

## March 2012 Mineral of the Month: Stalactitic Quartz

This month we are featuring unique Compound-Stalactitic quartz from India. Our write-up explains the unusual formation of our specimens, the rich history of the rock-crystal variety of quartz, and the many applications of quartz's remarkable electrical properties in modern electronics.

### OVERVIEW

### PHYSICAL PROPERTIES

Chemistry:  $\text{SiO}_2$  Silicon Dioxide

Class: Silicates

Subclass: Tectosilicates

Group: Quartz

Crystal System: Hexagonal

Crystal Habits: Usually as long, prismatic crystals striated crosswise and terminated by hexagonal pyramids (double rhombohedrons) or dihexagonal (12-sided) pyramids; less often as short to nearly bipyramidal prisms; also granular, disseminated, stalactitic, and massive (microcrystalline); sometimes distorted, skeletal, and drusy. Twinning common.

Color: Colorless, white, pink, rose-red, yellow, pale orange, lilac, purple, pale brown, brown, and near-black.

Luster: Vitreous to greasy

Transparency: Translucent to opaque

Streak: White

Refractive Index: 1.544-1.553

Cleavage: None

Fracture: Conchoidal; brittle to tough.

Hardness: Mohs 7.0

Specific Gravity: 2.65

Luminescence: Impurities sometimes create a weak, greenish-white fluorescence.

Distinctive Features and Tests: Best field marks are vitreous-to-greasy luster, distinct conchoidal fracture, hexagonal crystals with crosswise striations, and hardness.

Dana Classification Number: 75.1.3.1

**NAME** The word "quartz," pronounced KWORTZ, stems from the German *Quarz*, which apparently derives from the Slavic word *kwardy*, meaning "hard." The word "stalactite" comes from the Greek *stalaktos*, meaning "dripping," a reference to the usual manner of stalactite formation. Our specimens are the transparent, colorless variety of quartz called "rock crystal." Other names for rock crystal include "unripe diamond," "diamond quartz," "ice quartz," "mountain crystal," "mountain diamond," "beach diamond," and "clear quartz." In European literature, quartz appears as *Quarz*, *kwartz*, and *cuarzo*.

**COMPOSITION:** Quartz consists of 46.74 percent silicon (Si) and 53.26 percent oxygen (O). Silicon and oxygen are the most abundant elements in the Earth's crust; more than 2,000 silicate minerals make up 75 percent of its total crustal weight. The basic building block of all silicate minerals is the silica tetrahedron ( $\text{SiO}_4$ )<sup>4-</sup>, in which a silicon ion is surrounded by four equally spaced oxygen ions positioned at the corners of a tetrahedron (a four-faced polyhedron). Quartz is a framework silicate or tectosilicate and occurs in both macrocrystalline and microcrystalline forms. As an allochromatic (other-colored) mineral, quartz colors are caused by traces of nonessential, color-producing elements called chromophores. Pure quartz, or rock crystal, is colorless or "water clear," but traces of impurities and exposure to natural geophysical radiation can disrupt the lattice symmetry to impart a wide range of colors. Quartz, which is a component of most igneous, metamorphic, and sedimentary rocks, can form as a component of

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crystallized magma in intrusive and extrusive (volcanic) rocks; and by both the crystallization of silica-rich, hydrothermal fluids and silica-rich groundwater.

**COLLECTING LOCALITIES:** Stalactitic forms of macrocrystalline quartz are rare and occur only in certain basalt quarries of the Jalgaon and Nasik districts in Maharashtra, India. Non-stalactitic forms of the rock-crystal variety of quartz are collected in Austria, Belgium, England, Germany, Switzerland, Russia, Bolivia, Peru, Brazil, Mexico, Namibia, Madagascar, Pakistan, China, and Sri Lanka. In the United States, rock crystal is collected in New York, Arkansas, California, Colorado, Connecticut, Maine, New Hampshire, New Jersey, South Carolina, and Virginia.

