

December 2011 Mineral of the Month: Carnelian

This month's mineral, the carnelian gem variety of microcrystalline quartz, is from Madagascar. Our write-up details the mineralogy and rich lore of carnelian, and explains why Madagascar is poised to become one of the world's great gemstone sources.

OVERVIEW

PHYSICAL PROPERTIES

Chemistry: SiO_2 Silicon Dioxide, containing varying amounts of iron.

Class: Silicates

Subclass: Tectosilicates

Group: Quartz

Subgroup: Microcrystalline Quartz (Chalcedony)

Crystal System: Hexagonal

Crystal Habits: Microcrystalline, occurs in compact form as veins and nodules.

Color: Red to brownish-red, orange-red, and orange-brown.

Luster: Vitreous to waxy and dull

Transparency: Semi-transparent to translucent

Streak: White

Refractive Index: 1.530-1.539

Cleavage: None

Fracture: Conchoidal to subconchoidal and irregular; brittle to tough.

Hardness: Mohs 6.5-7.0

Specific Gravity: 2.58-2.64

Luminescence: None

Distinctive Features and Tests: Best field marks are translucency, reddish color, hardness, conchoidal fracture, and microcrystalline structure. Can be confused with agate, jasper, and other similarly colored types of chalcedony.

Dana Classification Number: 75.1.3.1



Figure 1, Polished carnelian from Madagascar.

NAME The name "quartz," pronounced KWORTZ, stems from the German *Quarz*, which is derived from the Slavic word *kwardy*, meaning "hard." The word "chalcedony," pronounced "cal-SEH-d'nie," stems from Chalcedon, an ancient Greek city in Asia Minor. The word "carnelian," pronounced car-NEEL-yen, is rooted in the Old French *cornele*, or "cornel cherry," alluding to the red color of the fruit of the European Cornel plant, a species of dogwood native to southern Europe. (In North America, the plant is known as "Cornelian Cherry.") The ultimate root of the word "carnelian" is the Latin *caro* meaning "flesh-like." Other names for carnelian are "cornelian," "cornaline," "corneole," "red agate," "red jasper," "sadoine," "Mecca stone," "pigeon's blood agate," "blood agate," "blood quartz," "canary stone," "touchenite," and "jadine." In European gemological literature, carnelian appears as *cornaline*, *cornalina*, *corniola*, and *Kornalin*.

COMPOSITION: Carnelian is a translucent, red form of chalcedony, the microcrystalline variety of quartz. The chemical formula of quartz, SiO_2 , shows that it contains two elements, the semimetal silicon (Si) and oxygen (O). The molecular weight of quartz is made up of 53.26 percent oxygen and 46.74 percent silicon. The silica tetrahedron (SiO_4)⁴⁻, the fundamental building block of all silicates, consists of a silicon ion surrounded by four, equally spaced oxygen ions positioned at the four corners of a tetrahedron (a four-

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faced polyhedron). Quartz is an allochromatic (other-colored) mineral, meaning that its colors are caused by traces of nonessential, color-producing elements called chromophores. Both the reddish colors and the soft translucency of carnelian are due to small, variable amounts of hematite. Carnelian is found in igneous, metamorphic, and sedimentary rocks, most importantly as amygdule fillings in volcanic basalt.

COLLECTING LOCALITIES: Gem-quality carnelian is found in Madagascar, India, and Brazil. Other sources are located in Mozambique, South Africa, Uruguay, Australia, China, Russia, Sri Lanka, Austria, France, Germany, Poland, Portugal, Switzerland, and England. In the United States, carnelian is collected in Alabama, Arizona, California, Colorado, Iowa, Maine, Michigan, New Jersey, New Mexico, Oregon, Tennessee, Texas, Utah, and Washington.

HISTORY, LORE, & GEMSTONE/TECHNOLOGICAL USES: Carnelian has served as a gemstone for thousands of years and was considered a precious stone at various times in antiquity. Early carnelian artifacts include Assyrian cylinder seals, Egyptian and Phoenician scarabs, and Greek and Etruscan gems. Ancient Egyptians placed carnelian amulets in the wrappings of mummies, hoping to aid the journey of the deceased into the afterlife; they also inlaid polished carnelian into the funeral masks of kings. Color and degree of translucency are the factors that determine carnelian's gemstone value. In jewelry, carnelian beads are used in bracelets, earrings, and necklaces; cabochons are set in rings and pendants. Oval or round cabochons up to 20 carats in weight are set into rings or worn as pendants. Carnelian is occasionally faceted into square or emerald-cut gems; while unusual and distinctive, these do not show off carnelian's beauty as well as cabochons. Carnelian gems are usually mounted in silver or low-carat gold settings. Only the finest grades of carnelian serve as gemstones; lesser grades are fashioned into small spheres, figurines, and other decorative objects. Carnelian is often heated to improve its color and translucency. Gray or white forms of chalcedony can be dyed to produce carnelian-like red colors. Our supplier assures us that, except for polishing, our Madagascar carnelian has not been treated in any way. Carnelian has no current technological uses. Metaphysical practitioners believe that carnelian can help its wearer overcome anger, maintain self-control, increase self-awareness, improve memory, and calm fears about death.

