

Mineral of the Month Club August 2016

BERYL var. AQUAMARINE (with SCHORL)

This month's featured mineral is aquamarine, the blue variety of beryl, from the pegmatites of Namibia. Crystals of black schorl are included within our specimens of translucent aquamarine. Our write-up explains the mineralogy, history, and lore of aquamarine, and discusses the origin, structure, and composition of pegmatites.

OVERVIEW

PHYSICAL PROPERTIES:

Chemistry: $\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$ Beryllium Aluminum Silicate. The aquamarine variety contains varying amounts of iron.

Class: Silicates

Subclass: Cyclosilicates (Ring Silicates)

Group: Beryl

Crystal System: Hexagonal

Crystal Habits: Usually as hexagonal (six-sided) prisms, often with flat or modified-flat terminations; also massive and compact.

Color: Colorless and white to blue, green, yellow, pink, and red. The aquamarine variety is blue to greenish-blue and grayish-blue.

Luster: Vitreous

Transparency: Transparent to translucent

Streak: Colorless to white

Cleavage: Poor in one direction

Fracture and Tenacity: Uneven to conchoidal; brittle.

Hardness: 7.5-8.0

Specific Gravity: 2.66-2.92

Refractive Index: 1.577-1.583

Distinctive Features and Tests: Best field marks for aquamarine are hardness; six-sided prisms with flat or modified-flat terminations; blue to greenish-blue and grayish-blue colors; and occurrence in granite pegmatites.

Dana Classification Number: 61.1.1.1

NAME: The word "aquamarine," pronounced ah-kwa-mah-REEN, stems from the Latin *aqua marina*, literally meaning "seawater" and alluding to the mineral's blue color. Aquamarine is also known as "blue beryl" and "aqua." In European mineralogical literature, aquamarine appears as *Aquamarin*, *aquamarina*, and *akvamarin*. The word "beryl" stems from *bēryllion*, the Indo-Aryan word for the mineral. Beryl appears in European mineralogical literature as *berilo*, *berylita*, and *Berylit*.

COMPOSITION & STRUCTURE: Beryl is a member of the silicates, the largest class of minerals, in which silicon and oxygen combine with one or more metals. It is a cyclosilicate, the most structurally complex of all silicate subclasses. Beryl consists of 5.03 percent beryllium,

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10.04 percent aluminum, 31.35 percent silicon, and 53.58 percent oxygen. Hard and durable, it usually forms elongated crystals, often with flat terminations. Beryl crystallizes in the hexagonal system, which is characterized by four axes, three of equal length and lying in a common plane with angles of 120° between them. The fourth, or hexagonal, axis is perpendicular to the plane of the other three and may be of any length. Beryl's most common habit is the hexagonal prism, in which six faces are parallel to the hexagonal axis. Because of close atomic packing within its crystal lattice, beryl's atomic bonding is unusually strong, which explains its very substantial Mohs hardness of 7.5-8.0. Despite its close atomic packing, beryl has a low specific gravity of 2.66-2.92 because of the low atomic weights of its essential elements. As an allochromatic or "other-colored" mineral, beryl's color is determined by traces of accessory elements. Pure beryl is colorless. In aquamarine, traces of iron that substitute for beryllium distort the crystal lattice, causing it to absorb all red, yellow, and violet wavelengths, and most green wavelengths of white light, and to reflect only blue with occasional hints of green or gray. Beryl occurs primarily in granite pegmatites and to a lesser extent in the schist of regional metamorphic rocks.

COLLECTING LOCALITIES: Aquamarine is collected in Namibia, Madagascar, Malawi, Mozambique, Zambia, Zimbabwe, Nigeria, Tanzania, Afghanistan, India, Mexico, Norway, Russia, Sri Lanka, Northern Ireland, China, Brazil, Pakistan, and the United States (California, Colorado, Connecticut, Idaho, and Maine).

