

December 2012 Mineral of the Month: Tourmaline

ELBAITE (Tourmaline Group)

This month we are featuring elbaite from Brazil. Elbaite is a tourmaline-group mineral and our write-up explains its pegmatitic origin, its history as a popular gemstone, and the cause of its many colors

OVERVIEW

PHYSICAL PROPERTIES

Chemistry: $\text{Na}(\text{Al}_{1.5}\text{Li}_{1.5})\text{Al}_6(\text{BO}_3)_3(\text{Si}_6\text{O}_{18})(\text{OH})_4$ Basic Sodium Aluminum Lithium Borosilicate (Sodium Aluminum Lithium Borosilicate Hydroxide). Usually contains small amounts of iron, magnesium, manganese, and calcium.

Class: Silicates

Subclass: Cyclosilicates

Group: Tourmaline

Crystal System: Hexagonal (Trigonal subsystem)

Crystal Habits: Usually as short-to-long, hexagonal prisms with rounded, triangular cross sections and flat terminations; striated lengthwise; also radiating, columnar, compact, and massive.

Color: Pink, reddish-pink, green, blue, blue-green; occasionally yellow and colorless.

Luster: Vitreous

Transparency: Transparent to translucent

Streak: White

Refractive Index: 1.615-1.651

Cleavage: None

Fracture: Irregular to uneven

Hardness: Mohs 7.0-7.5

Specific Gravity: 2.9-3.2

Luminescence: Often exhibits a weak bluish-white or blue fluorescence under shortwave ultraviolet light.

Distinctive Features and Tests: Best field marks are prismatic habit with rounded, triangular cross sections; lengthwise striations on prism faces; flat terminations; occurrence in lithium-rich, granite pegmatites; and absence of cleavage.

Dana Classification Number: 61.3.1.8

NAME: The word “elbaite,” pronounced ELL-buh-ite, is derived from the mineral’s type locality on the island of Elba in Italy. Elbaite is known for its color varieties as “red,” “pink,” “green,” and “blue” tourmaline. Other names are “lithia tourmaline,” “watermelon tourmaline,” and “gem tourmaline.” In European mineralogical literature, elbaite appears as *Elbait* and *elbaita*. The word “tourmaline,” pronounced TOUR-muh-leen, stems from the Sinhalese *toramalli*, a term referring generally to any of the varicolored gemstones of Sri Lanka (formerly Ceylon).

December 2012 Mineral of the Month: Tourmaline

COMPOSITION: Elbaite is made up of 2.51 percent sodium, 1.89 percent lithium, 19.13 percent aluminum, 18.38 percent silicon, 3.54 percent boron, 0.44 percent hydrogen, and 54.11 percent oxygen. It is a member of the silicates, the largest class of minerals, which has more than 2,000 members. Elbaite is a cyclosilicate in which layers of six-membered rings of silica ions (SiO_4)⁴⁻ form the crystal lattice. Elbaite crystallizes in the trigonal subsystem of the hexagonal system. Trigonal crystals have a three-fold symmetry and four axes, three of equal length lying in a common plane and separated by angles of *other* than 90 degrees and the fourth axis being longer or shorter and at a right angle to the other three. Elbaite is generally classified as an allochromatic or “other-colored” mineral, meaning its colors are caused by traces of nonessential, color-producing elements called chromophores (color-causing agents). However, it also exhibits certain idiochromatic (self-colored) properties in which colors are caused by its essential elements. Among its essential elements, lithium is the primary chromophore. Elbaite has many color varieties. Pink or reddish elbaite is known as rubellite, blue as indicolite, green as verdelite, and colorless as achroite. Bicolored elbaite crystals, which are common, result from variations in chemistry during the crystallization process. Elbaite crystals with green “rinds” and pink interiors are known as “watermelon tourmaline.” Elbaite and other tourmaline minerals exhibit pyroelectrical and piezoelectrical properties and generate electrical potential (current) when heated or mechanically stressed. Elbaite occurs primarily in lithium-rich granite pegmatites and also in lithium-rich environments in metamorphic rocks and hydrothermal veins.

COLLECTING LOCALITIES: The finest elbaite specimens come from Minas Gerais, Brazil; Nuristan and Konar provinces in Afghanistan; Gilgit-Balistan (Northern Areas), Pakistan; and California and Maine in the United States. Other sources include Angola, Myanmar, Italy, Madagascar, Mexico, Mozambique, Namibia, Nepal, Russia, South Africa, and Sri Lanka.