ABOUT OUR SPECIMENS: Our carnelian specimens were collected at a carnelian quarry at Amberjeby near the seaport city of Mahajanga in the Boeny Region of northeast Madagascar, by a company that has extensive gemstone mine and quarry holdings in Madagascar and also explores for new deposits. It has operated in Madagascar since the early 1980s, is a major employer of Madagascans, and operates two schools in remote mining areas to benefit local children. The Amberjeby quarry is located in a formation of heavily weathered, volcanic rock. When this rock was emplaced, it contained numerous barren vesicles that later filled with groundwater solutions rich in silica and hematite. These solutions eventually formed silica gels that solidified into the reddish carnelian variety of microcrystalline quartz. As erosion and weathering reduced the basalt formations into a coarse earth and gravel, the harder, more resistant carnelian survived as nodules dispersed through the sediments. Mining is conducted mainly by shallow digging, with blasting employed only when necessary.

10 YEARS AGO IN OUR CLUB: Moldavite, Ceske Budejovice, Bohemia, Czech Republic. Moldavite is the lovely, translucent, green natural glass found only in the Czech Republic, a variety of the naturally occurring rocks known as tektites. Tektites are classified as natural glass, created, according to a consensus of most scientists, by the force of large meteorite impacts on the earth. Some scientists believe that, about 15 million years ago, a meteorite more than half a mile wide slammed violently into southern Germany. In a fraction of a second, surface rocks were transformed into glass and flung a couple hundred miles east, into what is now the southwestern portion of the Czech Republic! Moldavite has become one of our best sellers at shows, and we eagerly obtain new lots of choice pieces whenever possible.

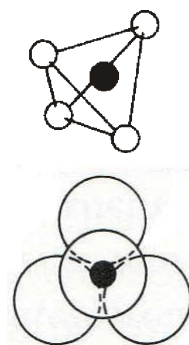
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COMPREHENSIVE WRITE-UP

COMPOSITION

Carnelian is the name for translucent, red chalcedony, the microcrystalline variety of quartz. The chemical formula of quartz, SiO_2 , shows that it contains two elements, the semimetal silicon (Si) and oxygen (O). The molecular weight of quartz is made up of 53.26 percent oxygen and 46.74 percent silicon. The cation (positively charged ion) in the quartz molecule is the silicon ion Si^{4+} with its +4 charge. The anion (negatively charged ion) consists of two oxygen ions 2O^{2-} with a collective -4 charge. The balance of these +4 cationic and -4 anionic charges provides the quartz molecule with electrical stability.

Quartz is a member of the silicates, the largest and most abundant mineral class. The silica tetrahedron (SiO_4)⁴⁻, the fundamental building block of the silicates, consists of a silicon ion surrounded by four equally spaced oxygen ions positioned at the four corners of a tetrahedron (a four-faced polyhedron). In the quartz-crystal lattice, all four oxygen ions in each silica tetrahedron bond covalently to the silicon ions of adjacent tetrahedra so that each silicon ion is surrounded by four oxygen ions, and each oxygen ion is surrounded by two silicon ions. This arrangement satisfies the -4 charge of each individual tetrahedron and creates the infinite, three-dimensional structure of quartz, in which each balanced molecular unit is represented by the formula SiO_2 . Silicon and oxygen are the most abundant elements in the Earth's crust, comprising three-quarters of its total weight. In silicate minerals, silica anions bond with metallic or semimetallic cations to form repeating chains with seven distinct, structural configurations: independent tetrahedral silicates (nesosilicates); double tetrahedral silicates (sorosilicates); single- and double-chain silicates (inosilicates); ring silicates (cyclosilicates); sheet silicates (phyllosilicates); and framework silicates (tectosilicates). Quartz is a framework silicate or tectosilicate.



Figures 2 and 3.
Silica tetrahedron,
represented in two
different ways.