HISTORY, LORE & GEMSTONE/TECHNOLOGICAL USES: Following the discovery of the element beryllium in the early 1800s, mineralogists learned that blue aquamarine, pink morganite, green emerald, colorless goshenite, and golden-yellow heliodor were all color varieties of beryl. Beryl's crystal structure was defined by X-ray diffraction methods in 1922. Because of its substantial hardness, excellent transparency, distinctive color, relatively high refractive index, abundance, and occurrence in large crystals that are sometimes of gem quality, the aquamarine variety of beryl has been a popular gemstone since medieval times. The value of aquamarine gems is based not on size, but primarily upon color intensity, degree of transparency, and the absence of visible inclusions. Available in a wide variety of cuts and styles, aquamarine gems are worn mainly in rings and also in brooches, necklaces, earrings, and bracelets. Because aquamarine gems usually exceed 3 carats and sometimes approach 20 carats in weight, they are ideal for "cocktail"-style rings. Aquamarine is traditionally mounted in white gold, and sometimes in silver and platinum. Fine gems of three or more carats now sell for about \$500 per carat. The prices of smaller aquamarine gems, which exhibit less color intensity, are considerably lower. Although aquamarine has been synthesized in laboratories, it is not cost-competitive with natural aquamarine gemstones. Until the 1960s, all non-gem forms of beryl, including aquamarine, were the primary ores of beryllium, a metal with many uses in science and industry. In 1912, the United States' National Association of Jewelers named aquamarine as the birthstone for the month of March. According to modern metaphysical practitioners, aquamarine provides foresight and courage, alleviates anxiety-related stress, and enhances happiness, intelligence, and youthful qualities.

ABOUT OUR SPECIMENS: Our composite aquamarine-schorl specimens were collected at Erongo Mountain in the Usakos and Omaruru districts, Erongo Region, Namibia. Erongo Mountain, a prominent, semicircular mountain 18 miles in diameter, is located in west-central

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Namibia 125 miles northwest of the national capital of Windhoek. The local climate is warm and semiarid, with only eight inches of annual rainfall to support a sparse, brushy, “thornveld”-type vegetation. Our specimens formed about 136 million years ago at the end of the Jurassic Period when a volcanic system collapsed to create a fractured caldera that was immediately intruded by granitic magma. The main body of magma solidified, leaving behind pockets of residual magma enriched with such unusual elements as tin, tungsten, boron, fluorine, and beryllium. This residual magma solidified very slowly on a mineral-by-mineral basis to form pegmatites, in which mariolitic (gas-formed) cavities sometimes provided space for the growth of large, well-developed crystals. These pegmatites, which were later exposed by erosion, are the source of our specimens. Erongo Mountain first attracted attention as a source of mineral and gemstone specimens in early 1999 and is now recognized as a classic locality for aquamarine. The aquamarine-containing pegmatite pockets or “nests,” as the local diggers call them, are exposed on the sides of sheer granite cliffs. The most accessible pockets have now been depleted of crystals. Because the remaining pockets are very difficult to reach and dangerous to work, aquamarine recoveries at Erongo Mountain have declined steadily in recent years. Our specimens are composites of two minerals: aquamarine and 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 latter a tourmaline-group mineral familiarly known as “black tourmaline.” Schorl is black and opaque, and typically forms long, prismatic crystals. The prisms of schorl are included within the transparent prisms of aquamarine.

COMPREHENSIVE WRITE-UP

COMPOSITION & STRUCTURE

Aquamarine, the blue, gemstone variety of the mineral beryl [beryllium aluminum silicate, $\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$], contains the elements beryllium (Be), aluminum (Al), silicon (Si), and oxygen (O) in the proportions of 5.03 percent beryllium, 10.04 percent aluminum, 31.35 percent silicon, and 53.58 percent oxygen. Like all molecules, those of beryl consist of a cation (positively charged ion) and an anion (negatively charged ion). Beryl’s compound cation consists of three beryllium ions 3Be^{2+} and two aluminum ions 2Al^{3+} , both with a collective +6 charge. This creates a total +12 cationic charge. Beryl’s compound anion is a radical, a group of atoms that acts as an entity in chemical reactions. The beryl anion is the silica radical $(\text{Si}_6\text{O}_{18})^{12-}$, in which 6 silicon ions 6Si^{4+} and 18 oxygen ions 18O^{2-} provide a total -12 anionic charge. The total -12 anionic charge balances the total +12 cationic charge to provide the beryl molecule with electrical stability.

