April 2012 Mineral of the Month: Astrophyllite

The month we are shining the spotlight on astrophyllite, a rare, complex silicate from one of the world's most remarkable mineralogical provinces—the Kola Peninsula of northern Russia. Read on to learn about astrophyllite's unusual colors, luster, and attractive starburst patterns, as well as the preparation that goes into our write-ups.

OVERVIEW

PHYSICAL PROPERTIES

Chemistry: $(K,Na)_3(Fe,Mn)_7Ti_2Si_8O_{24}(O,OH)_7$ Basic Potassium Sodium Iron Manganese Titanium Oxysilicate, often containing small amounts of fluorine, calcium, magnesium, aluminum, niobium, and zirconium.
Class: Silicates
Subclass: Single-chain Inosilicates
Group: Astrophyllite
Crystal System: Triclinic
Crystal Habits: Usually as small, thin, tabular or bladed crystals grouped in radiating, starburst-shaped aggregates; also disseminated, lamellar, and massive.
Color: Usually golden-yellow, bronze-yellow, yellowish-brown, or amber; less frequently brown, greenish-brown, or reddish-brown. Colors can be patchy or zoned. Crystals are often pleochroic, exhibiting shifts in color with changes in viewing angle.
Luster: Sub-metallic, pearly on cleavage surfaces
Transparency: Usually translucent to opaque; thin crystals may be transparent.
Streak: Golden to yellowish-brown
Cleavage: Perfect in one direction
Fracture: Uneven; brittle.
Hardness: 3.0-3.5
Specific Gravity: 3.3-3.4
Luminescence: None
Refractive Index: 1.680-1.700
Distinctive Features and Tests: Best field marks are yellow-to-brownish colors, color zoning, and pleochroism; perfect cleavage in one direction; brittleness; radiating, starburst-shaped crystal aggregates; sub-metallic luster; and occurrence in syenite and nepheline-syenite fissures and pegmatites. Can be confused with augite, which is harder and forms shorter prisms; and schorl, which is harder and forms hexagonal crystals. Astrophyllite is slightly soluble in acids and fuses into a dark, glassy, slightly magnetic material.
Dana Classification Number: 69.1.1.1

NAME The name "astrophyllite," pronounced as-TROH-fih-lite, is derived from three Greek words: *astron*, or "star," *phyllon*, meaning "leaf" or "sheet," and *lithos*, meaning "stone", alluding to its starburst-shaped, radiating patterns of thin, flat crystals–"Star-Leaf-Stone." Astrophyllite was originally known as "brown mica." The obsolete spellings of "aastrophyllite," "asterophyllite," and "astrofillite" persist in some literature. In European mineralogical literature, astrophyllite appears as *Aastrophylit and astrophyllita.*

COMPOSITION: Astrophyllite is a member of the silicates, the largest of all mineral classes, in which silicon and oxygen combine with one or more metals. It is classified as a single-chain inosilicate, an important group of rock-forming minerals also known as pyroxenes that consist of single chains of silica tetrahedra. Astrophyllite crystallizes in the triclinic system, which is characterized by three axes of different lengths, none of which are perpendicular to the others. Many chemically complex minerals such as astrophyllite crystallize in the triclinic system. Astrophyllite's substantial density (specific gravity 3.3-3.4) is due to close atomic packing and to the relatively heavy, essential metals iron, manganese, and titanium, which together account for one-third of its molecular weight. As an idiochromatic (self-colored) mineral, astrophyllite's characteristic colors are caused primarily by iron and to a lesser extent by manganese, together with the nature of its crystal lattice. Astrophyllite is a rare mineral that occurs in cavities, fissures, and pegmatites of feldspar-rich, silica-poor, igneous rocks, usually syenite and nepheline syenite. Astrophyllite also occurs occasionally in certain volcanic environments.

COLLECTING LOCALITIES: The finest astrophyllite specimens come from the Khibiny, Lovozero, and Keivy massifs on Russia's Kola Peninsula. Astrophyllite is also collected in Norway, Brazil, Chile, Canada, Greenland, China, Malawi, Namibia, Morocco, South Africa, and Pakistan. Sources in the United States are located in Arkansas, Colorado, Maine, Montana, New Hampshire, Rhode Island, Washington, and Wisconsin. We have never seen astrophyllite at shows from any location other than Kola.