Because the covalent bonding within the quartz lattice exerts omnidirectional strength, quartz crystals have neither symmetry nor cleavage planes. This lack of cleavage and the high bonding strength achieved through close atomic packing account for quartz's substantial hardness of Mohs 7.0. Yet despite its close atomic packing, the light atomic weights of silicon (28.09) and oxygen (16.00) give quartz a relatively low specific gravity of 2.65.

As an allochromatic (other-colored) mineral, the colors of quartz are caused not by essential elemental components or the nature of its crystal structure, but by traces of nonessential, color-producing elements called chromophores. Pure quartz is colorless or white, but impurities can create a wide range of colors. The diagnostic reddish colors and soft translucency of carnelian are due to small, variable amounts of the abundant mineral hematite [iron oxide, Fe_2O_3]. The ferric (Fe^{3+}) form of iron present in hematite is a strong red chromophore. In carnelian, ferric iron is present in two forms. The first is as included layers of microscopic hematite, which reflect light in a manner that creates the soft, deep, translucent "glow" exhibited by fine carnelian specimens. Iron is also present within the carnelian crystal lattice as iron (ferric) ions, which distort the lattice, causing it to absorb the violet, blue, green, and most of the yellow wavelengths of the white-light spectrum, and to reflect only the red and orange wavelengths.

The Dana mineral classification number 75.1.3.1 first identifies quartz as a framework silicate or tectosilicate (75). The subclassification (1) defines it by its four-oxygen coordination, in which each silicon cation is bound to four oxygen anions, as defined by the chemical formula of the silica tetrahedron (SiO_4)⁴⁻. Quartz is then assigned to the quartz group (3) as the first (1) and only member.

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It is important to understand that quartz occurs in two distinctly different forms: macrocrystalline and microcrystalline. Macrocrystalline quartz consists of crystals exceeding 50 microns (0.05 millimeters) in size. Macrocrystalline quartz includes such familiar varieties as amethyst, citrine, rock crystal, and milky, smoky, and rose quartz, all of which occur as large, well-developed, individual crystals or groups of crystals that are transparent to translucent, with the exception of rose quartz, which typically forms in large masses or as very small crystals. In microcrystalline quartz, also called chalcedony or compact quartz, individual crystals are less than 50 microns (0.05 millimeters) in size. Chalcedony consists of microscopic silica grains or fibrous silica crystals in which natural mineral pigments create a broad range of colors and color patterns. Types of chalcedony include carnelian and chrysoprase (which is green), along with agate and jasper in many colors and color patterns.

Macrocrystalline quartz grows by adding silica molecule by molecule to form successive layers on the crystal's surface. Growth takes place at high or low temperatures and pressures and in environments where sufficient space permits orderly crystal development. On the other hand, chalcedony, or microcrystalline quartz, forms from the solidification of colloidal silica suspensions in the absence of space and in the low temperatures and pressures of shallow environments. Chalcedony often forms horizontal bodies or "lenses" in chemical-sedimentary rocks (rocks formed by chemical precipitation) or occurs as fillings within amygdulose of volcanic rocks. In either case, the chalcedonic formation process begins with silica that has weathered free from silicate minerals and is carried in groundwater as microscopic particles in colloidal suspension. These silica particles eventually settle out of suspension as a water-based silica gel. Over time, this gel loses most of its water to form solid masses of chalcedony composed of interlocking, microscopic crystals.

Because of its microcrystalline nature, chalcedony lacks the structural homogeneity of macrocrystalline quartz. As a result, the hardness of chalcedony ranges from 6.0 to 7.0, somewhat less than that of quartz at Mohs 7.0. The density of chalcedony also varies from that of quartz (specific gravity 2.65). The specific gravity of chalcedony, which can contain up to four percent impurities, ranges from 2.58 to 2.64. With its homogenous crystal structure and higher purity, macrocrystalline quartz is transparent to translucent, while chalcedony, which is less pure and non-homogenous, ranges from semi-transparent to translucent and opaque. Quartz has little porosity, while chalcedony is quite porous. The structure of chalcedony varies from grain-shaped microcrystals (microgranular) to fibrous microcrystals (microfibrous), and is determined by the specific conditions of temperature, pressure, and chemistry that exist at the time of its formation.