Beryl is a member of the silicates, the largest class of minerals, in which silicon and oxygen combine with one or more metals. The basic silicate structural unit is the silica tetrahedron $(\text{SiO}_4)^{4-}$, in which four equally spaced oxygen ions positioned at the four corners of a tetrahedron surround a silicon ion. These oxygen ions are bound to the silicon ion by strong covalent bonding. In silicate minerals, silica anions and metal cations bond together like polymers (repeating chains) to form seven types of structures: double tetrahedral silicates (sorosilicates); framework silicates (tectosilicates); single- and double-chain silicates (inosilicates); sheet

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silicates (phyllosilicates); independent tetrahedral silicates (nesosilicates); and ring silicates (cyclosilicates).

Beryl is a cyclosilicate, which is the most structurally complex of all silicate subclasses. In cyclosilicates, silica tetrahedra share two of their oxygen ions with adjacent tetrahedra. Because each tetrahedra effectively loses one of its oxygen ions, this arrangement creates groups of linked $(\text{SiO}_3)^{2-}$ units. Rather than forming chain-type structures, these stubby, linked silica units combine into ring structures. In beryl, each ring consists of six $(\text{SiO}_3)^{2-}$ units, creating a six-fold geometry that is reflected in the external, hexagonal shape of its crystals. Within the crystal lattice, beryl's six-sided rings are arranged in flat sheets. Beryllium and aluminum ions bond ionically between these sheets, joining the sheets and balancing the negatively charged oxygen ions within the ring tetrahedra. Because intra-sheet distances are very small, the ionic bonding between the sheets is unusually strong, explaining why beryl has only poor, one-directional cleavage and a very substantial hardness of Mohs 7.5-8.0, much greater than that of quartz [silicon dioxide, SiO_2] at Mohs 7.0. Despite its close atomic packing, beryl has a relatively low specific gravity of 2.66-2.92 (only slightly more dense than quartz) because of the low atomic weights of its essential elements: beryllium, 9.01; aluminum, 26.98; silicon, 28.09; and oxygen, 16.00.

Beryl crystallizes in the hexagonal system, which has four axes, three of equal length and lying in a common plane and separated by angles of precisely 120 degrees. The fourth axis, called the unique or hexagonal axis, is perpendicular to the plane of the other three and may be of any length. Beryl's most common habit is the hexagonal prism with six faces that are arranged parallel to the hexagonal axis. Beryl crystals range in length from less than an inch to about 30 feet. Like most cyclosilicates, beryl usually crystallizes as elongated prisms with flat or modified-flat terminations.

As an allochromatic or "other-colored" mineral, beryl's color is determined by traces of accessory elements that distort its crystal lattice, and not by its essential elements or the inherent nature of its lattice. Pure beryl is colorless. However, the ring structures within the adjacent, superposed sheets of its crystal lattice are aligned in a manner that creates channels that readily accommodate traces of accessory metal ions, which sometimes impart distinctive colors. Red beryl is produced by traces of trivalent manganese Mn^{3+} , pink morganite by divalent manganese Mn^{2+} , golden-yellow heliodor by trivalent iron (ferric) Fe^{3+} , and emerald by trivalent chromium Cr^{3+} . In aquamarine, traces of divalent iron (ferrous, Fe^{2+}) replace beryllium (Be^{2+}), causing the beryl lattice to absorb all red, yellow, and violet Wavelengths, and most green wavelengths of white light, and to reflect only blue with occasional hints of gray or green.