HISTORY, LORE, & GEMSTONE/TECHNOLOGICAL USES: Astrophyllite was first identified in 1844, when it was known as "brown mica." Researchers confirmed its complex chemistry and recognized it as a new mineral species in 1854. Mineralogists defined its atomic structure using X-ray diffraction methods in 1927. Astrophyllite was thought to be a single mineral until the 1950s, when advanced analytical techniques enabled mineralogists to differentiate a series of chemically and structurally similar minerals. By the 1970s, they had identified eight closely-related minerals that, along with astrophyllite, now make up the astrophyllite group. Because of its rarity and softness, astrophyllite has very limited use in jewelry. Radiating patterns of astrophyllite that contrast with light-colored matrix material are occasionally cut and polished into beads and cabochons, the latter mounted in silver pendant settings. Mineral collectors value astrophyllite for its rarity, unusual chemical composition, and attractive, starburst-shaped, radiating crystal patterns. Large specimens with well-developed, starburst patterns make very unusual display pieces. Apart from serving as the mineralogical model for its own laboratory synthesis, astrophyllite has no technological uses. Modern metaphysical practitioners believe that astrophyllite enhances confidence, intellect, and insight, and assists one in reaching his or her full potential by creating an awareness that limitations and obstacles can be overcome.

ABOUT OUR SPECIMENS: Our specimens were collected at a classic astrophyllite locality—the Khibiny Massif on the Kola Peninsula in Murmanskaya Oblast' in the Northern Region of Russia. Located in Russia's far northwest and part of Lapland, the Kola Peninsula is one of the world's richest and most diverse mineralogical provinces. The Khibiny Massif, a horseshoe-shaped plateau with elevations reaching 3,900 feet, is a highland in the central part of the Kola Peninsula. Geologically, the Khibiny Massif originated some 360 million years ago when a large mass of alkaline magma intruded granite-gneiss country rock. This intrusion, about 20 miles in diameter, consists largely of nepheline syenite, a rock similar to granite but with less silica and higher levels of alkali and alkali-earth metals. After undergoing several complex metamorphic phases, the thoroughly fractured Khibiny Massif was subjected to a process of hydrothermal reflux, in which hot or superheated water circulated through faults and fissures, dissolving and transporting many minerals. With changes in temperature, pressure, and levels of acidity (or alkalinity), these solutions then redeposited their dissolved mineral content in the form of many unusual minerals. Our astrophyllite specimens were collected by Russian kyanite and rare-earth miners who supplement their incomes by selling specimens to mineral dealers from St. Petersburg and Moscow.

10 YEARS AGO IN OUR CLUB: Eudialyte, Kipawa, Temiscaminque County, Quebec, Canada. Another mineral with a hard-to-pronounce name found in nepheline-syenite! Beautiful specimens of eudialyte also come from Kola, though our pieces from Canada were a lovely pinkish-red color. There is very little eudialyte from either place on the market now, which is why we buy all we can afford when we do see it!

April 2012 Mineral of the Month: Astrophyllite

COMPREHENSIVE WRITE-UP

COMPOSITION

We are happy to be featuring astrophyllite now for the second time, the first being in July 2001, when it was first coming on the market in quantity from Kola. Now it is much less available and much more valuable. Other minerals we have featured from this mineral-rich peninsula are staurolite, featured in May 2000 and in May 2010; the unusual calcite pseudomorph after ikaite known as glendonite, in September 2003; kyanite, in October 2004; the ruby variety of corundum, in December 2006; and "Rainbow Pyrite" in July 2007. The mention of each of these names brings back wonderful memories! The latter two minerals are still available as part of the sets of twelve minerals we have going back to 2005 in Gold-level size, and the last four can be found in Silver-level size sets, which are available from 2002 on.

Astrophyllite, chemical formula $(K,Na)_3(Fe,Mn)_7Ti_2Si_8O_{24}(O,OH)_7$, contains the elements potassium (K), sodium (Na), iron (Fe), manganese (Mn), titanium (Ti), silicon (Si), oxygen (O), and hydrogen (H). Astrophyllite's ideal molecular weight consists of 6.37 percent potassium, 2.08 percent sodium, 23.05 percent iron, 4.56 percent manganese, 7.73 percent titanium, 17.73 percent silicon, 38.16 percent oxygen, and 0.32 percent hydrogen.

Astrophyllite is a member of the silicates, the largest of all mineral classes, in which silicon and oxygen combine with one or more metals. The basic structural unit of all silicate minerals is the silica tetrahedron $(SiO_4)^{4-}$, in which a silicon ion is surrounded by four equally spaced oxygen ions that are 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 single-chain and double-chain silicates (inosilicates).