HISTORY, LORE & GEMSTONE/TECHNOLOGICAL USES: Although known since antiquity, elbaite was not recognized as a distinct mineral species until 1913. Elbaite’s many gemstone qualities include sufficient hardness (Mohs 7.0-7.5); a lack of cleavage that enhances durability and facilitates cutting; a moderately high index of refraction (1.615-1.651) that imparts brilliance to well-cut stones; and an array of pleasing colors. Elbaite gems are often cut in rectangular styles to maximize cutting retention in the long, prismatic crystals. Elbaite gems are most often mounted in rings or worn as pendants or in earrings. Both gold and silver make attractive mounts. The most desirable and costly colors are the reddish-pinks of the rubellite variety and the greens of the verdelite variety, the latter known as “Brazilian emerald.” Elbaite’s piezoelectrical properties were applied during World War II when elbaite crystals served as pressure sensors in submarine hulls. Following the war, its piezoelectrical properties were applied to microphones, transducers, oscillators, amplifiers, and phonograph-record pickup sensors. According to modern metaphysical practitioners, pink elbaite dispels fear and negativity, calms the nerves, provides inspiration, and dispels grief; green elbaite promotes compassion and emotional healing, aids in connecting with the Earth, and is especially valuable in helping herbalists understand the flow of energy between minerals and plants.

ABOUT OUR SPECIMENS: Our elbaite specimens were collected at the Jenipapo district pegmatite mines near Itinga in the Jequitinhonha Valley, Minas Gerais, Brazil. Most of the beautiful mineral specimens and gemstones for which Brazil is famous are mined from the pegmatites of Minas Gerais. The Minas Gerais pegmatite belt, a geological zone of

December 2012 Mineral of the Month: Tourmaline

gemstone-rich, granite pegmatites, extends through the northeast part of the state. Granite pegmatites are bodies of very coarse-grained granite that originate as pockets of residual magma that cooled slowly and crystallized on a fractional, or mineral-by-mineral, basis to form irregular pods, lenses, veins, and dikes that often contain unusual minerals and well-developed crystals. The Jenipapo district has four relatively small, adjacent pegmatite deposits. All are basically open pits with limited underground workings. In the Jenipapo district, as in most of Brazil's pegmatite districts, miners blast and remove large quantities of surrounding rock to expose pegmatite veins. Elbaite crystals are then recovered manually, often with the use of hammers and drill steels. Recovered specimens from the Jenipapo district are sold to visiting buyers from the cities of Teófilo Otoni and Governador Valadares and passed along to international markets.

COMPREHENSIVE WRITE-UP

COMPOSITION

Before discussing the chemical and physical properties of elbaite, it is important to understand the difference between the terms “elbaite” and “tourmaline.” Tourmaline is the name of a group of complex, basic borosilicates and not of any specific mineral. Elbaite is the name of a distinct mineral species that is one of the 27 members of the tourmaline group. Elbaite is the primary tourmaline gemstone.

The elbaite molecule contains seven elements: sodium (Na), aluminum (Al), lithium (Li), boron (B), oxygen (O), silicon (Si), and hydrogen (H). Its molecular weight is made up of 2.51 percent sodium, 1.89 percent lithium, 19.13 percent aluminum, 18.38 percent silicon, 3.54 percent boron, 0.44 percent hydrogen, and 54.11 percent oxygen. Elbaite's chemical formula $\text{Na}(\text{Al}_{1.5}\text{Li}_{1.5})\text{Al}_6(\text{BO}_3)_3(\text{Si}_6\text{O}_{18})(\text{OH})_4$ is not as imposing as it may seem when we remember that all molecules consist of positively charged cations and negatively charged anions. The complex elbaite cation $[\text{Na}(\text{Al}_{1.5}\text{Li}_{1.5})\text{Al}_6]^{25+}$ has a +25 charge; its $[(\text{BO}_3)_3(\text{Si}_6\text{O}_{18})(\text{OH})_4]^{25-}$ anion has a -25 charge. The balance of the collective +25 cationic charge and the collective -25 anionic charge provides the elbaite molecule with electrical stability.

Elbaite is a member of the silicates, the largest class of minerals with more than 2,000 members. The basic building block of the silicates is the silica tetrahedron $(\text{SiO}_4)^{4-}$, in which a silicon ion is surrounded by four equally spaced oxygen ions positioned at the corners of a tetrahedron (a four-faced polyhedron). In all silicates, silica anions bond with metallic cations in repeating chains to form seven types of structures: independent tetrahedral silicates (nesosilicates); double tetrahedral silicates (sorosilicates); single- and double-chain silicates (inosilicates); sheet silicates (phyllosilicates); framework silicates (tectosilicates); and ring silicates (cyclosilicates). Elbaite and the other tourmaline-group minerals are ring silicates or cyclosilicates.