Beryl occurs primarily in granite pegmatites (see "Pegmatites: Origin, Structure, and Composition") in association with quartz, schorl, microcline and orthoclase [both members of the potash-feldspar group, potassium aluminum silicate, KAlSi_3O_8], and muscovite [mica group, basic potassium aluminum silicate, $\text{KAl}_3\text{Si}_3\text{O}_{10}(\text{OH})_2$]. Beryl occurs to a lesser extent in the schist of regional metamorphic rocks with quartz, microcline, orthoclase, muscovite, and almandine [garnet group, iron aluminum silicate, $\text{Fe}_3\text{Al}_2(\text{SiO}_4)_3$].

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The Dana mineral-classification number 61.1.1.1 first identifies beryl as a cyclosilicate with six-membered rings (61). It is then defined by its $(\text{Si}_6\text{O}_{18})^{12-}$ ring structure and the presence of either hydroxyl or aluminum ions (1). Beryl is assigned to the beryl group (1) as the first (1) of five members, the other four of which are rare.

COLLECTING LOCALITIES

Our aquamarine specimens were collected at Erongo Mountain in the Usakos and Omaruru districts, Erongo Region, Namibia. Namibian aquamarine is also found at the Tsaobismund pegmatite in the nearby Karibib District. Other African localities include the Mangochi District, Southern Region, Malawi; the Muiâne pegmatite, Alto Ligonha District, Zambezia Province, Mozambique; the Kaplinkese Mine, Lukusuzi National Park, Eastern Province, Zambia; St. Anne's Mine at Mwami, Karoi District, Mashanoland West, Zimbabwe; the Gwantu pegmatites in Kaduna, Nigeria; and the Uluguru Mountains, Dar es Salaam Region, Tanzania. Aquamarine is also collected at the Sakavalana Mine at Ambatovita, Ambatofinadrahana District, Amoron'i Mani Region, Flanarantsoa Province, Madagascar;

Aquamarine is also collected in the Nilaw-Kolum pegmatite field, Du Ab District, Nuristan Province, Afghanistan; the Karur District pegmatites in Tamil Nadu, India; the Delicias Mine, El Rodeo, Baja California Norte, Mexico; the Elgkauåsen Tunnel at Røyken, Buskerud, Norway; the Nerchinsk gem mines at Nerchinsk, Chitinskaya Oblast', Transbaikalia, Eastern-Siberian Region, Russia; the Ratnapura gem gravels, Ratnapura District, Sabaragamuwa Province, Sri Lanka; and Mourne Mountain in County Down, Northern Ireland, United Kingdom. Chinese sources are the Chengjawan pegmatite, Anyuan District, Pingxiang Prefecture, Jiangxi Province; and the Huya tungsten-tin-beryllium deposit at Mt. Xuebaoding, Mianyang Prefecture, Sichuan Province.

In Brazil's Minas Gerais state, aquamarine is collected at the Batatal and Papamel mines at Marambaia in the Jequitinhonha Valley; the Ipé Mine at Governador Valadares in the Doce Valley; the Miguri Mine at Teófilo Otoni in the Mucuri Valley; and the Santa Maria de Itabira and Ponte da Raiz mines at Santa Maria de Itabira. Other Brazilian sources are the Ursina, Mimoso do Sul, and Concordia mines at Mimoso do Sul in Espírito Santo. Pakistan's localities in the Northern Areas include Skardu and the Shigar, Braidu, and Basha valleys in the Skardu District and the Haramosh Mountains and Hunza Valley in the Gilgit District.

In the United States, aquamarine is found in California at the Pala Chief and Elizabeth R. mines in the Pala district and the Little Three and Hercules mines in the Ramona district, all in San Diego County; and at the Inyo claims on Haystack Mountain near Lone Pine, Inyo County. Other localities are the summit areas of Mt. Antero and Mt. White in Chaffee County, Colorado; the Hewitt Gem Quarry at Haddam and the Strickland pegmatite at Portland, both in Middlesex County, Connecticut; the Upper Cramer Lake pegmatites in the Sawtooth Batholith, Custer County, Idaho; and the Bumpus Quarry and adjacent pegmatites near Albany, Oxford County, Maine.

