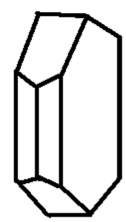
April 1997 Mineral of the Month: Labradorite

> *There is no art by which a reproduction or an imitation of [labradorite] in any way comparable to the original may be produced.--*
> *The Systematic Description of Precious Stones*

No doubt you have been amazed by the brilliant play of colors on your labradorite specimen. But only a small percentage of labradorite shines like these do. Why is that? And what is the scientific reason for the brilliance unique to labradorite alone? Read on and find out!

PHYSICAL PROPERTIES

Chemistry: (Ca,Na)(Al,Si)($AlSi_2O_8$) Calcium sodium aluminum silicate
Class: Silicates Subclass: Tektosilicates Group: Feldspar Series: Plagioclase
Crystal System: Triclinic
Crystal Habits: Blocky crystals rarely form outside the host rock. Twinning is very common so that the individual crystals form in layers or stacks; crystals range in size from a fraction of a millimeter to several millimeters thick
Color: Gray to greenish black to smoky black
Luster: Dull to vitreous
Transparency: Transparent to translucent
Cleavage: Perfect in one direction and good in another forming nearly right angled prisms
Fracture: Uneven to conchoidal; brittle
Hardness: 6-6.5
Specific Gravity: Approximately 2.70-2.74
Streak: White
Distinctive Features and Tests: Characteristic iridescence, striations



NAME

The name comes from Labrador, the sparsely populated area in northeastern Canada where it was first described, and is pronounced lab′-ră-dôr-īt. Formerly known as labrador spar, the Anglo-Saxon word “spar” referring to minerals that are easily cleaved, such as labradorite, calcite and fluorite. The name of the group of minerals to which labradorite belongs, “feldspar,” means “field spar”; all of the feldspars cleave easily.

COMPOSITION

In last month’s write-up about almandine garnet, we introduced the mineralogical terms **group**, **series**, **solid solution**, and **end-member**. We will redefine these as they all apply to labradorite as well. Labradorite is a member of the feldspar **group** of minerals, so grouped because they have a similar crystal structure. (It’s fascinating that all members of the feldspar group belong to the triclinic crystal system, as pictured above, except one, orthoclase, which belongs to the monoclinic crystal system!)

Within the feldspar group, two **series** or subgroup are recognized: potassium (also known as potash) feldspars and the sodium-calcium **plagioclase** (pronounced plā′-ji-ō-klās) feldspars. Labradorite belongs to this latter series. The potash feldspars include the minerals microcline, sanidine, and orthoclase

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(which is the sixth mineral in order of hardness on the Mohs Scale.) The plagioclase feldspars include albite, oligoclase, andesine, labradorite, bytownite, and anorthite, and are sometimes known as the soda-lime feldspars because sodium and calcium ("lime") are the main variables in their composition. This box and its explanation may help us understand the relationship between these soda-lime minerals:

Plagioclase Feldspar Series

Albite	Oligoclase	Andesine	Labradorite	Bytownite	Anorthite
Ab_{100}-An_0	Ab_{90}-An_{10}	Ab_{70}-An_{30}	Ab_{30}-An_{70}	Ab_{10}-An_{90}	Ab_0-An_{100}

←--→

$NaAlSi_3O_8$		$CaAl_2Si_2O_8$
Sodium (Na)	*← Less sodium. . . . . More calcium. . . . .→*	*Calcium (Ca)*
aluminum silicate		*aluminum silicate*

The percentage of sodium and calcium is the difference in the members of the plagioclase feldspar series. Albite and anorthite are the idealized end members; a perfect albite crystal would contain 100% sodium and 0% calcium; anorthite, 100% calcium and 0% sodium.

The feldspar crystal structure is such so that it will accept sodium and/or calcium ions. (Potassium also is accepted; the potash feldspars mentioned previously vary in composition from potassium to sodium, which we will consider more fully when featuring amazonite in the future.) When it contains 100% sodium and no calcium, it is known by the mineral name albite, and is white in color or colorless. When it contains no sodium and 100% calcium, it's called anorthite, and is usually gray. These two minerals are the **end-members** of the series.