Cyclosilicates are the most structurally interesting and chemically complex of all silicate subclasses. The structures of all silicate minerals are based on the silica tetrahedron $(\text{SiO}_4)^{4-}$. Cyclosilicates form when these tetrahedra share two of their oxygen ions with adjacent tetrahedra. Because each tetrahedron effectively loses one of its oxygen ions, this arrangement creates groups of linked $(\text{SiO}_3)^{2-}$ units that join together in a ring-type structure. In elbaite, each

December 2012 Mineral of the Month: Tourmaline

ring consists of six $(\text{SiO}_3)^{2-}$ units, hence the “ Si_6O_{18} ” arrangement of the silica radical in the elbaite chemical formula. The basic, six-sided geometry of this arrangement is modified in the cross section of elbaite crystals, in which three of the alternating prism edges are rounded to resemble a triangle. Technically, elbaite and other tourmaline-group minerals actually crystallize in the trigonal system, which is a subsystem of the hexagonal system. The trigonal system is characterized by three-fold symmetry and four crystal axes. Three axes are of equal length and lie in a common plane separated by angles of *other* than 90 degrees; the fourth axis is longer or shorter and at right angles to the other three. The characteristic, six-sided external shape of hexagonal-system crystals is simply a multiple of the basic trigonal three-fold symmetry.

Elbaite's six-sided silica rings are arranged in stacks of flat sheets. Borate ions $(\text{BO}_3)^{3-}$ are arranged within the ring structures, while ions of sodium, aluminum, and lithium are bound ionically between the sheets. These metal cations both join the sheets together and balance the negatively charged oxygen ions within the ring tetrahedra. Hydroxyl ions also bond ionically and satisfy residual positive charges in the rings. Because inter-sheet distances are very small, the ionic bonding between the sheets is unusually strong, explaining why elbaite has no cleavage. The rings within adjacent, superposed sheets are aligned in a manner that creates spaces to accommodate the ions of accessory metals, which sometimes contribute to elbaite coloration. Like most cyclosilicates, elbaite is hard, durable, and forms elongated, longitudinally striated crystals. Because unusually strong ionic bonding complements the strong covalent, oxygen-oxygen bonding between the silica tetrahedra, elbaite (Mohs 7.0-7.5) is even harder than quartz. Despite close atomic packing, the low atomic weights of its essential elements (sodium, 22.99; lithium, 6.94; aluminum, 26.98; silicon, 28.09; boron, 10.81; oxygen, 16.00; and hydrogen, 1.01) account for elbaite's moderate specific gravity of 2.9-3.2.

Elbaite occurs primarily, and attains its greatest degree of crystal development, in lithium-rich granite pegmatites where it is associated with quartz [silicon dioxide, SiO_2], lepidolite (a series of basic potassium lithium aluminum fluorosilicates of the mica group), and albite [sodium aluminum silicate, $\text{NaAlSi}_3\text{O}_8$]. It is found to a lesser extent in lithium-rich environments in metamorphic rocks, especially where granitic magma has altered limestone, and also in high-temperature, hydrothermal veins. Because its density is greater than that of silica-based sands and gravels, elbaite, after weathering free from its host rock, sometimes concentrates in economically valuable placer deposits.

Elbaite is considered an allochromatic or “other-colored” mineral, meaning its colors are caused by traces of nonessential, color-producing elements called chromophores. When pure or nearly pure, elbaite is colorless. But elbaite has unusually complex color-causing mechanisms and also exhibits certain idiochromatic (self-colored) tendencies where its essential elements also create colors. Of these essential elements, lithium is the primary chromophore (color-causing agent). Traces of accessory elements can indirectly create colors by displacing lithium ions and distorting the crystal lattice to affect the manner in which elbaite crystals absorb and reflect white light. Various positions of lithium ions within the lattice can create pinks, reddish hues, blues, greens, and yellows. The trace presence of manganese ions often contributes to the pink color of elbaite, and is intensified when natural geophysical radiation from granitic-pegmatite environments converts divalent manganese ions Mn^{2+} to trivalent manganese ions Mn^{3+} . Pink or reddish elbaite is known as rubellite, blue as indicolite, green as verdelite, and colorless as

December 2012 Mineral of the Month: Tourmaline

achroite. Elbaite crystals are often multicolored, the result of variations in chemistry during the crystallization process. Some multicolored crystals may display two or three color bands along their length; others exhibit internal, concentric color-zoning. Elbaite crystals with cross sections of green “rinds” and pink interiors are called “watermelon tourmaline.”