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JEWELRY & DECORATIVE USES

Aquamarine has been a popular gemstone since medieval times because of its relative abundance, hardness, excellent transparency, distinctive blue color, relatively high refractive index, and occurrence in large crystals that are often of gem quality. The gem value of aquamarine is based on color intensity and degree of transparency. Unlike the color of blue sapphire [corundum, aluminum oxide, Al_2O_3], aquamarine's blue color is never intense and is, in fact, sometimes too pale for gem use. Clean, moderately-to-slightly-intense, blue colors with little hint of green or gray are most desirable and valuable. Even though aquamarine may have a water-clear transparency, it is rarely free of inclusions, which concentrate in a translucent "cloud" at the base of the prism. Termination ends, from which gems are cut, have the fewest inclusions and the greatest transparency. With a Mohs hardness of 7.5-8.0 (much harder than quartz and nearly as hard as topaz), aquamarine can easily endure everyday wear in jewelry. Aquamarine gems, which are available in many cuts and styles, are worn mainly in rings and also in brooches, necklaces, earrings, and bracelets. Because aquamarine gems usually exceed 3 carats and often approach 20 carats in weight, they are ideal for "cocktail"-style rings. Aquamarine is traditionally mounted in white gold, and occasionally in silver and platinum.

Because it can be cut into large gems, aquamarine has an unusual price structure. The per-carat price of most gems, including diamond [carbon, C], the emerald variety of beryl, ruby and sapphire [corundum, aluminum oxide, Al_2O_3], and topaz [basic aluminum fluorosilicate, $\text{Al}_2\text{SiO}_4(\text{F},\text{OH})_2$] varies greatly with individual gem size. But the per-carat value of aquamarine, whether in a 3-carat gem or a 20-carat gem, is basically the same. Aquamarine's per-carat value depends not on gem size, but on color intensity, cut, transparency, and the absence of visible inclusions.

The largest-known, gem-quality aquamarine crystal, mined in 1910 in Minas Gerais, Brazil, measured 19 inches in length and weighed 70 pounds. The American Museum of Natural History in New York City displays a 13-pound piece of the greenish-blue, outer portion of this crystal. A flawless, 879.5-carat, step-cut, blue-green aquamarine gem from this same crystal is displayed at the British Museum of Natural History in London.

In past decades, the aquamarine market has been erratic. During the 1960s and 1970s, when Brazilian stones dominated the aquamarine market, wealthy Brazilians acquired large quantities of fine aquamarine as investments, which kept prices high. Per-carat aquamarine prices approached record levels in 1980, but then plummeted as inexpensive, irradiated blue topaz (also from Brazil) flooded the market. Another factor in the market collapse was a new supply of aquamarine from Africa. Aquamarine prices are now stable, with fine gems of three or more carats selling for about \$500 per carat. Smaller aquamarine gems, which have paler color and therefore limited popularity, sell for considerably less. Gem-quality aquamarine has been synthesized in laboratories, but is not cost-competitive with natural stones. Natural aquamarine gems are often irradiated or heat-treated to intensify their blue color and remove hints of green or gray.

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HISTORY & LORE

The oldest-known aquamarine artifacts are amulets dating to 480 B.C. that were recovered from Greek tombs. According to Roman scholar Pliny the Elder (Gaius Plinius Secundus, A.D. 23-79), the Roman Emperor Nero (Nero Claudius Caesar Drusus Germanicus, A.D. 37-68) sometimes wore eyeglasses made of “emerald”; modern scholars believe that this was actually aquamarine, which forms much larger and more transparent crystals than emerald. Because aquamarine’s color so closely resembles the blue waters of the Mediterranean Sea, the stone’s lore focuses on the sea. The ancient Romans believed that aquamarine was sacred to Neptune, their god of freshwater and the sea. Roman mariners carried aquamarine talismans engraved with the likeness of Neptune to protect them on voyages. In medieval times, aquamarine was thought to impart its powers to water; medieval physicians placed aquamarine in water, then prescribed the water as a tonic to treat various ailments. Ornate statues with eyes of aquamarine supposedly enabled their owners to see into the future. Such statues were placed overlooking the sea so that their aquamarine “eyes” would calm storms and assure the safe return of ships.