As a single-chain inosilicate, astrophyllite is part of an important group of rock-forming minerals known as pyroxenes. Single-chain inosilicates consist of single chains of silica tetrahedra that bond together by sharing two of their oxygen ions with adjacent tetrahedra. This bonding arrangement reduces the number of oxygen ions per tetrahedron by one, resulting in groups of $(SiO_3)^{2-}$ units. Although these single chains are often diagrammed as being straight, they are actually twisted or helical, in a manner that provides space to accommodate many different ions between them. The two negative charges on each tetrahedral unit, which are carried by the two unshared oxygen ions, are balanced by positive ions. In astrophyllite, these positive ions are potassium (K^{1+}), sodium (Na^{1+}), iron (ferrous, Fe^{2+}), manganese (Mn^{2+}), and titanium (Ti^{4+}) which bond ionically to the negatively charged oxygen ions. Astrophyllite forms single-width, branched chains of molecular units, each unit consisting of eight bonded $(SiO_3)^{2-}$ radicals, an arrangement that is reflected in the $(Si_8O_{24})^{16-}$ radical of its chemical formula $(K,Na)_3(Fe,Mn)_7Ti_2Si_8O_{24}(O,OH)_7$.

Although astrophyllite's chemical formula is lengthy and complex, it is easily understood by remembering that, like all molecules, those of astrophyllite are composed of positively charged cations and negatively charged anions. Astrophyllite's compound cation consists of two separate radicals (bonded groups of different ions that behave as entities in chemical reactions) and the ions of a separate element. These are three potassium-sodium radicals $3(K,Na)^{1+}$, seven iron-manganese radicals $7(Fe,Mn)^{2+}$, and two titanium ions $2Ti^{4+}$. Together, these give the astrophyllite molecule a total cationic charge of +25. Astrophyllite's compound anion consists of two radicals, the silicate radical $(Si_8O_{24})^{16-}$ and the oxy-hydroxide radical $[(O,OH)_7]^{9-}$, which provide a total anionic charge of -25. Note that the oxy-hydroxide radical $(O,OH)^{1-}$ consists of a divalent oxygen ion O^{2-} and varying numbers of hydroxide ions $(OH)^{1-}$, and thus has a variable charge. Additional hydroxide ions balance the added positive charge of trivalent aluminum ions (Al^{3+}) that are sometimes present in the cation. These slightly variable cationic and anionic charges are coordinated in a manner that provides the astrophyllite molecule with electrical stability.

Within the astrophyllite lattice, single chains form sheets of silica tetrahedra from which branch-like structures extend outward. These branches consist of free oxygen ions, hydroxyl ions, and ions of potassium, sodium, iron, manganese, and titanium that form their own sheet-like structure between the silica sheets. Within the silica sheets, the bonding is covalent and quite strong. But the bonding between the silica sheets and their "sandwiched" layers of metal, hydroxyl, and oxygen ions, is ionic and much weaker. This bonding arrangement accounts for astrophyllite's perfect, mica-like cleavage in one direction and its relative softness of Mohs 3.0-3.5. Because of the presence of three relatively heavy metals—iron (atomic weight 55.85), manganese (atomic weight 54.94), and titanium (atomic weight 47.88)—the astrophyllite molecule contains a significant amount of unshielded metallic bonding, which produces its diagnostic, sub-metallic luster.

Astrophyllite crystallizes in the triclinic system, which is characterized by three axes of different lengths, none of which are perpendicular to the others. Many chemically complex minerals, astrophyllite being a good example, crystallize in the triclinic system. Astrophyllite's substantial density (specific gravity 3.3-3.4) is due to close atomic packing and to the relatively heavy metals iron, manganese, and titanium, which together account for one-third of its total molecular weight.

The Dana mineral-classification number 69.1.1.1 first identifies astrophyllite as an inosilicate with single-width, branched chains (69). The subclassification (1) defines it structurally as having branches (of hydroxyl, free oxygen, and metal ions) extending from every second and fourth silica tetrahedron within the chains. Astrophyllite is assigned to the astrophyllite group (1) as the first (1) of nine members. Like astrophyllite, the other group members are chemically complex and vary compositionally with cationic replacement by such elements as niobium, calcium, lithium, and zirconium, and with anionic replacement by fluorine. The members most closely related to astrophyllite are kupletskite and kupletskite-(Cs). Their comparative chemistries appear below:

Astrophyllite $(K,Na)_3(Fe,Mn)_7Ti_2Si_8O_{24}(O,OH)_7$ basic potassium sodium iron manganese titanium oxysilicate