Elbaite and other tourmaline minerals exhibit pyroelectrical and piezoelectrical properties, which are detectable with electrical instrumentation. Pyroelectricity (from the Greek *pyr* or “fire”) refers to voltage generated by heat; piezoelectricity (from the Greek *piezein*, “to press”) is voltage generated by pressure. Both phenomena are due to elbaite’s cyclosilicate structure in which silica tetrahedra are bound together in closed rings. Because this arrangement provides great strength, rigidity, and spatial stability, elbaite expands only negligibly when heated. In this case, thermal energy energizes ions and displaces them from their normal positions in the crystal lattice. Due to the repetitive nature of the elbaite crystal structure, this ionic displacement accumulates until an opposing electrical potential—pyroelectricity—is generated among certain crystal faces. In piezoelectricity, mechanical energy only minimally deforms the elbaite ring structure, displacing ions from their normal positions to convert mechanical energy into electrical energy. The piezoelectrical property of elbaite has had industrial and scientific applications (see “Technological Uses”).

The Dana mineral classification number 61.3.1.8 first identifies elbaite as a cyclosilicate with six-membered rings (61). The subclassification (3) next defines elbaite as a six-membered, ring-structured cyclosilicate containing borate groups $(\text{BO}_3)^{3-}$. Elbaite is then assigned to the tourmaline group (1) as the eighth (8) member, all of which are related structurally and chemically (see “The Tourmaline-Group Minerals”). One cause of elbaite’s unusually broad range of colors is its ability to form solid-solution series with the tourmaline-group minerals dravite, schorl, and liddicoatite. The formulas below show the cationic substitution within these series:

elbaite	$\text{Na}(\text{Al}_{1.5}, \text{Li}_{1.5})\text{Al}_6(\text{BO}_3)_3(\text{Si}_6\text{O}_{18})(\text{OH})_4$
dravite	$\text{NaMg}_3\text{Al}_6(\text{BO}_3)_3(\text{Si}_6\text{O}_{18})(\text{OH})_4$
schorl	$\text{NaFe}_3\text{Al}_6(\text{BO}_3)_3(\text{Si}_6\text{O}_{18})(\text{OH})_4$
liddicoatite	$\text{Ca}(\text{Al}_{1.5}, \text{Li}_{1.5})\text{Al}_6(\text{BO}_3)_3(\text{Si}_6\text{O}_{18})(\text{OH})_4$

In the elbaite-dravite solid-solution series, magnesium substitutes for aluminum and lithium. In the elbaite-schorl series, iron substitutes for aluminum and lithium. And in the elbaite-liddicoatite series, calcium substitutes for sodium. In each of these series, the chemistry varies but the crystal structure remains unchanged.

COLLECTING LOCALITIES

Although not at all abundant, elbaite occurs worldwide. The finest specimens come from Brazil, Pakistan, Afghanistan, and the United States. The pegmatites of Brazil’s Minas Gerais state are the world’s leading source of elbaite. Other Important Brazilian localities include Agua Boa, Conselheiro, Galiléia, Governador Valadares, Itambacuri, and Mendes Pimentel in the Doce Valley; and Araçuaí, Coronel Muria, Diamantina, Itinga, Marlica, and Mucuri in the

December 2012 Mineral of the Month: Tourmaline

Jequitinhonha Valley. Brazilian elbaite is also found at the Borborema mineral complex near Equador and Parelhas in Rio Grande do Norte state, and at Salgadinho and Frei Martinho in Paraiba state.

Afghanistan's localities include the mines of the Wama, Nuristan, Kamdesh, and Du Ab pegmatite districts in Nuristan Province; and the Chapa Dara district in Konar Province. Pakistan's leading elbaite sources are in Gilgit-Balistan (Northern Areas) and include the Haramosh Mountains in the Gilgit District; Raikot and Chilas in the Diamar District; the Shigar, Haramosh, Skardu, and Braidu valleys in the Balistan District; and the Astore Valley mines in the Astore District.