Quartz and chalcedony are colored in different ways. Quartz is colored mainly by a primary process in which traces of chromophores alter the crystal lattice to impart color. Secondary coloration in quartz is usually limited to surface mineral staining. Primary coloration in chalcedony occurs only to a limited extent. Most chalcedony colors are of secondary origin. Because chalcedony is porous, it is easily permeated by mineral-bearing groundwater solutions containing the chromophoric ions of such elements as iron, manganese, and nickel. These groundwater solutions can deposit minerals in the interstitial spaces between chalcedony's microcrystals to create a range of colors and color patterns. When formed, most chalcedony is gray, grayish-white, or tan, colors that indicate minimal chromophoric content and are most common in chalcedony from deep deposits. Shallow deposits of chalcedony, however, are often exposed to circulating, mineral-rich groundwater that imparts the secondary coloration and translucency typical of carnelian, chrysoprase, agate, and jasper.

Carnelian is found in igneous, metamorphic, and sedimentary rocks. Carnelian with the purest red colors and largest size occurs in basalt formations. As an extrusive (volcanic) igneous rock, basalt forms when magma solidifies at or near the earth's surface. Basalt is a fine-grained rock with relatively little quartz, but containing large amounts of iron and magnesium that impart its characteristic dark color. The structure of

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basalt frequently includes vesicles (cavities) and amygdules. Vesicles form from gas bubbles within the flowing magma, usually near the top of the flow where reduced pressure permits expansion of steam and gases. Amygdules are vesicles that later became filled with secondary minerals such as quartz. When lava solidifies, its vesicles are barren or hollow. But contraction of basalt formations upon cooling creates fissures and fractures through which groundwater later circulates. As this water percolates downward through the basalt, it becomes alkaline and transports silica as microscopic particles in colloidal suspensions that fill vesicles and eventually form silica gels. In the low temperatures and low pressures of shallow mineralogical environments, these gels can crystallize into solid masses of chalcedony composed of interlocking, microscopic crystals. The formation of carnelian requires the presence of hematite [iron oxide, Fe_2O_3]. In basalt, hematite is abundant and forms from the weathering and oxidation of other iron minerals. Under proper conditions, gels rich in silica, hematite, and free iron ions can crystallize as the reddish, iron-rich carnelian variety of chalcedony.

COLLECTING LOCALITIES

Carnelian is widely distributed and relatively abundant. Because carnelian tends to occur throughout large volcanic or sedimentary formations, sources are often not site-specific and thus poorly documented. Large quantities of carnelian also weather free from their original host formations. Carnelian, which is hard and durable, can survive alluvial transport over long distances and is often found in riverbed, plain, and valley sediments far from its original source.

The finest carnelian is found in Madagascar, India, and Brazil. Our specimens were collected at a carnelian quarry at Amberjeby in the Boeny Region of northeast Madagascar. African carnelian also occurs in Mozambique at Limbombas, Maputo Province; and in South Africa in the Messina District in Limpopo Province, the Kimberly and Hay districts of Northern Cape Province, and Lichtenburg in Northwest Province. Botswana in southern Africa is also a source of excellent carnelian.

In India, carnelian is mined at Rajpipia and Ratnapur in the state of Gujarat. Other notable worldwide localities are Iguaçu Falls, Foz do Iguaçu, Paraná, Brazil, and the immediately adjacent areas of Uruguay; Cornelian Bay at Hobart, Tasmania, Australia; the Kaiputai iron-copper deposit in Yili Hasake Prefecture, Xinjiang Province, China; Imakane in Hiyama Province, Hokkaido Island, Japan; the Salmi basalt outcrops at Pitkyaranta, Karelia Republic, Northern Region, Russia; and the Ratnapura District, Sabaragamuwa Province, Sri Lanka. In Europe, carnelian is found in Austria at the Waldisch iron deposit at Ferlach, Karawanken Mountains, Carinthia; in France at the La Corveraine Mine at Saphoz, Haute-Saône, Franche-Comté; in Germany at Idar-Oberstein, Rheinland-Phalz; in Poland at Kamienia Góra, Lower Silesia; in Portugal at Monte Suímo, Lisboa District; in Switzerland at Séprais, Bassecourt; and in England at the Botallack Mine at St. Just, St. Just District, Cornwall.

In the United States, carnelian is collected at Blountville, Blount County, Alabama; the Holbrook district, Navajo County, Arizona; at Nipomo, San Luis Obispo County, California; the Embargo district, Mineral County, Colorado; Big Creek and Skunk River, Henry County, Iowa; at Loring and Lewis coves, Washington County, Maine; the southern shore of Lake Superior, Michigan; at Stirling Creek (Carnelian Creek), Warren Township, Somerset County, New Jersey; the Cookes Range, Luna County, New Mexico; the Coyote Gulch agate locality at Chandler Mountain, Linn County, Oregon; Horse Mountain in Yarrow County, Tennessee; the Ritchie and Woodward ranges near Alpine, Brewster County, Texas; in the Colorado River gravels near Cisco, Grand County, Utah; and Salmon and Lewis creeks in Lewis County, Washington. It is interesting that Nipomo, California, is listed as a source of carnelian—we live about 50 miles northwest of Nipomo, and know many rockhounds from that area, and cannot recall anyone speaking of Nipomo carnelian! Perhaps the locality has been worked out. Guess we will have to do some further research among the local rockhounds and see if anyone has collected carnelian in Nipomo!