Between these two end-members are the intermediate species listed in the box above, which are composed of a percentage of both sodium and calcium. They are listed as they grade by percentage from albite to anorthite; going from left to right, as the percentage of sodium ions decreases, the percentage of calcium ions increases. However, rather than designating each mineral by the percentage of sodium and calcium, they are designated by the percentage of albite ($NaAlSi_3O_8$) unit cells (which contain sodium [Na]), and the percentage of anorthite ($CaAl_2Si_2O_8$) unit cells (which contain calcium [Ca]). Thus in the formula written beneath each mineral name, the 'Ab' stands for albite and the 'An' for anorthite, and the small numbers after the abbreviation lets us know the percentage of each kind of unit cell for each mineral species.

Thus a perfect crystal of labradorite would be composed of 30% albite ($NaAlSi_3O_8$) unit cells and 70% anorthite ($CaAl_2Si_2O_8$) unit cells. The term **solid solution** is used to express the relationships in any mineral series in which the compositions lie between two pure compounds (end-members) as limits. Another term for such a series of mineral species is **isomorphous**.

Where exactly in the series do our specimens fall? Would they fit into the labradorite species range as highlighted in the box? The only way to know would be to crush each specimen and determine the proportions of sodium and calcium in each! So our specimens could possibly fit in the series anywhere

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between andesine and bytownite. They are called labradorite because they are emitting the characteristic color and brilliance (called labradorescence) associated with labradorite, but they could actually be closer in composition to andesine or bytownite!

The feldspar group is the most abundant and widespread group of minerals in the crust of the earth, as well as being major constituents of moon rocks! Granite, the rock that forms the framework of the continents and the cores of mountain ranges, is composed chiefly of feldspar and quartz.

The technical term for the characteristic brilliance of labradorite is **iridescence**, which means color produced by light interference. This iridescent quality in labradorite is called **labradorescence** and **schiller**, which is the German word for play of colors.

COLLECTING LOCALITIES

Since it puts the "Labrador" in "Labradorite," the Nain and Tabor Island area in far northeastern Labrador will always be considered the classic locality. Since the labradorite-rich area is now on Innuit Eskimo land, no collecting by outsiders is allowed. Ylaava, Finland, is famed for the labradorite quarried there under the trade name "spectrolite," and other sources of fabulously brilliant labradorite are at Peterhof near St. Petersburg in Russia, and Volhynia and Kiev, now in Ukraine, formerly U.S.S.R. The Adirondack Mountains in northeastern New York State are composed of labradorite in the form of a soda-lime feldspar- rich rock call anorthosite. In fact, a river flowing from these mountains contains so many boulders of labradorite (evidently placed there by glaciers) that it is named Opalescent River. (Just wondering: shouldn't it be called the Labradorescent River or the Schiller River?)

Our glorious specimens come from the fourth largest island in the world, Madagascar, which is separated from the southeastern part of Africa by the Mozambique Channel. This almost 1000 mile long (1600 kilometers) island republic covers 226,658 square miles (587,041 square kilometers) and has an ethnically diverse population of more than twelve million. This land where lemurs and many other rare animal species thrive is one of the world's poorest countries. The chief languages are Malagasy and French. Antananarivo, located in about the center of the island, is the capital and largest city.

It appears that immigrants from Malaya and Indonesia settled in Madagascar about 2000 years ago. Diogo Dias, a Portuguese sea captain bound for India, was the first European to sight the island, in 1500. During the 17th century, the Portuguese, the English, and the French successively and unsuccessfully attempted to colonize Madagascar. Finally, in 1896, Madagascar became a French colony, becoming self-governing within the French Community in 1958 as the Malagasy Republic, finally gaining full independence in 1960 and assuming the name Democratic Republic of Madagascar in 1975. Periods of political unrest have continued to occur since then.

JEWELRY & DECORATIVE USES

It would seem that such a striking mineral as labradorite would be extremely popular as a gemstone. Yet this is not so, for a couple of reasons. First, when used in jewelry, labradorite must be carefully oriented so that the play of colors will show. To observe this yourself, hold your piece upright as if you were going to wear it as a pendant and take a good look. Does the brilliance still show? If so, that might be a piece suitable for making a cabochon to be set into a lovely pendant setting. No brilliance? Good thing the orientation was checked before someone wasted their time cutting and polishing a cabochon! (A **cabochon** is a gem featuring a top surface of smoothly rounded shape and a bottom surface that is usually, but not always, flat.)

The other, and more serious hindrance, is fracturing. Your piece no doubt contains many fractures, which appear as dark lines on the surface. Finding any labradorite free from fractures enough to make anything is difficult other than a small cabochon, which are usually quite expensive. Perhaps due to the gorgeously brilliant labradorite coming out of Madagascar right now we are observing more and more labradorite jewelry (often made in India or Indonesia) and cut stones at the shows we regularly participate in, yet these pieces usually have fractures. In the fine jeweler's eyes, these fractures are considered unacceptable, but to the rest of us they are just the nature of this stone we love!