Kupletskite $(K,Na)_3(Fe,Mn)_7(Ti,Nb)_2Si_8O_{24}(O,OH)_7$ basic potassium sodium iron manganese titanium niobium oxysilicate

Kupletskite-(Cs) $CsK_2Na(Mn,Fe,Li)_7(Ti,Nb)_2Si_8O_{26}(OH)_4F$ basic cesium potassium sodium manganese iron lithium titanium niobium fluorosilicate

The color, structure, habits, and occurrence of astrophyllite, kupletskite, and kupletskite-(Cs) are virtually identical. These minerals, which form continuous solid-solution series, occur in intimate association and laboratory analysis is usually required for positive differentiation. Of the three minerals, astrophyllite is by far the most abundant.

As an idiochromatic (self-colored) mineral, astrophyllite's characteristic golden-yellow, bronze-yellow, yellowish-brown, amber, brown, greenish-brown, and reddish-brown colors are caused primarily by the essential element iron and to a lesser extent by the essential element manganese, together with the nature of its crystal lattice. Astrophyllite often exhibits pleochroism, an optical phenomenon caused by the absorption of different wavelengths of white light in different sections of doubly refractive mineral crystals. All mineral crystals refract or bend light, but doubly refractive crystals, such as those of astrophyllite, also divide that light into two polarized beams that vibrate in perpendicular planes. These divided, polarized light beams travel at different speeds and along different paths through the crystal lattice. Along each separate path, the lattice absorbs different wavelengths of white light, causing the beams, as they emerge from the crystal, to exhibit different colors or different intensities of the same color. In astrophyllite, these shifts are apparent in intensity and color, the latter most often from yellow-gold to brown.

Astrophyllite is a rare mineral that occurs in cavities, fissures, and pegmatites of feldspar-rich, silica-poor, igneous rocks such as syenite and nepheline syenite. These rocks, which are medium-to-coarse-grained and generally light in color, are similar to granite, but contain less silica and higher levels of the alkali metals potassium, sodium, and lithium and the alkali-earth metal calcium. Because of their higher contents of alkali and alkali-earth metals, syenite and nepheline syenite are sometimes referred to as "alkaline granite." Astrophyllite is usually associated with quartz [silicon dioxide, SiO_2]; microcline [potash-feldspar group, potassium aluminum silicate, $KAlSi_3O_8$]; zircon [zirconium silicate, $ZrSiO_4$]; calcite [calcium carbonate, $CaCO_3$]; aegerine [sodium iron silicate, $NaFeSi_2O_6$]; nepheline [sodium potassium aluminum silicate, $(Na,K)AlSiO_4$]; muscovite [basic potassium aluminum silicate, $KAl_3Si_3O_{10}(OH)_2$]; goethite [basic iron oxide, $FeO(OH)$]; and titanite [calcium titanium oxysilicate, $CaTiOSiO_4$]. Astrophyllite also occasionally occurs in certain volcanic environments.

COLLECTING LOCALITIES

Astrophyllite is a rare mineral and collectible crystals come from only a few localities worldwide. Our specimens were collected at a classic locality for astrophyllite— the Khibiny Massif on the Kola Peninsula, Murmanskaya Oblast', Northern Region, Russia. The Kola Peninsula also produces astrophyllite specimens from the Keivy and Western Keivy massifs, and the Lovozero Massif. Other Russian sources are the Korgeredaba alkaline massif at Sangelin Upland in the Tuva Republic; the Burpala alkaline massif near the Maigunda River in the Buryiatia Republic; and the Alden Shield Formation in the Sakha Republic, all in the Eastern-Siberian Region.

Norwegian occurrences include the astrophyllite type locality at Låven Island near Barkevik, Langesundfjorden, Vestmark. Nearby localities are Vøra near Vesterøya, the Røyås and Heia quarries at Tvedalen, and the Långendalen pegmatite at Larvik. Other Norwegian sources include Øvre Eiker and Kongsberg in Buskerud; Nordmarka and Lunner in Oppland; and Østre Brattholmen in Telemark.