**HISTORY, LORE, & GEMSTONE/TECHNOLOGICAL USES:** Rock crystal has been collected since antiquity. Much of rock crystal's history and value is based on its visual similarity to diamond and its use as a diamond substitute. During the Middle Ages and the Renaissance, stoneworkers fashioned beautifully engraved drinking glasses, vases, and other objects from rock crystal. Medieval physicians prescribed the ingestion of powdered rock crystal to generally relieve pain and to specifically alleviate the symptoms of renal and intestinal ailments. Modern metaphysical practitioners call rock crystal the "universal crystal" because of its many purported abilities to sharpen insight, enhance spiritual development, improve concentration, refine focus, and energize the mind. Quartz's unusual electrical properties were discovered in the late 1800s. Until the 1960s, natural rock crystal was employed in electrical and electronic uses. Today, thin wafers of synthetic quartz are standard in electronic filters, frequency controls, and timers for watches, computers, cellular phones, digital games, televisions and many other electronic and electrical devices. More than 200 tons of synthetic quartz are now manufactured each year. Electronic-grade synthetic quartz costs about \$60 per pound.

**ABOUT OUR SPECIMENS:** Our specimens of compound-stalactitic quartz were collected in the Jalgaon District of the state of Maharashtra in the Republic of India. Maharashtra is part of the Deccan (DEH-kenn) Traps, one of the world's largest volcanic regions. The Deccan Traps formed from massive extrusions of basaltic magma some 65 million years ago at the end of the Mesozoic Era. Basalt often contains vesicles (cavities) that form from gas bubbles within solidifying magma. After solidification, these vesicles are initially devoid of mineralization. But upon further cooling, basalt contracts and fractures to create a network of fissures through which groundwater can circulate. As this groundwater percolates downward through the basalt, it dissolves various minerals. Our specimens formed when silica-rich groundwater filled vesicles and precipitated silica as quartz crystals. Our specimens are in the form of stalactites, which are defined as mineral formations resembling icicles that hang from the roofs of caves or cavities and that form from the crystallization of dripping, mineral-rich solutions. This definition assumes that stalactite formation takes place within an atmospheric environment. Our specimens of compound-stalactitic quartz, however, were formed in a *fluid* environment as the result of the slow, downward migration of silica-rich solutions that deposited quartz crystals on the roof of vesicles. These crystals then grew in a downward direction in keeping with the continued downward migration of fluids.

**10 YEARS AGO IN OUR CLUB:** Fluorite, Rogerley Mine, Weardale, County Durham, England, the only mineral we've featured from Great Britain. "Fiercely fluorescent" is how the *Mineralogical Record* described these amazing glassy-green crystals, whose crystal edges give off blue fluorescence when exposed to the Sun's ultraviolet rays! In a dark room under longwave ultraviolet light, they give off the eerie whitish-blue color so prized by collectors of English fluorite. The fluorescence is caused by the presence of REE (rare earth elements) that cause lattice defects in the crystal structure. Analysis of Rogerley fluorite have found they contain small amounts of the rare earth elements (also known as rare earth metals) yttrium, lanthanum, cerium, neodymium, samarium, europium, gadolinium, dysprosium, erbium, and ytterbium.

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## **COMPREHENSIVE WRITE-UP**

### *COMPOSITION*

Quartz is a member of the silicates, the largest of all mineral groups. Silicon and oxygen, the essential elements in all silicate minerals, are the most abundant elements in the Earth's crust. More than 2,000 silicate minerals make up 75 percent of the weight of the Earth's crust. Quartz alone makes up about 12 percent of the total crustal weight. Quartz is widely distributed and occurs in many interesting, beautiful, and unusual forms. The various forms of quartz that we have featured in our Mineral of the Month Club include: Amethyst, the purple gem variety of quartz, from Uruguay (December 1996); Herkimer "Diamonds," the sometimes water-clear, doubly terminated quartz from Herkimer County, New York (June 1997); Rock crystal quartz from Brazil (December 1997); Citrine, also from Brazil (February 2000); Scepter quartz from a new find in Mexico (June 2003); Cactus quartz, also a new find, from South Africa (March 2004); Japan-law quartz twinned-crystals (September 2004); and Quartz geodes from Morocco (January 2009). We have also featured seven chalcedonic varieties: Condor agate from Argentina (November 1998); Ocean jasper from Madagascar (October 2001); Mookaite jasper from Australia (August 2008); Chrysoprase, the green gem variety, also from Australia (August 2009); Soledade agate from Brazil (October 2009); a pseudomorphic variety of jasper-after-aragonite from Argentina (July 2010); and Carnelian, the red gem variety, from Madagascar (December 2011). This month, we are again featuring quartz, this time in one of its rarest forms—as stalactites composed of many individual crystals.