The popularity of aquamarine gems soared in the mid-1600s when a large supply of high-quality aquamarine from the Portuguese colony of Brazil reached Europe. The word “aquamarine,” from the Latin *aqua marina*, literally meaning “seawater,” appeared in the English language about 1670. Early scientists assumed that blue aquamarine, pink morganite, green emerald, colorless goshenite, and golden-yellow heliodor were all different minerals species. But following the discovery of the element beryllium in the early 1800s, mineralogists realized that these were all actually color varieties of the mineral beryl. Aquamarine gems regained their popularity in Europe in the mid-1800s, when German immigrants in Brazil began mining gem-quality aquamarine and shipping it to Idar-Oberstein, Germany. During this time, Brazilian aquamarine fueled much of Idar-Oberstein’s growth as an internationally known gem-cutting center. Mineralogists used newly developed X-ray diffraction methods to define beryl’s crystal structure in 1922.

In 1912, the United States’ National Association of Jewelers named aquamarine as the birthstone for the month of March. Aquamarine also became the suggested gift gem for 18th wedding anniversaries. On April 30, 1971, the Colorado Legislature designated aquamarine as the official state gemstone in recognition of the fine crystals being recovered from the summit areas of Mt. Antero and Mt. White in Chaffee County. Aquamarine appeared on the 15-pfennig stamp of the German Democratic Republic (East Germany) in 1974, the 1.30-real stamp of Brazil in 1977, the 3-schilling stamp of Kenya in 1977, the 15-cent stamp of South-West Africa (now Namibia) in 1979, and the 200-riel stamp of Cambodia in 1998.

TECHNOLOGICAL USES

Until the 1960s, non-gem-quality beryl was the only ore of beryllium, a gray, brittle, alkaline-earth metal with a high melting point of 2349° F. (1287 ° C.). Beryllium ranks 51st in crustal abundance, about the same as tin and uranium. It is found in approximately 100 minerals, but

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does not occur free in nature. With an atomic weight of just 9.01, beryllium is the second lightest metal; only lithium (atomic weight 6.94) is lighter. Although just one-third as dense as aluminum, beryllium has much greater stiffness and structural strength. Beryllium's primary use is in exotic alloys, but its X-ray transparency and neutron-absorbing properties give it many other high-tech applications in science and industry. Beryllium is no longer obtained from beryl, but from mining volcanic tuffs rich in bertrandite [basic beryllium silicate, $\text{Be}_4\text{Si}_2\text{O}_7(\text{OH})_2$].

PEGMATITES: ORIGIN, STRUCTURE, AND COMPOSITION

Our August Mineral of the Month, the aquamarine variety of beryl, is a classic example of a pegmatite mineral. Most mineral collectors are familiar with the term “pegmatite,” and with good reason. Pegmatites have yielded many of the world's finest gemstones and mineral specimens, along with various industrial minerals and rare metals. The word “pegmatite” stems from the Greek words *pēgma*, meaning “something fastened together,” and *lithos*, meaning stone. This conjunctive usage—“stones fastened together”—refers to the texture and composition of pegmatites as conglomerates of large, individual crystals. In its simplest definition, a pegmatite is a body of very coarse-grained igneous rock that formed directly from the cooling and solidification of magma. For a rock to be classified as a pegmatite, its individual grains must be at least 3mm (0.12 inch) in diameter. Pegmatites can form from granitic-, syenitic-, dioritic-, or gabbroic-based magmas.

From the standpoint of gemstones and collectible minerals, this special section of our write-up will focus on granite pegmatites. Granitic magma is composed primarily of quartz and feldspar minerals, with lesser amounts of mica-group minerals. Granitic magma also contains traces of phosphorus, sulfur, fluorine, chlorine, rare metals, and other unusual elements. When granitic magma intrudes existing rock, it usually cools relatively quickly, solidifying or “freezing” into fine-grained granite consisting of evenly disseminated mineral components. But after most of the magma has solidified, occasional pockets of residual magma retain their heat and remain fluid. This residual magma, which is often enriched with rare or unusual elements, cools very slowly from the outside to the center to form zoned, concentric pegmatite bodies. Crystal sizes of the quartz, feldspar, and mica minerals at the outside of a pegmatite body are only slightly larger than those of the surrounding granite. But crystal size and the concentration of unusual minerals increase rapidly toward the center. The final solidification of pegmatites is a process of fractional crystallization that takes place on a mineral-by-mineral basis. Mariolitic (gas-formed) cavities at the center of pegmatites sometimes provide space for the growth of exceptionally large and well-developed crystals of unusual minerals.