In Brazil, astrophyllite is collected in the Papanduva Pluton exposures of the Morro Redondo igneous complex in Paraná state, and at Morro de Serote on the Poços de Caldas Plateau in Minas Gerais state. Chilean specimens come from the Del Salto Pluton in Aisén Province, Aisén del General Carlos Ibáñez del Campo Region. Canadian localities include the Poudrette, Desourdy, and Uni-Mix quarries at Mont-St-Hilaire, Rouville, Montérégie, Québec. In Greenland, astrophyllite is found in the Llimaussaq igneous complex at Narsaq, Kitaa (West Greenland) Province. Other localities include Namjagbarwa Mountain in Motou County, Linzhi Prefecture, Tibet Autonomous Region, China; Zomba Mountain in the Chilwa Alkaline Province, Zomba District, Malawi; the Brandberg igneous complex in the Brandberg District, Erongo Region, Namibia; the Tamazeght igneous complex in Khénifra Province, Meknès-Tafilalet Region, Morocco; the Lujavrite igneous outcrop in the western Bushveld Complex, Northwest Province, South Africa; and Hameed Abad Kafoor Dheri near Peshawar, North-West Frontier Province, Pakistan.

In the United States, astrophyllite is collected at Magnet Cove, Hot Spring County, Arkansas; the St. Peter's Dome district in El Paso County, Colorado; the Dennis Hill sodalite locality at Litchfield, Kennebec County, Maine; the Homestake Pass area of the Boulder Batholith, Jefferson County, Montana; Red Hill near Moultonboro and Hurricane Mountain near Conway, both in Carroll County, New Hampshire; the Beacon Pole Hill and Diamond Hill quarries at Cumberland, Providence County, Rhode Island;

Washington Pass in the Golden Horn Batholith, Okanogan County, Washington; and the nepheline-syenite outcrops of the Stetin Pluton in Marathon County,

JEWELRY & DECORATIVE USES

Because of its rarity and softness, astrophyllite has limited use in jewelry. Radiating patterns of astrophyllite that contrast nicely with light-colored matrix material are occasionally cut and polished into beads and cabochons, the latter mounted in silver pendant settings. Cutting and polishing is difficult because of the great difference in hardness between astrophyllite and its nepheline-syenite matrix rock.

Mineral collectors value astrophyllite for its rarity, unusual chemical composition, and attractive, starburst-shaped, radiating crystal patterns. Large specimens with well-developed, starburst patterns make eye-catching display pieces. The value of the largest, most attractive astrophyllite has greatly increased over the last few years, as supplies are dwindling and Russian miners, collectors, and dealers are placing a higher value on rare Russian minerals like astrophyllite. We hear that interest in mineral collecting has greatly increased in Russia, and that Russian mineral dealers who import to the United States are bringing some of their stock back to Russia where outstanding pieces fetch even higher prices than they do here!

HISTORY & LORE

Astrophyllite was first collected from islands in southern Norway in the late 1700s, but the inability to define its complex chemical composition precluded its recognition as a distinct mineral species. In 1829, the bishop of Brevik and amateur earth scientist Hans Morten Thrane Esmark (1801-1882) collected specimens at Låven Island in Langesundsfjorden on Norway's southern coast. Esmark sent these specimens to the prominent Swedish chemist Jöns Jacob Berzelius (1779-1848) in Stockholm, Sweden. Although Berzelius identified aegerine [sodium iron silicate, $NaFeSi_2O_6$] as a new mineral species, he overlooked astrophyllite, which occurred with Esmark's specimens. Norwegian chemist Paul Christian Hansen Weibye (1820-1889) finally identified astrophyllite in Låven Island specimens in 1844. Weibye published his findings in 1848, but the new mineral, then known as "brown mica," was not accepted as a new species until 1854, when German mineralogist Teodor Scheerer (1813-1873), working at the Freiberg Mining Academy in Freiberg, Germany, independently confirmed its complex chemical composition. Scheerer then named the new mineral "astrophyllite," literally "star sheet rock," for its radiating, starburst-shaped patterns of thin crystals. The original type specimens remain part of the collection of the Freiberg Mining Academy.

Mineralogists defined the atomic structure of astrophyllite using X-ray diffraction methods in 1927. Astrophyllite was considered to be a single mineral until the 1950s, when mineralogists employed advanced analytical techniques to identify a series of closely related and intimately associated minerals. By the 1970s, they had differentiated eight chemically and structurally similar minerals that now, along with astrophyllite, make up the astrophyllite group.

Modern metaphysical practitioners believe that astrophyllite enhances confidence, intellect, and insight, and assists one to achieve his or her full potential by creating an awareness that limitations and obstacles can be overcome.

TECHNOLOGICAL USES

Apart from serving as the mineralogical model for its own laboratory synthesis, astrophyllite has no technological uses.