Don't be surprised if at some time you see a lovely labradorite cabochon or specimen being called spectrolite. This is a trade name given originally to the labradorite found near Ylamaa, Finland, which is often considered the world's finest. However, it is not uncommon for gemstone and mineral dealers to call their labradorite spectrolite, even if it is not from Finland, perhaps out of ignorance or perhaps to enhance the potential value of their wares in a buyer's eyes.

Moonstone, sunstone, and amazonite are other gems that are cut from feldspars of varying compositions. Occasionally beautiful translucent faceted labradorite is seen for sale, but it does not show the characteristic play of colors.

The labradorite quarried in Russia has been used there prolifically in the construction of fireplaces, urns, buildings, and walls. At one mineral show, Keenan saw a slide presentation entitled "Mineral Treasures of Russia" featuring a photo of a street in Russian where the curb was made from labradorite! The lower outside of the Chrysler Building in New York City has a rich blue sheen like labradorite gives off, and was thought for many years to be made of labradorite-- but it turned out to be rock composed mainly of another species of feldspar, namely, orthoclase.

HISTORY & LORE

The Algonkian (Red Paint) people of Maine used labradorite in their decorations around the year 1000 A.D. Native Eskimos on the Eastern coast of Labrador called it "Fire Rock" and used labradorite in ornaments for their chiefs. A Moravian missionary named Mr. Wolfe introduced it to Europe in 1770 and created quite a sensation. A slab two feet long and a foot wide was presented to the British Museum in 1777 by Rev. Mr. Latrobe, who gave the first description of its occurrence.

A few years later (1781), the Russian deposit near St. Petersburg was found. Now labradorite from both locations was being used in Europe for gemstones and decorative objects, typically at very high prices. Small carvings of mandrill baboons were cut so that the flashes of color appeared only where the brightly colored parts occur on the baboon! A Parisian jeweler tells of a piece found in Russia on August 11, 1799, that showed a perfect image of the head of Louis XVI (1754-1793) wearing a pomegranate-colored crown surmounted by a silver plume and framed by blue sky. This piece reportedly sold for a sum of money equivalent to as much as $50,000 today!

ABOUT OUR SPECIMENS

As we give attention to our brilliant specimens, let's examine the source of the iridescence. Shall we start by looking again at the information found under "Physical Properties" concerning labradorite's crystal habits:

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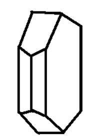
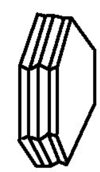
Crystal Habits: Blocky crystals rarely form outside the host rock. Twinning is very common so that the individual crystals form in layers or stacks; crystals range in size from a fraction of a millimeter to several millimeters thick.

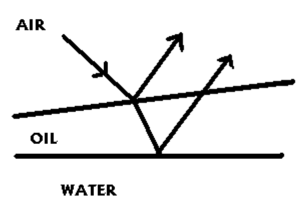
The labradorite crystal faces (such as illustrated in the drawing to the right) are not visible in our specimens. Twinning, a fascinating phenomenon that we will explain more fully in a later write-up is very common in labradorite, and results in a number of labradorite crystals forming side by side, sandwiched together, as shown in the second drawing to the right. Repeated twinning of this sort is called **lamellar** or **polysynthetic** twinning. These groups of crystals can be oriented at various angles in the rock mass, which explains why there are non-iridescent areas, as the color only comes from cleavages (or breaks) along certain crystal planes. Another reason for non-iridescent areas on a specimen may be that it contains no labradorite crystals and consists only of the host rock.



Most of the crystals in our specimens are of the extremely thin type mentioned in the crystal habit. On a few of our specimens, striations are visible, and these mark the edges of thicker crystals. The presence of these striations is one way by which plagioclase feldspar is identified. Most of the lines on our specimens, however, are fractures, caused by heating and cooling and other natural phenomenon.



Now to the cause of the iridescence. Our rather primitive drawing to the right shows what happens to light waves when they hit an oil slick on water. At the air-oil boundary, the incoming white light (which contains light rays of all wavelengths in the visible spectrum), is partly reflected and partly transmitted; the part being transmitted through the oil changes its direction slightly; when the transmitted light reaches the oil-water boundary, the same thing happens. The light reflected at the oil-water boundary passes back through the oil and out into the air. When it passes through the oil, its direction is again changed slightly, so that upon emerging into the air, it is now heading in the same direction as the first reflected ray, although it has traveled a little bit further.