In the United States, fine elbaite specimens occur in California in San Diego County at the Tourmaline Queen Mine at Pala Mountain, the Hiriati and Vanderberg mines at Hiriati Mountain, and the Elizabeth R. and Ocean View mines in the Pala district; the Cota, Green Ledge, Himalaya, Mesa Grande and San Diego mines at Gem Hill in the Mesa Grande district; the Mountain Lily and Maple Lode mines at Aguanga Mountain in the Aguanga Mountain district; and the Ramona and Rincón mines in the Ramona district. Other California sources are the Thomas Mountain, Sage, Cahuilla and Anza mines in the Cahuilla district of Riverside County. Maine's elbaite specimens come primarily from pegmatites near Albany, Buckfield, Greenwood, Hebron, Newry, Norway, Paris, Peru, Rumford, Stoneham, and West Paris, all in Oxford County.

Other sources are the Girauk pegmatite field in Namibe Province, Angola; the Pyin-Oo-Lwin district in the Mogok Valley, Mandalay Division, Myanmar; Fonte del Prete (the elbaite type locality) and the Rosina and San Silvestre veins at Campo nell'Elba, Elba Island, Livorno Province, Tuscany, Italy; the Sahatany pegmatite field in the Sahatany Valley, Vakinaratra Region, Antananarivo Province, Madagascar; the Chuqui Mine at Tecate, Baja California, Mexico; the Muhano-Magamala-Cocheline pegmatites in the Alto Ligonha district, Zambezia Province, Mozambique; the Brandberg, Karibib, Swakopmund, and Omaruru district pegmatites, Erongo Region, Namibia; the Haje pegmatite, Manang District, Gandaki Zone, Nepal; the Malkhan pegmatite at Krasnyi Chikoy, Chitinskaya Oblast', Transbaikalia, Eastern-Siberian Region and the Alabashka pegmatite, Ekaterinburgskaya, Middle Urals, Urals Region, Russia; the Straussheim pegmatite, Kenhardt District, Namaqualand, Northern Cape Province, South Africa; and the Ratnapura gem gravels in the Ratnapura District, Sabaragamuwa Province, Sri Lanka.

JEWELRY & DECORATIVE USES

Among elbaite's many fine gemstone qualities are sufficient hardness (Mohs 7.0-7.5); a lack of cleavage that enhances durability and facilitates cutting; a moderately high index of refraction (1.615-1.651) that imparts brilliance to well-cut stones; and an array of pleasing colors that many gemologists consider the most dazzling and varied of any gemstone. Elbaite gems are often cut in rectangular styles to maximize cutting retention of its long, prismatic crystals. Elbaite gems are mounted in rings and worn in pendants or earrings. Both gold and silver make attractive elbaite mounts. Color intensity and clarity determine the value of elbaite gems, with the most desirable and costly colors being the reddish-pinks of the rubellite variety and the greens of the

December 2012 Mineral of the Month: Tourmaline

verdelite variety, the latter often called “Brazilian emerald.” Color-zoned elbaite is also cut into gems, especially the concentrically banded crystal sections of “watermelon tourmaline” that have green “rinds” and pink interiors. Translucent pink and green elbaite crystals with numerous inclusions sometimes exhibit chatoyant sheens and are fashioned into cabochons. While most elbaite gems are not treated, enhancing techniques are occasionally used to improve the appearance of inferior stones. Irradiation can intensify the color of pink and reddish stones; heat treatment can often enhance the transparency of included stones. The term “elbaite” is rarely used in the jewelry trade, with most retailers preferring such terms as “pink tourmaline,” “green tourmaline,” etc.

Composite specimens in which elbaite is associated with such other pegmatite minerals as albite [sodium aluminum silicate, $\text{NaAlSi}_3\text{O}_8$] and quartz [silicon dioxide, SiO_2] can be spectacular. Cabinet specimens of fine elbaite crystals as long as ten inches can cost tens and even hundreds of thousands of dollars. The privately owned “Rose of Itatiaia” is considered the world’s most valuable elbaite specimen. This 14-inch-long, 5-inch-wide prism of gem-quality, raspberry-colored elbaite on a gleaming matrix of white albite was recovered in Brazil in 1980 and became the first “million-dollar” mineral specimen brought into the United States. The National Museum of Natural History (Smithsonian Institution) in Washington, D.C., has an extensive elbaite collection with specimens from Pakistan, Brazil, the United States, Nepal, and Italy. Its largest tourmaline gem, a flawless, pink, oval-cut elbaite weighing 191.87 carats and measuring 1.5 inches in width, was mined in Brazil in 2003. Because of its wide range of colors and exceptional crystal development, mineral collectors value both individual crystals and composite specimens of elbaite for study, display, and investment purposes.