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JEWELRY & DECORATIVE USES

Carnelian has served as a gemstone for thousands of years and was considered a precious stone at various times in antiquity. Color and degree of translucency are the primary factors that determine carnelian's gemstone value. Ideally, carnelian will have a pure, evenly distributed, red color. In most carnelian, however, the basic red color is tinged with hues of brown, orange, or yellow. Fine carnelian also exhibits a soft translucency that reflects and transmits light as a warm glow. Carnelian is often confused with two other forms of microcrystalline quartz: sard and reddish jasper. Sard, also a semi-precious gemstone, is generally brown or reddish-brown in color. Although the differentiation between sard and carnelian is imprecise, browns generally dominate in sard, while reds dominate in carnelian. The degree of translucency distinguishes red jasper from carnelian: Jasper is opaque, while carnelian is translucent.

Although relatively abundant, carnelian rarely occurs in colors, degrees of translucency, and sizes that are suitable for gemstone or decorative uses. In jewelry, carnelian is most often used as beads and cabochons. Most carnelian beads weigh between 5 to 10 carats and are used in bracelets, earrings, and necklaces. Oval or round cabochons up to 20 carats in weight are set into rings or worn as pendants. Carnelian is occasionally faceted into square or emerald-cut gems; while unusual and distinctive, these do not show off carnelian's beauty as well as cabochons. Carnelian gems are usually mounted in silver or low-carat gold settings. Only the finest grades of carnelian serve as gemstones; lesser grades are fashioned into small spheres, figurines, and other decorative objects.

Carnelian is often enhanced to improve its color and translucency. Heating is routinely used to darken light colors, eliminate objectionable brownish tinges, bring out more desirable red colors, and increase translucency. Gray or white forms of chalcedony are often dyed to produce carnelian-like, red colors. Carnelian is also widely imitated with colored glass and bone-china ceramics.

HISTORY & LORE

Wherever it could be obtained in sufficient size, prehistoric cultures fashioned carnelian into tools and weapons. Archaeologists have recovered carnelian amulets and beads from cultural sites in Turkey and Crete dating to 3000 B.C and earlier. Carnelian artifacts recovered from later sites include Assyrian cylinder seals, Egyptian and Phoenician scarabs, and early Greek and Etruscan gems. Ancient Egyptians placed carnelian amulets into the wrappings of mummies, in an attempt to aid the journey of the deceased into the afterlife; they also inlaid polished carnelian into the funeral mask of King Tutankhamen (ca 1370-1352 B.C.) and other kings. Additionally, Egyptians carved heart-shaped carnelian amulets as symbols of immortality. The high value of carnelian in ancient times is apparent in the elaborate necklaces of gold and carnelian beads recovered from Cypriot graves. Because polished carnelian does not adhere to hot wax, it was employed extensively during Roman times as the engraved gem in signet or seal rings. The Romans also believed that carnelian enhanced strength, courage, and confidence. During medieval and Renaissance times, healers and physicians advised wearing carnelian to provide protection from storms and evil enchantments. Carnelian, which symbolized the warm blood of life, was also thought to purify the blood and relieve back pain. The modern word "carnelian" entered the English language about 1695 as an anglicized pronunciation of the French *cornele*, or "cornel cherry," a reference to the stone's reddish color.

In his book *The Mystical Lore of Precious Stones*, George Frederick Kunz (1856-1932), America's first gemologist, wrote that the *lapidario* or gemological consultant of Alfonso X (King of Castile and León, 1221-1284) advised wearing carnelian gems to enhance public-speaking skills. Kunz also noted that carnelian gems were especially popular among Muslims because the prophet Muhammad (Abû al-Qâsim Muhammad ibn 'Abd Allâh, ca 570-632 A.D.) wore on the little finger of his right hand a silver signet ring

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with an engraved carnelian. The preeminent imam Jafar (Ja'far ibn Muhammad al-Sâdiq, 702-765 A.D.) believed that men who wore carnelian would have all their desires gratified. The French emperors Napoleon I (1769-1821) and Napoleon III (1808-1873) also wore engraved carnelian gems.