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THE STORY BEHIND OUR WRITE-UPS

A big part of our job in providing our members with Minerals of the Month is preparing the write-ups that accompany each specimen. We started our club with the belief that mineral collecting and education go hand-in-hand and that the study of minerals is a wonderful way to learn more about our world, often in ways that go beyond mineralogy itself. With that in mind, we provide a write-up about each month's mineral. Initially, our write-ups were somewhat shorter than they are now. But as we realized the extent and richness of the stories behind each mineral, and as our members expressed growing interest in these stories, we lengthened our write-ups by providing additional information and greater detail.

Each of our write-ups requires a substantial effort in research and writing. The first step in preparing our write-ups often takes place when we acquire our specimens, which is usually at the big, annual gem-and-mineral-shows in Tucson, Arizona, and Denver, Colorado. Sometimes the individuals who supply our specimens have personally collected them in the field, purchased them directly from miners or others who did the actual collecting, or visited the sites where they were collected. We always interview our suppliers to gain firsthand information about specimen localities, knowing that this information does not always appear in mineralogical literature.

The second phase of preparation involves lengthy, academic research. Because there is no single source, or even limited numbers of sources, that can provide the range of information needed for our write-ups, we rely on a combination of on-line sources, hobby and technical magazines, scientific journals, reference books, and publications in university libraries and government repositories. Sometimes we even confer with mineralogists and other scientists, museum curators, and geologists from mining corporations.

We begin by researching the basics of each mineral, including the various aspects of its mineralogy, chemistry, crystallography, and geological occurrence. Because mineralogy is a dynamic and continuously evolving science, we rely heavily on current scientific journals and reports. We often find that mineralogical reference books only 10 or 20 years old are often out-of-date, particularly in matters of newly recognized minerals and current mineral nomenclature and taxonomic placement.

After compiling sufficient data on chemical composition, structure, physical properties, and nature of occurrence, we begin researching other aspects of the mineral. This is somewhat similar to searching for mineral specimens in the field, because we never know exactly what we will find. With some minerals, there is a wealth of readily available information, so much, in fact, that it must be condensed to fit the length of our write-ups. Yet at other times, certain rare, unusual, or obscure minerals can be difficult to research. At first, there seems to be little information about the history, lore, or uses of these mineals. But, somehow, if we dig deeply enough and in the right places, we always uncover material of interest for our write-ups.

Geography is a particularly interesting aspect of our research, and we make every effort to describe in detail the source of our minerals. Researching the geography of our Minerals of the Month localities has taken us on virtual journeys to every continent except Antarctica. Some of our specimens have literally come from "side-of-the-highway" sites and mines that are easily pinpointed on standard highway maps. Others, however, are from remote parts of the world where detailed, readily accessible maps are simply not yet available. An example is this month's mineral—astrophyllite from the Khibiny Massif on Russia's Kola Peninsula. Our locality description—Khibiny Massif—is general, but as specific as possible for two *reasons. First, the miners who collected our specimens do not divulge their exact sources in order to protect their interests. Second, the Kola Peninsula is a militarily sensitive region and both the Soviet Union and more recently Russia have classified many regional maps for reasons of military secrecy and national security. Other regions where we have had difficulty pinpointing localities include the Australian outback, certain inland areas of China, and western Pakistan. Among the best, readily available references for defining remote localities are the oversized world atlases usually found only in university libraries.*

To present a rounded discussion of a particular mineral, our research often takes us to such fields as gemology, jewelry, and gem economics, and thus to such sources as gemological journals and jewelry-trade magazines. In the fields of mining and mineral resources, we often find more material than we can use. An example is the famous Ojuela Mine at Mapimí, Durango, Mexico, that has been the source of several of our Minerals of the Month. A plethora of rich historical accounts covers everything from the discovery of the Ojuela silver-lead deposit and four centuries of production to the mine's present status as a source of mineral specimens. And for information on mineral uses and current production statistics, no sources are more up-to-date than the commodity specialists at the United States Geological Survey.

We have always been intrigued by the human element in mineralogy and have discovered a remarkable degree of interaction between many prominent chemists and mineralogists of different nations during the early Age of Science (the late 1700s and early 1800s), the period when mineralogy became established as a true science. Many of the same names appear repeatedly in connection with our minerals. It is interesting to realize how these scientists sometimes worked together to make joint contributions to mineralogy, but at other times competed furiously to be first to propose new mineral species.

How much time is needed to prepare a Mineral-of-the-Month write-up? That varies greatly with the particular mineral and the amount and accessibility of associated history, lore, and uses. In research, we've found that one interesting point often leads unexpectedly to another—and another. And that makes every write-up a unique research adventure, as well as a great deal of work. Our reward is preparing write-ups that our club members find educational, informative, detailed, concise, and enjoyable to read. And we know that many of you have expressed your appreciation for the in-depth nature of our write-ups, and we are happy to know you feel that way!