Although they yield many fine mineral specimens and valuable gemstones, pegmatites are not common. Compared to the size of the overall granitic bodies in which they form, they are actually quite rare. Most pegmatites constitute only about 0.003 percent of the mass of their host granitic bodies. Pegmatite bodies vary widely in zoning structure, chemical composition, and length, from only a few inches to more than a mile.

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Pegmatites are important sources of such industrial minerals as microcline [feldspar group, potassium aluminum silicate, KAlSi_3O_8], which is used in ceramics and mild abrasives, and muscovite [mica group, basic potassium aluminum silicate, $\text{KAl}_3\text{Si}_3\text{O}_{10}(\text{OH})_2$], which has numerous uses, notably as an electrical-insulation material. Commercially important pegmatite districts are found in Brazil, Namibia, Pakistan, and the United States (California, Maine, South Dakota, Colorado, and North Carolina).

Pegmatites are also commercial sources of rare metals. Such pegmatite minerals as beryl have been a source of beryllium, while the lepidolite-series of lithium-rich mica-group minerals and spodumene [lithium aluminum silicate, $\text{LiAlSi}_2\text{O}_6$] are sources of lithium. Pollucite [hydrous cesium sodium aluminum silicate, $(\text{Cs},\text{Na})(\text{AlSiO}_2) \cdot n\text{H}_2\text{O}$] is a source of cesium, and columbite-(Fe) [iron niobium oxide, FeNb_2O_6] and tantalite-(Fe) [iron tantalum oxide, FeTa_2O_6] are sources of niobium and tantalum.

Pegmatite gemstones include aquamarine and other color varieties of beryl; the purple kunzite variety of spodumene; the amethyst, smoky, and rose varieties of quartz [silicon dioxide, SiO_2]; the tourmaline-group mineral elbaite [basic sodium aluminum lithium borosilicate, $\text{Na}(\text{Al}_{1.5},\text{Li}_{1.5})\text{Al}_6(\text{Si}_8\text{O}_{18})(\text{OH})_4$], chrysoberyl [beryllium aluminum silicate, BeAl_2O_4]; and topaz [basic aluminum fluorosilicate, $\text{Al}_2\text{SiO}_4(\text{F},\text{OH})_2$].

ABOUT OUR SPECIMENS

Our composite specimens of aquamarine and schorl were collected at Erongo Mountain in the Usakos and Omaruru districts, Erongo Region, Namibia. Located in southern Africa, Namibia adjoins the Atlantic Ocean on the west, Angola on the north, Botswana on the east, and South Africa on the south. Covering 318,259 square miles, Namibia's area roughly equals that of the combined American states of Texas and Oklahoma. Because much of Namibia is arid, inhospitable desert, its population is only 2.2 million, making it the world's second least-densely populated nation after Mongolia. In 1884, Great Britain annexed part of the region to its Cape Colony (now South Africa), while Germany claimed adjacent sections as its Südwestafrika (South-West Africa) colony. During World War I, South Africa occupied South-West Africa, then assumed regional administration in 1920 before finally annexing South-West Africa in 1946. In 1968, the United Nations renamed the region Namibia and appointed an international council to supervise its affairs prior to independence. Fighting between South African troops and the South-West Africa People's Organization (SWAPO) rebels continued through the 1980s. In 1992, Namibia adopted a SWAPO-controlled, constitutional, Western-style government and received its independence. Today, Namibia's economy relies on farming and ranching, along with mining for diamonds, gold, copper, and uranium.