HISTORY & LORE

Known since antiquity, elbaite has served as a gemstone since about 2000 B.C. Because of its many colors, the ancient Egyptians knew tourmaline as “rainbow rock” and believed that it gathered all the colors of the rainbow as it worked its way upward through the earth. The pyroelectrical properties of elbaite and the tourmaline-group mineral schorl [basic sodium iron aluminum borosilicate, $\text{NaFe}_3\text{Al}_6(\text{BO}_3)_3(\text{Si}_6\text{O}_{18})(\text{OH})_4$] were known since Greco-Roman times, when heated crystals were observed to attract dust particles. The Dutch East India Company introduced elbaite gemstones from Ceylon (now Sri Lanka) to Europe in the late 1600s. Dutch merchants of the early 1700s utilized tourmaline’s pyroelectrical properties, then believed to be a type of “magnetism,” by using heated crystals called *ashentrekkeren*, or “ash drawers,” to extract ashes from tobacco pipes. But because of its chemical complexity, early mineralogists were unable to recognize elbaite as a mineral species. In 1818, elbaite was one of the pegmatite minerals that Swedish chemist Johan August Arfwedson (1792-1841) analyzed during his work that resulted in the discovery of the element lithium. The basic chemistries of the tourmaline-group minerals were unraveled in the late 1800s by mineralogists who studied their piezoelectrical and pyroelectrical properties. By the 1890s, the unusual chemical complexity of the tourmaline minerals had become apparent. When John Ruskin (1819-1900), the leading English art critic of the Victorian era, was shown a collection of multi-colored elbaite gems and told of their chemical complexity, he described their general character and appearance as being “more like a medieval doctor’s prescription than that of a respectable mineral.”

December 2012 Mineral of the Month: Tourmaline

In 1913, Russian geochemist and philosopher Vladimir Vernadsky (1863-1945) studied tourmaline specimens from Fonte del Prete, Campo nell'Elba, Elba Island, Livorno Province, Tuscany, Italy, and determined their chemical composition accurately enough to propose the recognition of a new mineral species. He named this species "elbaite" after Elba Island, which became recognized as the type locality. The first detailed account of elbaite's complex crystal structure was not published, however, until 1972.

Modern metaphysical practitioners believe that pink elbaite dispels fear and negativity, calms the nerves, provides inspiration, and dispels grief, while green elbaite promotes compassion and emotional healing, aids in connecting with the Earth, and is especially valuable in helping herbalists understand the flow of energy between minerals and plants. Elbaite (called "tourmaline") is the official state mineral of Maine and has been featured on the Brazil's 50-centavos stamp of 1989, Kenya's two-shilling stamp of 1977, Switzerland's 20+10-centime stamp of 1959, the United States' 10-cent stamp of 1974, and the 375-franc stamp of the Comoros Islands in 1998.

THE TOURMALINE-GROUP MINERALS

Initially, the term "tourmaline" referred to a variety of colored gemstones that had no mineralogical ties. Today, the term refers specifically to a group of structurally and chemically related minerals with 27 members, a number that will likely be revised upward in the future.

The first tourmaline group mineral to be recognized a distinct species was schorl [basic sodium iron aluminum borosilicate, $\text{NaFe}_3\text{Al}_6(\text{BO}_3)_3(\text{Si}_6\text{O}_{18})(\text{OH})_4$]. The iron-rich member of the tourmaline group, schorl was recognized as a species in the 1500s after studies of specimens from German tin mines. Because of its high iron content, schorl is opaque and has a brownish-black to jet-black color. By far the most abundant tourmaline-group mineral, schorl accounts for about 95 percent of all the tourmaline in the Earth's crust. During the Victorian era, Schorl gained great popularity as a gemstone, especially in mourning jewelry. Relatively inexpensive and able to take a high polish, schorl was cut into both cabochons and faceted, opaque gems, often of large carat size. Schorl still serves as a minor gemstone today.

The second tourmaline mineral to be recognized as a species was dravite [basic sodium magnesium aluminum borosilicate, $\text{NaMg}_3\text{Al}_6(\text{BO}_3)_3(\text{Si}_6\text{O}_{18})(\text{OH})_4$]. Mineralogists recognized dravite a species in 1884 after studying specimens from the Drau (*Drava* in Latin) River in what is now Austria. Dravite, which was named for the Drau River, is a magnesium-rich tourmaline mineral with a yellow to brownish-yellow color and good transparency. Mineralogists estimate that dravite accounts for about one percent of all tourmaline minerals. Dravite is occasionally cut into gems for jewelry use, but is usually fashioned into collector's gems for display and study purposes.