The world's largest carnelian mines are located at Rajpipia near the city of Bharût in the state of Gujarat in western India. At Rajpipia, carnelian had originally formed within amygdules in the basalt formations of the Deccan Traps. Weathering and erosion eventually reduced the surface of these formations to a coarse, crumbly earth. The resistant carnelian remained intact and could be recovered by digging. Carnelian mining at Rajpipia began about 1500 A.D. to supply stonecutters in nearby Bombay (now Mumbai), then a center for Indian lapidary arts. In the 1830s, British surveyors reported more than a thousand miners digging pits 30 feet deep and shafts 50 feet deep to search for carnelian nodules. These nodules weighed as much as three pounds each, but not all had an attractive red color. The nodules that were heavily tinged with brown were laid in the sun for a year and turned every 15 days. Then they were placed in large, earthenware crocks and heated in fires for 12 hours. The combination of heat and long periods of sunlight reduced the brownish cast to produce brighter red colors and greater translucency. This treated carnelian was then cut into cabochons, beads, and decorative items and distributed throughout India and much of the world. The Rajpipia mines are still producing carnelian today.

Carnelian was featured on the 5-cent stamp of New Zealand in 1982. Modern metaphysical practitioners believe that carnelian possesses an unusual array of empowering properties. As a healing stone in the emotional realm, carnelian, which now symbolizes the warm, positive, vitalizing energy of the Earth, is said to help its wearer overcome anger, maintain self-control, increase self-awareness, improve memory, and calm fears about death.

TECHNOLOGICAL USES

Although it has no current technological uses, carnelian and other forms of microcrystalline quartz played a vital role in prehistoric technological advancement. Throughout the Paleolithic and Neolithic stone ages, chalcedony, due to its abundance, hardness, durability, and conchoidal fracture, was a valuable mineral resource that was fashioned into weapons and tools. It was also an important trading commodity.

THE GEMSTONES OF MADAGASCAR

During the last two decades, Madagascar has emerged as a leading source of precious and semi-precious gemstones. Because of complex geology that has led to an abundance of various gemstones in easily mined, sedimentary deposits, and a huge, underemployed workforce, artisanal mining has greatly increased in one of the world's poorest nations. Gemstones were discovered in Madagascar in French colonial times, but never commercially mined. Madagascar's current gemstone-mining boom has its roots in the nation's difficult transition from colonial status to independence during the 1950s and 1960s (see "About our Specimens") that created an unstable government, along with economic stagnation and rampant unemployment. During the 1970s, as demand and prices for gemstones, gems, decorative and ornamental stones, and mineral specimens increased rapidly, many of Madagascar's unemployed workers turned to artisanal gemstone mining and prospecting. By the 1980s, the remarkable abundance, variety, and quality of Madagascar's gemstones had begun to attract foreign gemstone dealers and gemstone-mining companies, while the numbers of artisanal miners continued to grow. Here is a brief history of the factors that led to the explosion of fine gem material, mineral specimens, fossils, and decorative stone coming from this fascinating island nation.

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In 1992, prospectors discovered sapphire, the non-red, gem variety of corundum [aluminum oxide, Al_2O_3], and alexandrite, the dichroic, gem variety of chrysoberyl [beryllium aluminum oxide, BeAl_2O_4], in river and alluvial gravels at Ilakaka in southwestern Madagascar. These extraordinarily rich “Swiss Bank” deposits, as they became known, triggered a gemstone rush in which the tiny settlement of Ilakaka exploded into a boomtown of 60,000 people, most of whom were engaged in pick-and-shovel mining. Ilakaka was, and still is, plagued by the typical boomtown problems of overcrowding, environmental degradation, crime, and poor sanitation.

Other discoveries followed at Andranondambo and Tranomaro near Madagascar's southeastern coastline, where blue sapphires occurred in river plain under only a few feet of clay and gravel. Prospectors next found alluvial deposits of ruby, the red-gem variety of corundum, at Vatmandry and Andilamena in the nation's interior. Then in 1999, pegmatites rich in emerald, the green gem variety of beryl [beryllium aluminum silicate, $\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$], were found in weathered granite outcrops near the east-coast city of Mananjary. Prospectors subsequently found aquamarine, the blue, gem variety of beryl, at Tsaramanga in southern Madagascar—where aquamarine mining was hindered by large sections of valuable rose quartz! These large masses of pretty pink quartz were carved into spheres, eggs, crystal-like points, figurines, and even plates and bowls, among other things,