ABOUT OUR SPECIMENS

Our specimens were collected at a classic astrophyllite locality—the Khibiny Massif on the Kola Peninsula in Murmanskaya Oblast' in the Northern Region of Russia. Located in Russia's far northwest, the Kola Peninsula is part of Lapland. (See map in Figure 1 on next page.) It is bordered by the Barents Sea on the north, the White Sea on the east, and the White Sea and the Kandalaksha Gulf on the south. The western limit of the Kola Peninsula (a peninsula is defined as a body of land surrounded on three sides by water) is a line about 100 miles east of the borders of northern Finland and Norway that extends south from the Kola Gulf near Murmansk through Imandra Lake to the Kandalaksha Gulf. Almost entirely above the Arctic Circle, the Kola Peninsula covers 39,000 square miles and is roughly equal in area to the state of Tennessee. Its topography is dominated by rocky hills, low mountains, lakes, taiga, and tundra that are drained by numerous, fast-flowing rivers. Despite its Arctic location, the Kola Peninsula has a relatively mild climate, thanks to the influence of the Atlantic Drift, the Arctic arm of the warm-water Gulf Stream. Its average annual January temperature is 14˚ F. (-10˚ C.), while the average July temperature is 50˚ F. (10˚ C.). The name "Kola" is an anglicization of the Russian *Kol'skij* that stems from *Guoladat*, the Saami (Lapp) word for the region.

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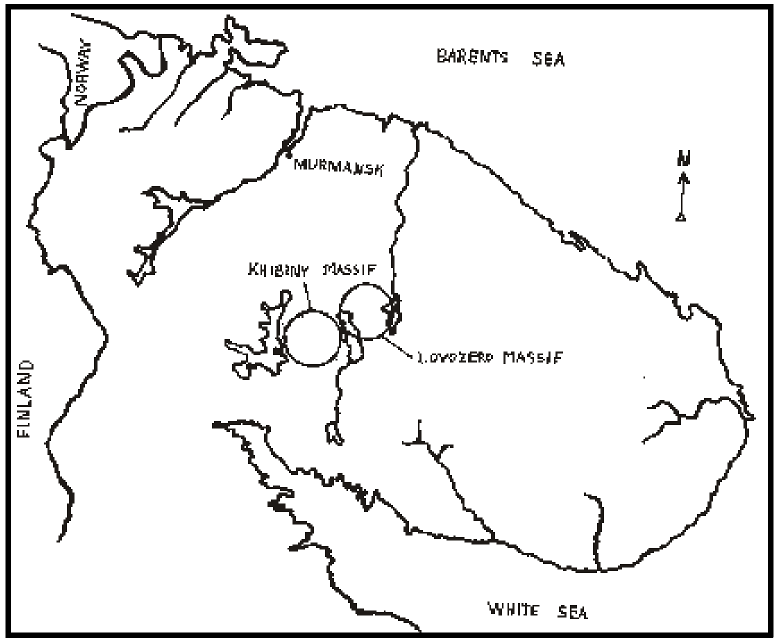

Figure 1. Kola Peninsula map.

Geologically, the Kola Peninsula is part of the Baltic (Fennoscandian) Shield, the exposed northwestern section of the East European Craton. As an ancient continent that grew through repeated collisions with adjacent crustal fragments, the Baltic Shield consists of intensely metamorphosed rocks as old as three billion years. Complex fault systems have hosted at least five major intrusions of granitic magma, all with unusual chemistries. Most are deficient in aluminum and silica, but rich in the alkali and alkali-earth metals, along with titanium, zirconium, phosphorus, manganese, zinc, lead, uranium, barium, and rare-earth elements. Deep burial, continuing intrusive activity, and tectonic stresses provided the heat and pressure for the intensive regional and contact metamorphism that formed the highly mineralized Khibiny, Lovozero, and Keivy massifs. Parts of these massifs were later uplifted to form the Khibiny, Lovozero, and Keivy mountains, which have since been reduced nearly to their bases by erosion. Between 100,000 and 20,000 years ago, five major phases of Pleistocene glaciation scoured the Baltic Shield of its overlying sediments to expose the highly mineralized massifs and shape its modern topography.

