alleviates anger, stress, and self-doubt. Muscovite was featured on the 4.50 escudo stamp of Angola in 1970.

TECHNOLOGICAL USES

Due to its ability to cleave into thin, nearly transparent sheets of considerable size, low coefficient of friction between individual sheets, a low coefficient of thermal expansion, thermal resistance, general inertness, and excellent electrical- and heat-insulating properties, muscovite has many industrial and scientific uses. As large, thin, semitransparent sheets called “isinglass,” muscovite has been used for windowpanes and oven glass at least since the 16th century.

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Today, finely ground muscovite makes an excellent solid lubricant for applications in which conventional liquid lubricants are heat-labile. Even when finely ground, each muscovite particle retains its sheet-like shape to provide smooth, low-friction surfaces. As an electrical insulator, thin, high-quality muscovite sheets, known as “India ruby mica” or “ruby muscovite mica,” have many electrical and electronic applications ranging from dielectric capacitors to components for missiles and medical instruments. Because they are transparent to alpha radiation, thin muscovite sheets serve as windows in radiation-detection instruments. Other optical uses include optical filters, pyrometers, and gauge glass of high-pressure steam boilers. Ground mica is used in joint compounds for gypsum wallboard, as a brightener in pigmented paints, as a flow-enhancing additive to oil-well drilling muds, as a reinforcing agent in plastics, and as an inert filler in rubber tires and roofing products. Very finely ground mica is an extender and filler in plastics, especially in automotive components where it functions as a sound and vibration insulator. Ground mica is also a substitute for asbestos in automotive brake linings. And because each particle of finely ground mica retains the brilliancy of its cleavage faces, it is the preferred “glitter” agent in pearlescent automotive paints. In the cosmetics industry, mica’s high reflective properties make it a key ingredient in blushes, eyeliner, eye shadow, foundation, lipstick, lip gloss, and nail polish.

Most muscovite is recovered as a by-product of mining pegmatites for feldspar minerals, beryl, and rare-earth metals, and from mining garnet-mica schist. Smaller amounts are recovered as a primary product of mining mica-rich, granite pegmatites. Today, 400,000 metric tons of mica are mined worldwide each year. Muscovite makes up 90 percent of all mined mica. Russia leads the world in mica production, followed by the United States, Finland, Iran, and South Korea. In the United States in 2009, nine companies mined 84,000 metric tons of mica. North Carolina is the leading producer, followed by Georgia, South Carolina, and South Dakota. The price of crude (as-mined) mica varies widely depending upon size and grade. Small, industrial-grade mica flakes sell for only about 50 cents per pound, while high-quality, hand-sorted sheet muscovite suitable for special electronic and optical applications can cost nearly \$1000 per pound.

MINERAL OCCURRENCES: SO NEAR, YET SO DIFFERENT

In “About Our Specimens,” we explain that our muscovite-fluorite specimens were collected from a vein-pegmatite occurrence. The commercial collector who recovered these specimens made an interesting observation about the locality: Within a few feet from the point where he extracted the specimens, the character of the rock changed dramatically from a muscovite-rich, vein-pegmatite environment to a metamorphic environment characterized by such minerals as phlogopite [basic potassium magnesium aluminosilicate, $\text{KMg}_3\text{AlSi}_3\text{O}_{10}(\text{OH})_2$, another member of the mica group], epidote [basic calcium aluminum iron aluminosilicate, $\text{Ca}_2\text{Al}_2(\text{Fe,Al})\text{Si}_3\text{O}_{12}(\text{OH})$], and clinozoisite [basic calcium aluminum silicate, $\text{Ca}_2\text{Al}_3\text{Si}_3\text{O}_{12}(\text{OH})$].

Understanding that dramatic changes in mineral environments can occur over very short distances aids not only geologists, but also commercial and amateur mineral collectors. Changes in mineral environments can be quite abrupt along the contact zones of different rock formations. Examples include the contact zones where igneous rock intrudes sedimentary rock and where volcanic rock covers older rock formations. But the most dramatic changes of all are associated with vein-type emplacements. Geologists describe veins as linear deposits of a particular type of mineralization within host rock of radically different mineralization.