In 1913, elbaite became the third tourmaline mineral to be recognized as a species. Mineralogists now believe that elbaite accounts for about two percent of all tourmaline minerals. Despite the radically different colors and degrees of transparency of schorl, dravite, and elbaite,

December 2012 Mineral of the Month: Tourmaline

mineralogists nevertheless began to consider these minerals as members of a “tourmaline group.” During the 1920s, newly developed, X-ray diffraction analysis methods confirmed that all three had similar cyclosilicate structures. By the 1950s, about six minerals had been included in the tourmaline group.

Working with continuously advancing analytical methods, mineralogists steadily recognized additional tourmaline-group members and, by 1999, had raised their number to 14. Today, after a major revision of tourmaline-classification standards in 2009, the tourmaline group has 27 members. With the exception of schorl, dravite, and elbaite, which together comprise about 98 percent of all tourmaline minerals, the remaining 24 members are rare and difficult to chemically differentiate.

The tourmaline group is now defined by the general formula $XY_3Z_6(BO_3)_3(T_6O_{18})V_3W$ in which:

X = calcium, sodium, potassium (or a vacancy)

Y = lithium, magnesium, divalent or trivalent iron, divalent manganese, aluminum, trivalent chromium, trivalent vanadium, or titanium (or a vacancy)

Z = magnesium, aluminum, trivalent iron, trivalent chromium, or trivalent vanadium

T = silicon, aluminum, or boron

B = boron (or a vacancy)

V = OH (hydroxyl) or O (free oxygen)

W = OH (hydroxyl), fluorine, or O (free oxygen)

With many potential cationic substitutions between a dozen metallic or semimetallic elements, along with the presence of the halogen element fluorine, the number of possible combinations becomes considerable. Given the growing ability to precisely determine even the most complex chemical compositions, the number of recognized tourmaline-group minerals will undoubtedly continue to increase. No matter how many new members are added to the tourmaline group, the “big three,” in order of gem importance and general familiarity, will always be elbaite, schorl, and dravite.

TECHNOLOGICAL USES

Elbaite’s piezoelectrical properties were first put to practical use in the early 1900s as pressure sensors in hydraulic presses. By World War II, elbaite crystals had become the standard sensor for most electrical pressure gauges. In these applications, the mechanical pressure on the elbaite crystals generated a proportionate amount of electrical potential (current) that could be read directly on electrical gauges. One of the most interesting and critical uses of elbaite in this regard was as the pressure sensors that were built into the hulls of submarines during World War II. During the post-World War II technological boom, elbaite’s piezoelectrical properties served in microphones, transducers, oscillators, amplifiers, and phonograph-record pickup sensors. Today, elbaite crystals have been replaced in virtually all pressure-sensing applications by synthetic piezoceramic materials.

December 2012 Mineral of the Month: Tourmaline

ABOUT OUR SPECIMENS

Our elbaite specimens were collected at the Jenipapo district pegmatite mines near Itinga in the Jequitinhonha Valley, Minas Gerais, Brazil. The Brazilian state of Minas Gerais, population 18 million and roughly the size of Texas, is bordered by the Atlantic Ocean on the east and the states of Bahia on the north, Tocantins on the west, and São Paulo on the south. In the 1700s, the mines of Minas Gerais (Portuguese for “General Mines”) made the Portuguese colony of Brazil the world’s leader in gold production. Today, Minas Gerais has a more balanced economy based on the mining of gold, gemstones, iron, manganese, zinc, and aluminum; the agricultural production of coffee, sugarcane, cotton, and oranges; and a growing manufacturing industry.

Most of the beautiful mineral specimens and gemstones for which Brazil is famous come from the pegmatites of Minas Gerais. The Minas Gerais pegmatite belt, a geological zone of gemstone-rich, granite pegmatites, extends 170 miles east-west and 360 miles north-south in the northeast part of the state. Granite pegmatites are bodies of very coarse-grained granite that originate as pockets of residual magma. This magma cooled slowly and crystallized on a fractional, or mineral-by-mineral, basis to form irregular pods, lenses, veins, and dikes. Residual magma is often enriched with accessory or rare elements that can produce unusual minerals. Also, gases within residual magma can create mariolitic cavities that provide space for the growth of large, very well-developed crystals. Minas Gerais has produced many extraordinary specimens of elbaite; topaz [basic aluminum fluorosilicate, $\text{Al}_2\text{SiO}_4(\text{F},\text{OH})_2$]; cat’s-eye chrysoberyl [beryllium aluminum oxide, BeAl_2O_4]; beryl [beryllium aluminum silicate, $\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$] and its many colored-gem varieties; quartz, especially purple amethyst; spodumene [lithium aluminum silicate, $\text{LiAlSi}_2\text{O}_6$], including the yellow-green hiddenite and pink kunzite varieties; spinel [magnesium aluminum oxide, MgAl_2O_4]; and greenish-yellow brazilianite [basic sodium aluminum phosphate, $\text{NaAl}_3(\text{PO}_4)_2(\text{OH})_4$].