Erongo Mountain, a prominent, semicircular mountain 18 miles in diameter, is located in central Namibia, 125 miles northwest of the national capital of Windhoek, and 10 miles north of the towns of Usakos and Karibib. The local climate is warm and arid; an annual rainfall of just eight inches supports the brushy, "thornveld" vegetation. Erongo Mountain is geologically complex, with both extrusive (volcanic) rocks and granitic (plutonic) rocks. About 136 million years ago

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at the end of the Jurassic Period, a volcanic system collapsed to form a caldera. Magma then intruded the fractured caldera to emplace the alkaline (silica-poor) Erongo Granite as a ring-shaped system of dikes around the edge of the caldera that contained numerous pegmatites. German geologists conducted the first mineralogical studies of Erongo Mountain in the early 1900s. In the 1920s, prospectors discovered pegmatite outcrops rich in ferberite [iron tungstate, FeWO_4] and cassiterite [tin oxide, SnO_2]. Several tin-tungsten mines opened in the 1930s, the largest being the Krantzberg Mine where ores graded as high as 60 percent tungsten.

Prior to the late 1990s, Erongo Mountain provided only a few mineral specimens of schorl and quartz. Then in 1999, local specimen “diggers” discovered small pegmatite pockets filled with fine aquamarine crystals. These were snapped up by collectors in Europe and the United States, driving demand and prices for Erongo Mountain aquamarine up and attracting growing numbers of diggers. Along with aquamarine, the diggers also recovered specimens of jet-black schorl and twinned crystals of orthoclase [potash-feldspar group, potassium aluminum silicate, KAlSi_3O_8]. Other valuable specimens included yellow beryl (heliodor); gemmy monazite-Ce [cerium lanthanum neodymium phosphate, $(\text{Ce}, \text{La}, \text{Nd})\text{PO}_4$]; Japan-law twinned quartz, emerald-green fluorite [calcium fluoride, CaF_2]; and exceptional crystals of jeremejevite [aluminum fluoroborate, $\text{Al}_6(\text{BO}_3)_5\text{F}_3$]. In 2006, *The Mineralogical Record* carried a feature article on Erongo Mountain minerals by Bruce Cairncross, South Africa’s preeminent mineralogist. The cover featured an extraordinary, deep-blue, seven-inch-long aquamarine specimen that established Erongo Mountain’s current status as a classic aquamarine locality.

Collecting aquamarine and other mineral specimens at Erongo Mountain is difficult. Although a dirt road follows the mountain’s perimeter, only foot trails access the rugged interior. The aquamarine-containing pegmatite pockets or “nests,” as the local diggers call them, are exposed on the sides of sheer, 200-foot-high granite cliffs. Unstable and exceedingly dangerous, these cliffs have claimed the lives of several diggers. The most easily accessible pegmatite nests have already been cleaned out. And because the remaining nests are difficult to reach and work, the supply of Erongo Mountain aquamarine has declined in recent years.

Our composite specimens consist of aquamarine and schorl [basic sodium iron aluminum borosilicate, $\text{NaFe}_3\text{Al}_6(\text{BO}_3)_3(\text{Si}_6\text{O}_{18})(\text{OH})_4$]. Schorl, a member of the tourmaline-mineral group, is commonly known as “black tourmaline.” Opaque and usually jet-black in color, schorl has a specific gravity of 3.1-3.2, a Mohs hardness of 7.5, and indistinct cleavage. Crystallizing in the trigonal (hexagonal) system as stubby-to-acicular prisms, schorl was once a popular gemstone, especially in Victorian-era mourning jewelry.

When examining your specimen, note first the pale-blue color of the aquamarine, which is caused by traces of iron. Then observe the nearly perfect, hexagonal cross section of the aquamarine prism and its flat termination, which is the primary habit of beryl crystals. Notice how the long prisms of black schorl, some of which are needle-like, are completely included within the aquamarine crystal. This indicates that the aquamarine and the schorl crystallized at the same time. As the aquamarine crystal was developing, crystals of schorl formed on its surface and became enveloped in the continuing growth of the aquamarine.

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