Veins can be hydrothermal or magmatic in origin. Hydrothermal veins form when magma intrudes and fractures country rock, enabling associated hydrothermal fluids under great pressure to force their way

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into fissures. These fluids then solidify into networks of veins of hydrothermal mineralization that vary greatly in size and configuration. The thickness of the contact zone between veins and their host rock depends largely upon the porosity and chemical composition of the host rock. As an example, when hydrothermal fluids intrude a granitic host rock of low porosity and relatively low chemical reactivity, contact zones can be very sharp, sometimes only a matter of inches. But when the host rock consists of a porous and chemically reactive rock such as limestone, hydrothermal fluids can penetrate and metamorphose the limestone to create very wide contact zones. These zones can be hundreds of feet thick with a mineral content that grades gradually between that of the vein and that of the host rock.

Some veins, such as those that yielded our muscovite specimens, are magmatic in origin and are created by magma itself. When a body of magma intrudes a host rock, it cools and solidifies from the outside inward, often retaining a fluid core of residual magma that can be enriched with rare or unusual elements.

As the outer part of the magmatic intrusion solidifies, it contracts and fractures to create fissures into which the fluid core of residual magma, which is under great pressure, can escape. When this residual magma forces itself into fissures and solidifies slowly, it forms pegmatitic veins with large, well-developed crystals of quartz, feldspar, and muscovite, along with more unusual minerals. Furthermore, the heat from the slowly cooling veins of residual magma can metamorphose the surrounding rock. This happened when our muscovite specimens were formed. The residual magma solidified into pegmatitic granite with well-developed crystals of muscovite and associated fluorite. Although a sharp contact wall initially developed between the coarse-grained pegmatite veins and the fine-grained host granite, the heat from the slow cooling magma metamorphosed the surrounding rock. This resulted, as the commercial collector of our specimens observed, in radically different mineralogical environments with different suites of minerals just a few feet from each other.

When veins, either of hydrothermal or magmatic origin, outcrop on the surface, they are physically eroded and chemically weathered, but can usually be visually identified. In searching for mineral specimens, knowledge of geology and the ability to identify and interpret weathered contact zones and adjacent zones of weathered mineralization can be the key to success for both exploration geologists and specimen collectors. Often, sought-after specimens can be found in a totally different mineralogical environment only a few feet away.

ABOUT OUR SPECIMENS

As noted, our muscovite specimens were collected in the White Mountains of Inyo County, California. Covering 10,266 square miles, Inyo County is larger than the state of Vermont, yet has only 19,000 residents. Located in east-central California, Inyo County is bounded on the east by Nevada, and on the west by the crest of the Sierra Nevada. Inyo County's variation in topographical relief, the greatest of any county in the nation, ranges from Badwater Basin in Death Valley National Park at 282 feet below sea level to Mt. Whitney, the highest point in the United States at 14,494 feet above sea level. Our muscovite specimens were collected in Inyo National Forest approximately 20 road miles northeast of Big Pine and 20 miles west of the Nevada line. This remote area is 200 air miles northwest of Las Vegas, Nevada, and 50 air miles southeast of Mammoth Lakes, California. The nearest town is Big Pine, population 1,500, on U.S. Highway 395.