Normally, when two bright lights are combined, the result is an increase in brightness as the light waves come together as one wavelength. When the two beams are out of phase, as they are in our oil on water scenario, the out of synch light rays interfere with one another and tend to cancel each other, sometimes all but one part of the light spectrum. Wavelengths of that portion of the spectrum are left over and are visible. The color we perceive depends on the thickness of the oil slick, which is what determines if shorter wavelengths, which we see as blue, or longer wavelengths that produce what we perceive as red, or perhaps colors in between, like green, yellow, and orange, emerge.

Basically, the same thing happens in labradorite. So what is it about labradorite crystals that causes light waves to go out of phase? Good question! The answer lies in the conditions in which it crystallizes and is stable. We know that a crystal is formed when the ions “line up” in a regular, repeating three dimensional pattern, based on their electrical charges. The plagioclase feldspars do this at a high temperature, and remain stable as long as the temperature stays high. Yet when conditions change, and the surrounding rock cools, the ions regroup somewhat into an arrangement that will remain stable at the cooler temperature. As a result the stacks of lamellar crystals evidently end up with a slightly different combination of sodium and calcium than their neighboring groups. Although extremely similar in every way, light passes through these lamellar crystal groups at a slightly different rate, causing it to go out of phase with light reflected through neighboring groups; similar to the oil on water scenario, the light rays cancel one another out, leaving just part of the spectrum to be perceived by us. It’s possible that in some of the colorless portions of our specimens, phased light is being refracted, just not light that is part of the visible spectrum!

Some references suggest that labradorite iridescence can also be caused by lamellar crystals of other minerals that crystallized in the labradorite, such as magnetite and hematite. Other members of the feldspar group, such as moonstone and sunstone, have different yet equally fascinating optical properties due to different causes! And you’ll find it fascinating to know that light interference among layers with slightly different optical properties is the also the source of the brilliant color of a peacock feather!

Our family has now had the privilege to examine perhaps as many as two thousand pieces of labradorite from Madagascar, with the following observations. The most common colors are the yellow and green, with varying shades therein. The deep metallic blue is somewhat rare but devastatingly beautiful. The rarest range of color is pink to purple, followed by salmon to orange. We have not observed any red yet. These rarer colors just mentioned seem weaker in the strength of the color and can be seen only from a very precise angle, no doubt due to the properties of light interference.

> "A man is like a bit of labradorite spar, which has no luster as you turn it in your hand until you come to a particular angle; then it shows deep and beautiful colors."-- Ralph Waldo Emerson

It seems by the volume of this iridescent labradorite available right now that one or more large areas of it have been discovered in Madagascar. How long it will continue is the $64,000 question. We have not yet found an answer, so let us all enjoy it as long as we can. Now that we all have a brilliant piece as part of our collection, we may enjoy the gorgeous schiller of labradorite forever!

References: Mineralogy, John Sinkankas, Van Nostrand Reinhold Company; Getting Acquainted with Minerals, George Letchworth English, McGraw-Hill; Minerals and Man, Cornelius S. Hurlbut, Random House; Dana's Manual of Mineralogy, 18th Edition, Cornelius S. Hurlbut, John Wiley & Sons, Inc.; Minerals and Rocks, Keith Lye, Ward Lock, Ltd; The Magic of Minerals, Olaf Medenbach & Harry Wilk, Springer-Verlag; Minerals, George Robinson, Ph.D., Simon & Schuster; Gemstones, George Smith, Pitman Publishing Corp.; Gems & Crystals of the American Museum of Natural History, Anna S. Sofianides & George E. Harlow, Simon & Schuster; Rare & Beautiful Minerals, Fritz Hofmann, Exeter Books; The Mineral Kingdom, Paul DeSautels, Madison Square Press; 1001 Questions Answered About the Mineral Kingdom, Richard M. Pearl, Dover Publications, Inc.; Encyclopedia of Minerals, Van Nostrand, Reinhold; Interference Colors on Oil Slicks and Feldspars, P.H. Ribbe, Mineralogical Record, January-February 1972; The Gem Feldspars: A Colorful Ménage à Trois, and Spectacular Sprectrolite, both by Si and Ann Frazier, Lapidary Journal, August 1993; http://geology/wisc.edu/~jill/feldspar.html; Amethyst Galleries Mineral Shop; Special thanks to Keith Harschberger