The chemical formula  $\text{SiO}_2$  shows that quartz contains two elements: the semimetal silicon (Si) and oxygen (O). Its molecular weight is made up of 46.74 percent silicon and 53.26 percent oxygen. All molecules consist of positively charged cations and negatively charged anions. The cation in the quartz molecule is the silicon ion ( $\text{Si}^{4+}$ ) with its +4 charge. The anion consists of two oxygen ions ( $2\text{O}^{2-}$ ) with a collective -4 charge. The balance of the +4 cationic and -4 anionic charges provides the quartz molecule with electrical stability.

In the past, mineralogists have classified quartz both as an oxide mineral and as a silicate mineral. Chemically, quartz (silicon dioxide) is an oxide, which is defined as a mineral in which metals or semimetals combine with oxygen. But in terms of structure, which is the key to modern mineral-classification systems, quartz is classified as a silicate—a group of minerals in which the basic building block is the silica tetrahedron ( $\text{SiO}_4$ )<sup>4-</sup>. The silica tetrahedron ( $\text{SiO}_4$ )<sup>4-</sup> consists of a silicon ion surrounded by four equally spaced oxygen ions positioned at the corners of a tetrahedron (a four-faced polyhedron). In the quartz-crystal lattice, all four oxygen ions in each silica tetrahedron bond covalently with the silicon ions of adjacent tetrahedra. In this configuration, each silicon ion is surrounded by four oxygen ions, and each oxygen ion is surrounded by two silicon ions. Because this "four-oxygen-coordination" arrangement satisfies the -4 charge of each individual tetrahedron, no other ions are needed for electrical stability. The result is the infinite, three-dimensional structure of quartz, in which each electrically balanced molecular unit within the lattice is described by the formula  $\text{SiO}_2$ .

In all silicates (except quartz itself), 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); ring silicates (cyclosilicates); sheet silicates (phyllosilicates); and framework silicates (tectosilicates). Quartz is a framework silicate or tectosilicate that occurs in two distinct forms: macrocrystalline and microcrystalline. Macrocrytalline quartz forms large, individual, transparent-to-translucent crystals or groups of crystals. Microcrystalline quartz or chalcedony is a compact or massive form of silica that consists of interlocked, microscopic silica grains or fibrous silica crystals and includes such varieties as chert, jasper, and agate.

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Quartz, which is a component of virtually all igneous, metamorphic, and sedimentary rocks, forms in three basic ways: as a component of crystallized magma in both intrusive and extrusive (volcanic) rocks; by crystallization of silica-rich, hydrothermal fluids; and, in the case of our compound-stalactitic specimens, by the downward percolation and crystallization of silica-rich groundwater. Macrocrystalline quartz most often occurs in granite pegmatites and hydrothermal-emplacement veins. Microcrystalline quartz usually forms from the crystallization of silica-rich groundwater in shallow environments under conditions of low temperature and pressure.

Quartz crystallizes in the hexagonal system and has four axes, three of which are of equal length and lie in a plane. The fourth axis, which is unique to the hexagonal system, is perpendicular to the plane of the other three axes and is of variable length. The most common quartz habit is the hexagonal or six-sided prism in which all six prismatic faces are parallel to the unique axis. Quartz crystals are usually terminated by hexagonal pyramids or dihexagonal (12-sided) pyramids. Atomic bonding within the quartz lattice is exclusively covalent. Because covalent bonding exerts omnidirectional strength, quartz crystals have neither cleavage planes nor a center of symmetry. This lack of cleavage and the high bonding strength derived from close atomic packing account for quartz's substantial durability and hardness of Mohs 7.0. Despite its close atomic packing, the light atomic weights of its essential elements silicon (28.09) and oxygen (16.00) produces a relatively low specific gravity of 2.65. Quartz is the most highly resistant of all detrital (fragmented) minerals. Most minerals eventually abrade and are ground into fine particles, but huge quantities of hard, durable quartz sand accumulate as beaches, sea bottoms, desert soils, dune fields, and other formations that consist mainly of silica. These granular silica deposits often lithify into sandstone, the most common sedimentary rock. Sandstone often metamorphoses into quartzite, an extremely tough, hard, compact rock that is capable of enduring most processes of weathering and erosion.

Quartz is an allochromatic (other-colored) mineral, meaning its colors are caused by traces of nonessential, color-producing elements called chromophores. Pure quartz, or rock crystal, is colorless or "water clear." But traces of chromophores and exposure to natural geophysical radiation can disrupt the symmetry of the quartz lattice to impart a wide range of colors. Many hues have varietal names: Rock crystal is colorless; rose quartz is pink to rose-red; amethyst is lilac to purple; milky quartz is white; smoky quartz is pale brown to near-black; and citrine is yellow to golden.