The White Mountains are a north-south-trending, fault-block mountain range about 60 miles long and 20 miles wide. The highest peak in this range (and California's third highest peak) is White Mountain Peak, which is a 14,252-foot-high remnant of an extinct volcano. The White Mountains have seven other summits above 13,000 feet. Geologically, the White Mountains are part of the lower Inyo Mountains to the

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south; structural geologists often refer to both ranges as the “White-Inyo Mountains.” Some 500 million years ago during the early Paleozoic Era, the ancient sea that covered this region deposited thick formations of sediments that lithified into sandstone, dolomite, and other sedimentary rocks. Crustal stresses generated by distant tectonic collisions then slowly but dramatically uplifted great sections of crust. This uplift was accompanied by volcanic action, magmatic intrusions, and extensive faulting and folding. The White-Inyo Mountains initially rose as a single range, but broke into two parts during later stages of uplifting. The White Mountains block then rose faster and tilted to the east, while the Inyo block rose more slowly with an opposite tilt. Erosion has since reduced the White-Inyo Mountains to its present elevation, resulting in a geologically contiguous range divided by a topographical “twist” in its middle. At the site of that “twist,” California Route 168 crosses Westgard Pass.

The White Mountains lie in the “rain shadow” of the Sierra Nevada 60 miles to the west and across the Owens Valley. Accordingly, the White Mountains have dry winds and an annual precipitation of only 12 inches, most of which falls as winter snow. At elevations of 6,500 to 8,200 feet, the lower mountain slopes are covered with piñon and juniper. On the upper slopes near the timberline elevation of 11,500 feet, the White Mountains host the continent’s greatest subalpine forests of the Earth’s oldest living tree—the Great Basin Bristlecone Pine (*Pinus longaeva*). Some of these gnarled, wind-sculpted trees are more than 4,600 years old. The high slopes also host North America’s oldest known bioherms—500-million-year-old, fossilized remnants of marine reefs. These fossilized coral reefs once flourished beneath a Paleozoic sea before being geologically uplifted more than two miles.

Our muscovite specimens were formed during the long uplift of the White Mountains when granitic magma intruded country rock. As this magma cooled slowly and solidified into granite, it retained a central core of molten residual magma enriched with such unusual elements as fluorine. When the outer sections of solidified granite contracted and fractured, residual magma forced its way into the resulting fissures to solidify slowly into erratic veins of pegmatitic granite (see “Composition”). In places where voids provided space for unrestricted growth, large, well-formed crystals of quartz and muscovite developed, sometimes in association with fluorite. Erosion eventually exposed these pegmatitic veins, which are the source of our specimens. The occurrence of muscovite in association with fluorite was first documented in the White Mountains in the 1960s.

To reach this general locality from Big Pine and U.S. Highway 395, turn east on California Route 168 and proceed 13 miles to Bristlecone Road. Turn left (north) on Bristlecone Road and drive eight miles to the end. Our specimens were recovered by commercial collectors who excavated several partially exposed and previously undiscovered pegmatitic veins. Our muscovite specimens were formally identified by mineralogist and crystallographer Dr. Anthony R. Kamph of the Natural History Museum of Los Angeles County. The collectors are continuing to explore the area, believing that the veins could also contain the aquamarine gem variety of beryl and phenakite.

As you examine your muscovite specimen, note first its micaceous crystal structure that consists of aggregates of thin, tough, elastic plates, all aligned parallel to the cleavage planes, which appear as shiny, smooth, vitreous-to-pearly surfaces. In some crystals, the six-sided (pseudo-hexagonal) form that is typical of muscovite is readily apparent. Apart from well-formed crystals, muscovite also appears as grains, plates, scales, and scaly masses. To demonstrate the elasticity of muscovite crystals, gently prod a thin, exposed crystal with the tip of a needle. Most muscovite crystals in your specimen will be white, silvery, gray, or colorless. Some, however, may show pale hues of green or brown, which are due to the presence of iron, either within the crystal lattice or between the thin muscovite crystals. Multi-coloration, with colors varying within the same specimen, is also typical of muscovite. Along with muscovite, your specimen also contains two other minerals: quartz and fluorite [CaF₂]. The quartz forms translucent, milky crystals or masses, while the fluorite appears as transparent, colorless or purple crystals. The purple is fairly intense

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and adds an attractive flash of color to your muscovite specimen. Muscovite and fluorite, common minerals though they are, rarely are found together, other fascinating feature of this exciting new find.