By 2005, more than 500,000 Madagascans were engaged in some aspect of the gemstone-mining industry. While rough gemstones were being exported in huge quantities, only a tiny fraction of this overall production was being cut, polished, or treated in Madagascar. Most sapphires and rubies went to Thailand for heat-treatment, while other stones went to India or Hong Kong for cutting. Much rough was smuggled out of the country to avoid production taxes. In 2005, an estimated \$20 million in rough gemstones was legally exported, yet the value of the smuggled gemstones was estimated at 5 to 10 times higher. The smuggling issue exploded in 2007, when a French gemstone-mining company recovered a 536-kilogram (1,179-pound) emerald-in-matrix and exported it. Asserting that the exportation had been illegal, the government in 2008 imposed a ban on all further gemstone exports. The intent of this ban was to encourage the development of domestic lapidary industries to benefit the local economy, increase employment, and attract foreign stone-cutting companies. Instead, the ban dramatically reduced gemstone production and drove several foreign mining companies out of the country. Economic pressure forced the government to lift the ban in 2009, after which mining recovered rapidly. We would like to point out that the supplier of our carnelian specimens, operates a number of mines as well as a large lapidary facility in Madagascar and is a major local employer (see “About our Specimens”).

Recent discoveries in Madagascar include deposits of tsavorite, a green variety of grossular [garnet group, calcium aluminum silicate, $\text{Ca}_3\text{Al}_2(\text{SiO}_4)_3$] at Behara in southern Madagascar and demantoid, a green, gem variety of andradite [garnet group, calcium iron silicate, $\text{Ca}_3\text{Fe}_2(\text{SiO}_4)_3$] at Antetetzambato in the north. Within three months after the demantoid discovery, the number of artisanal miners at Antetetzambato grew from 30 to 5,000. Another new mine at Ambatonrazaka, also in the north, is now producing 90 tons of gem- and ornamental-grade amethyst each year.

With the world's largest reserves of gem-quality sapphire and enormous deposits of other gemstones, Madagascar has great potential to become a world leader in gemstone production, eventually matching or exceeding the historic production of such nations as Sri Lanka, Myanmar, and Thailand. But government instability (a violent rebellion was suppressed in 2009) has made it difficult to attract the foreign investment and expertise necessary to further develop its mining industry and expand its domestic lapidary industry.

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ABOUT OUR SPECIMENS

As noted, our carnelian specimens were collected at the Madagascar Minerals carnelian quarry at Amberjeby near the seaport city of Mahajanga, population 160,000, in the Boeny Region of northeast Madagascar. (Note: On older maps, Mahajanga appears with the French spelling of "Majunga." Prior to 2009, Mahajanga was also a province, but national redistricting has since replaced the old arrangement of six provinces with 22 newly designated regions. In most mineralogical literature and source references, the Boeny Region still appears as "Mahajanga Province" or "Majunga Province.")

The Republic of Madagascar occupies an island in the Indian Ocean 400 miles off the east coast of Africa. It is 800 miles long in a north-south direction and roughly 250 miles wide. With an area of 226,656 square miles, it is somewhat smaller than the state of Texas. It has a population of 20 million and is the world's largest island nation and its fourth largest island. Madagascar has a tropical climate tempered by proximity to the Indian Ocean. Its widely varied ecological zones include tropical rain forests, savannah woodlands, grasslands, and semiarid deserts. Madagascar's highest point, Mt. Maramakotro, rises 9,436 feet above sea level.

Originally settled by Malayo-Indonesian immigrants more than 2,000 years ago, Madagascar's population was later supplemented by African and Arab immigrants. A Portuguese attempt at colonization in the late 1500s failed. By the late 1700s, the British were backing a unified native kingdom. Foreign interests, largely British and French, developed extensive coffee and vanilla plantations in the mid-1800s. France made Madagascar a protectorate in 1885, a colony in 1896, and finally granted it full independence in 1960. The nation has two official languages: French and the Merina dialect of Malagasy. As an independent democratic republic, Madagascar's unstable governments have survived several rebellions that were triggered by government corruption and ethnic conflicts. Today, Madagascar, one of the world's poorest nations, relies on an agricultural economy that employs 80 percent of its workforce.