The Khibiny Massif, a horseshoe-shaped plateau with elevations reaching 3,900 feet, rises in the central Kola Peninsula, where the terrain is dominated by alpine tundra and drained by steep canyons. The Khibiny Massif was emplaced some 360 million years ago when a large mass of alkaline magma (see "Composition") intruded granite-gneiss country rock. This intrusion is about 20 miles in diameter and consists almost entirely of nepheline syenite. After a series of complex metamorphic phases, the thoroughly fractured massif underwent a process of hydrothermal reflux, in which hot or superheated water circulated through faults and fissures, dissolving and transporting many minerals. With changes in temperature, pressure, and levels of acidity (or alkalinity), these solutions then redeposited their dissolved mineral content in the form of many unusual minerals. In the Khibiny Massif, the predominant minerals of the nepheline-syenite rock were nepheline [sodium potassium aluminum silicate, $(Na,K)AlSiO_4$] and plagioclase and potash feldspars (a group of complex sodium potassium calcium aluminum silicates). These original minerals made available large quantities of sodium, potassium, and silica ions, while the presence of accessory elements such as iron, manganese, and titanium completed the chemistry necessary for precipitation of such rare minerals as astrophyllite and the astrophyllite-group members.

The Kola Peninsula is one of the Earth's richest and most varied mineralogical provinces. Mineralogists have identified 600 minerals species on the Kola Peninsula and recognize more than 270 type localities—places where new minerals were first discovered. No other region of similar size can boast such mineralogical variety or so many type localities. Of the Kola Peninsula's three main geological massifs—the Khibiny, Lovozero, and Keivy—the Khibiny Massif is the most remarkable. Within the Khibiny Massif, mineralogists have identified 477 individual species and recognize 112 type localities.

April 2012 Mineral of the Month: Astrophyllite

In the early 1830s, Russian geologist Nikolay Vasilievich Shirokshin (1809-?) was the first scientist to visit the Kola Peninsula. Shirokshin's report, published in 1835, noted the region's unusual mineralization and attracted other researchers, but the remoteness and inaccessibility delayed mine development for nearly a century. The Kola region became more readily accessible during World War I, when Russia constructed an 800-mile-long rail line from St. Petersburg (Petrograd) to the port of Murmansk on the Barents Sea. Following the war, the rail-accessible Kola Peninsula became a primary target for geological exploration within the rapidly developing Soviet Union. Beginning in 1919, mineralogist Aleksandr Evgenievich Fersman (1883-1945) led several surveys into the Kola Peninsula and in 1924 discovered an enormous apatite-(CaF) deposit in the Khibiny Massif. Apatite-(CaF) [formerly fluorapatite, calcium fluorophosphate, $Ca_5(PO_4)_3F$] is the primary component of phosphate rock and the only commercial source of elemental phosphorus and its compounds that are needed to manufacture agricultural fertilizers and many industrial chemicals. Subsequent surveys also found large deposits of copper, nickel, iron, and kyanite [aluminum silicate, Al_2SiO_5], the latter an ore of aluminum and a raw material for ceramics and refractory firebrick. To develop these resources in the 1930s, the government built a spur rail line east into the Khibiny Mountains. During World War II, the port of Murmansk and the mineral resources of the Kola Peninsula were vital to the survival of the Soviet Union. Today, the Kola Peninsula and the Khibiny Massif in particular are major sources of phosphate rock, rare-earth elements, and aluminum.

Our astrophyllite specimens were collected by kyanite and rare-earth miners who supplement their incomes by selling mineral specimens. The preparation of our specimens was especially time-consuming and labor-intensive, and required the breaking of large amounts of tough nepheline-syenite rock to expose the astrophyllite crystals. Some of our specimens were obtained directly from the collectors, while others came from mineral dealers from St. Petersburg and Moscow who periodically visit the Khibiny region and export them to international markets.

This month's mineral is a composite specimen consisting of astrophyllite on a light-colored matrix of nepheline syenite, a feldspar-rich, silica-poor, igneous rock that is similar in general appearance to light-colored granite. The astrophyllite, which formed in fissures within the host nepheline-syenite rock, is a deep-gold-to-brown color, which is typical for the species. To see the pleochroic effect, keep your eye on one crystal as you rotate the specimen in your hand and cause the colors to shift from deep gold to brown. Your specimen exhibits several of astrophyllite's diagnostic features, including a bright, sub-metallic luster; thin, flat crystals that reflect perfect cleavage in one direction; and the distinctive, starburst-shaped, radiating patterns of the crystals.

Your specimen is a classic example of astrophyllite, one of the rare silicate minerals from Russia's mineralogically diverse Kola Peninsula. Thirty years ago, few would have had the opportunity to add such a marvelous specimen to their collection–how delighted we are to be able to do so this month!

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