We have enough room to reprint part of our September 1997 write-up, including the drawing in the box: "This year, the Mineral of the Month Club has considered quartz and feldspar, the two major components of **granite**. Mica is also in much granite, accounting for as much as 10% of the content. Not all granite used in construction is truly granite, and there are different kinds of granite in different colors, depending on what other minerals are in the mix with the quartz and feldspar. Granite, then, is a coarse-grained rock with grain sizes that usually range from ¼ to ½ inch that forms when magma from deep in the earth reaches the earth's surface and cools. When examining a piece, you should be able to differentiate the various grain of quartz (clear or milky white), feldspar (white, creamy, pink, red or sometime yellow) and mica (dark green, silvery-white or colorless), but there will be no visible crystal faces. Since granite forms most of the mountains, islands, and a major portion of the crust of the earth, it is all around us.

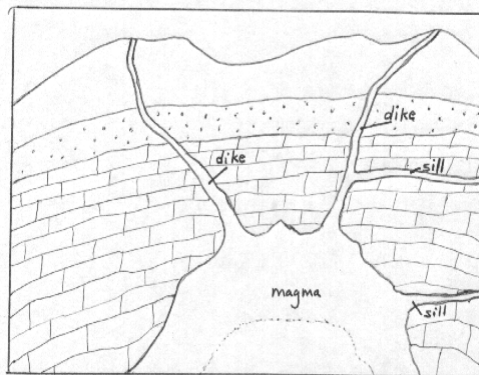


Figure 1. Slightly off-center drawing based on one found in the then-new book "Minerals" by George W. Robinson, Ph.D, as found in our September 1997 write-up on "Star" Mica.

"Now please examine the diagram to the right. It shows a cross-section of a typical geological landscape, where magma from deep in the earth is able to flow into cracks, fissures and gas pockets in the earth below and the hillside above. The magma which formed the landscape cooled relatively quickly, which explains why only coarse crystal grains formed rather than the well-developed crystals we all love to find. Conditions allow this more recent flow of magma to cool much, much more slowly, and conditions are right for glittering individual crystals of minerals both common and exotic to form.

"This intrusion of magma is what is known as a **pegmatite**. If the magma is made up of the elements that comprise quartz and feldspar, as most is, the term **granitic pegmatite** would be used. In fact, since most pegmatites are granitic, it is understood to be granitic unless designated otherwise. When the magma cuts across the rocks it is intruding, it is called a **dike**, when it lies parallel, it is known as a **sill**, as noted in the diagram. Other intrusion shapes are common. In pegmatites, the crystals are much more coarsely grained, and huge crystals of quartz, feldspar, and mica may be found. It is in cavities in the rock intruded upon by the pegmatite that conditions are right for the formation of outstandingly beautiful crystals, such as tourmaline, beryl, apatite, topaz, and many others."

When we wrote those words in 1997 we had no idea we would be including them in our 192nd write-up, soon to celebrate the sixteenth anniversary of the start of our Club! Thank you for making it happen!

References: *Dana's New Mineralogy*, Eighth Edition; *Encyclopedia of Minerals*, Second Edition, Roberts, et al, Van Nostrand Reinhold Company; *2008 Glossary of Mineralogical Species*, J. A. Mandarino and Malcolm E. Back, The Mineralogical Record, Inc.; *Mineralogy*, John Sinkankas, Van Nostrand Reinhold Company; *Rocks and Minerals*, Joel Arem, Geoscience Press; *Gemstone and Mineral Data Book*, John Sinkankas, Geoscience Press; *The Complete Guide to Rocks & Minerals*, John Farndon, Hermes House, 2007; *Rock-Forming Minerals: Phyllosilicates*; Deer, Haves, and Zussman, Wiley & Sons, 1978; *An Introduction to Rock-Forming Minerals*, Deer and Zussman, Addison-Wesley Publishing Co., 1996; *The Economics of Mica*, 7th Edition, Roskill Information Services, 1991; "Mica," Thomas P. Dolley, *2008 Minerals Yearbook*, United States Geological Survey.