The Minas Gerais pegmatites formed about 490 million years ago during the early Paleozoic Era when the present-day surface was deeply buried. Basement rock then consisted of highly metamorphosed gneiss, quartzite, and schist. As tectonic stresses faulted this basement rock, granitic magma surged upward through fissures to be initially capped within the basement rock. But before these intrusions cooled and solidified, the overlying metamorphic “roof” fractured to enable columns of residual magma to surge higher into fissures where they cooled very slowly to form pegmatites. Over hundreds of millions of years, geological uplifting and erosion eventually exposed these intruded bedrock formations along with the many pegmatites that are now the basis of the gemstone-mining industry in Minas Gerais.

The northern limit of the Minas Gerais pegmatite belt extends through the Jequitinhonha Valley in the northeast part of the state, an area some 460 air miles northeast of the coastal city of Rio de Janeiro. The source of our elbaite specimens is the Jenipapo district pegmatite mines near Itinga in the middle Jequitinhonha Valley. About the size of the state of Maine, the Jequitinhonha Valley has about one million residents living in 80 towns. Itinga, elevation 850 feet, lies on the Jequitinhonha River and has a warm, tropical climate and an agricultural economy based on cattle ranching and farming. Most of the 1,400 small farms near Itinga grow coconuts, coffee, sugarcane, manioc, and corn.

December 2012 Mineral of the Month: Tourmaline

The nearby Jenipapo mining district has four small pegmatite mines: the Guta Gusmão, João Pego, Jorge, and Santa Maria. All are open pits with shallow underground workings. The primary economic minerals, elbaite and brazilianite, are mined as both gemstones and specimens. Rose quartz and “blue” quartz, the latter taking its blue color from included, needle-like prisms of the blue indicolite variety of elbaite, are also mined as specimens and decorative stone. Associated minerals include schorl; albite [sodium aluminum silicate, $\text{NaAlSi}_3\text{O}_8$]; apatite-CaF [calcium fluorophosphate, $\text{Ca}_5(\text{PO}_4)_3\text{F}$]; muscovite [basic potassium aluminum silicate, $\text{KAl}_3\text{Si}_3\text{O}_{10}(\text{OH})_2$]; the lepidolite series of basic potassium lithium aluminum fluorosilicates of the mica group; microcline [potassium aluminum silicate, KAlSi_3O_8]; and kosnarite [potassium zirconium phosphate, $\text{KZr}_2(\text{PO}_4)_3$].

In the Jenipapo district, as in Brazil’s other pegmatite districts, miners blast and remove large quantities of surrounding rock to expose pegmatite veins. Elbaite and brazilianite crystals are then recovered manually, often with the use of hammers and chisels. These are sold to visiting buyers from the cities of Teófilo Otoni and Governador Valadares, which are respectively 160 miles and 220 miles to the south. These buyers then move the specimens to the major cities of Belo Horizonte and Rio de Janeiro to sell to foreign dealers who bring them to international markets.

Our elbaite specimens formed from the fractional crystallization of residual, granitic magma enriched with lithium and boron. As this enriched, residual magma cooled, the first minerals to crystallize were albite and muscovite, which formed the exterior of the developing pegmatite veins. This phase of crystallization left a depleted, silica-rich magma containing the molten components of elbaite and quartz. The next mineral to crystallize was elbaite, which formed pink prisms that remained suspended in what had now become essentially pure silica magma. In the final cooling and crystallization phase, this magma solidified into massive, milky quartz that contained huge numbers of pink elbaite prisms.

As you examine your specimen, note first the delicate pink color that is typical of the rubellite variety of elbaite. This color is due both to lithium and to traces of manganese, and has been intensified by exposure to natural geophysical radiation. Note also that the prisms are longitudinally striated and that their cross sections have a rounded triangular shape, both of which are diagnostic features of elbaite. Many of the elbaite prisms are translucent, but the terminal ends of some may approach gem-quality transparency. Some specimens may also have radiating clusters of elbaite prisms or bands of massive elbaite. The matrix of milky quartz provides an attractive color contrast with the pink elbaite. Your specimen is a fine example of the tourmaline-group mineral elbaite and a keepsake from the pegmatites of Minas Gerais, Brazil—one of the world’s leading gemstone sources.

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