Madagascar, with both a complex geology and a tectonic origin, was once part of the ancient Gondwanaland supercontinent, which began breaking up about 160 million years ago. This breakup was accompanied by the formation of two large rifts, or separations in the Earth's crust. The Mozambique Channel Rift widened to separate Madagascar from Africa on the west, and the island drifted to its current position relative to Africa about 90 million years ago. The spreading of the Mid-Indian Ridge then began to separate Madagascar from the Indian subcontinent to the east. Because the Mozambique Channel Rift is no longer widening, geologists now consider Madagascar to be part of the African Plate. Today, three-quarters of Madagascar's surface geology consists of outcropped, Precambrian igneous rock older than 500 million years. The remaining surface geology consists of sediments derived from the weathering and erosion of the igneous basement rock. Although geologists believe that Madagascar is rich in mineral resources, there has been relatively little mining for minerals other than ilmenite [iron titanium oxide, FeTiO_3], rutile [titanium oxide, TiO_2], chromite [iron chromium oxide, FeCr_2O_4], and gemstones (see "The Gemstones of Madagascar").

Our carnelian specimens were mined by an American-owned, vertically integrated company that mines, processes, and markets Madagascar gemstones, ornamental and decorative stones, and mineral specimens. The company, which has operated in Madagascar for 20 years, has extensive mine and quarry holdings and also explores regularly for new deposits. It is a major employer of Madagascans and operates two schools in remote mining areas for the benefit of local children. The company mines and quarries an array of gemstones and minerals, including various types of agate and jasper, carnelian, amazonite [gem variety of microcline, potassium aluminum silicate, KAlSi_3O_8], calcite [calcium carbonate, CaCO_3], celestine [strontium sulfate, SrSO_4], hematite [iron oxide, Fe_2O_3], labradorite [gem variety of albite, sodium aluminum silicate, $\text{NaAlSi}_3\text{O}_8$], rhodonite [calcium manganese silicate, $\text{CaMn}_4\text{Si}_5\text{O}_{15}$],

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tourmaline (a group of complex sodium aluminum magnesium lithium silicates), opal [mineraloid, hydrous silicon dioxide, $\text{SiO}_2 \cdot n\text{H}_2\text{O}$], petrified wood, ammonite fossils, and the rose and amethyst varieties of quartz. These are sold as specimens or rough, or are fashioned into faceted gems, cabochons, beads, spheres, figurines, tiles, free-form carvings, and other decorative objects. All carving, cutting, and polishing is performed by Madagascans in the large company facility in the capital city of Antananarivo, then exported and marketed internationally.

The source of our carnelian specimens, the carnelian quarry at Amberjeby, exploits a section of heavily weathered volcanic rock. When this rock was emplaced, it contained numerous barren vesicles that later filled with groundwater solutions rich in silica and hematite. These solutions eventually formed silica gels that solidified into carnelian. As erosion and weathering reduced the basalt formations into a coarse earth and gravel, the harder, more resistant carnelian survived as nodules dispersed through the sediments. Mining is conducted mainly through digging, with blasting employed only when necessary.

As you examine your polished, free-form carnelian specimen, note first the smooth, vitreous surface that is typical of carnelian and other forms of microcrystalline quartz. This level of polishing is possible because of the microscopic size of the individual crystalline grains and fibers. Now backlight your specimen with an intense light source and notice the translucency. Despite its thickness, your specimen will transmit light as a warm, soft, reddish glow. This translucency is the property that distinguishes carnelian from similarly colored jasper, which is opaque. Your specimen's color ranges from brownish-red to orange-red, which is also typical of carnelian. (Some pieces may even grade into the brown-dominant variety Sard, as described under *JEWELRY & DECORATIVE USES*.) Under strong reflected light, your specimen will exhibit the swirling flow patterns that existed in the original silica gel at the time it crystallized. The different hues and intensities of color in these patterns indicate varying concentrations of hematite. Sections of your specimen are of gem quality, meaning they could be cut into thin cabochons having evenly distributed, fine color, and excellent translucency. A few pieces even contain small vugs with minute quartz crystals inside!

As mentioned in last month's newsletter, Silver-level members received a tumble-polished piece of Carnelian from Botswana in southern Africa this month, as we were unable to obtain small pieces of Madagascar carnelian for them. This is the first time in many years that all members did not receive minerals from the same locality—probably ten years or more. The smallest carnelian pieces from Madagascar we could obtain were much too heavy and too costly for us to use for the Silver-level, so we found the beautiful pieces from Botswana, instead. Our December newsletter offers members the opportunity to obtain a Madagascar carnelian for \$16 in a size that was too big for the Silver-level, and too small for the Gold-level. As we examine our specimen, we might think about this ancient gemstone treasured by our distant ancestors, and appreciate it as a representation of what promises to become one of the world's greatest gemstone sources—Madagascar!

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