The Dana mineral classification number 75.1.3.1 first identifies quartz as a tectosilicate or framework silicate (75). The subclassification (1) next defines quartz by the chemical formula  $\text{SiO}_2$  and by its four-oxygen coordination in which four oxygen ions (in the lattice configuration) are bound to each silicon ion. Quartz is then assigned to the quartz group (3) as the first (1) and only member. The subclassification includes several other minerals that are polymorphs of quartz. These minerals, which have identical chemistries but different crystal structures, are cristobalite (tetragonal), tridymite (triclinic), coesite (monoclinic), and stishovite (tetragonal).

### ***COLLECTING LOCALITIES***

Our specimens of rare, compound-stalactitic rock-crystal were collected in a basalt quarry in the Jalgaon District in the state of Maharashtra, Republic of India. Similar specimens are occasionally found in the Nasik basalt quarry of the adjacent Nasik District in Maharashtra.

European specimens of non-stalactitic rock crystal are collected at Lassach Glacier on Kleiner Ankogel Mountain and at Plattenkogel Mountain in the Hohe Tauern Mountains, Carinthia, Austria; at Marvie and Wardin near Bastogne, Luxembourg Province, Belgium; at the Spearn Moor and Wheal Diamond mines at St. Just in the St. Just District, Cornwall, England; and at the Büchlberg rock-crystal quarry at

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Hausenberg, Lower Bavaria, Bavaria, and the Trechtingshausen Quartz Quarry at Bingen in the Hunsrück Mountains of Rhineland-Palatinate, both in Germany. Swiss specimens are collected at the Vals Quarry in the Vals Valley in Grischun, at Galenstock Mountain near Tiefenbach in Uri, and at Alpsjühorn Mountain at Visp, Wallis.

Russian specimens come from the Zhelannoe quartz deposit at Prepolar Ural in the Komi Republic, Far-Eastern Region. Other localities include the Pacuné Mine, Caracoles District, Inquisivi Province, La Paz Department, Bolivia; the Rosario Mine at Casapalca, Huarochiri Province, Lima Department, Peru; the Itambucuri and Buenópolis pegmatite mines in the Doce Valley, Minas Gerais, Brazil; the Santa Rita Mine near the city of Guanajuato, Guanajuato, and the San Bartolo Mine at Charcas in San Luis Potosí, both in Mexico; the Tsumeb Mine at Tsumeb, Otjikoto Region, Namibia; the Fianarantsoa pegmatites in the Fianarantsoa Region of southern Madagascar; the Gilgit and Skardu pegmatite districts, Northern Areas, Pakistan; the Yanganxian Mine in Yizhang County, Chenzou Prefecture, Hunan Province, China; and the Ratnapura gem gravels in the Ratnapura District, Sabaragamuwa Province, Sri Lanka.

The two world-class rock-crystal sources in the United States are in New York at the Herkimer diamond localities in Herkimer, Fulton, and Montgomery counties; and in Arkansas at the rock-crystal mines of Garland, Montgomery, Saline, Polk, and Pulaski counties. California sources include Crystal Hill in Deep Spring Valley and the Cerro Gordo district in the Inyo Mountains, both in Inyo County; and the Elizabeth R. and Sempe mines in the Pala district, San Diego County. Colorado specimens come from Crystal Park, El Paso County; the Calumet Mine in the Turret district, Chaffee County; the Crystal Hill Mine in the Crystal Hill district, Saguache County; and the Amphitheater glacial cirque in the Ouray district, Ouray County. Other sources in the United States include the Strickland pegmatite mine at Portland, Middlesex County, Connecticut; the Diamond Ledge locality near Greenwood, Oxford County, Maine; the Palermo pegmatite mine at Groton, Grafton County, New Hampshire; the Prospect Park Quarry at Prospect Park, Passaic County, New Jersey; the Kings Creek Mine in the Kings Creek district, Cherokee County, South Carolina; and the Morefield pegmatite mine at Winterham, Amelia County, Virginia.

### ***JEWELRY & DECORATIVE USES***

When diamonds were scarce prior to the early 1700s, faceted rock crystal, despite its relatively low refractive index (1.544-1.553), was a popular diamond substitute in Europe. Even after diamonds became more readily available, rock crystal continued to serve as a traditional diamond substitute until the 1950s and the introduction of synthetic, colorless gemstones with much higher indices of refraction. Rock crystal was faceted for use in costume jewelry until it was replaced in the 1960s by faceted, high-refraction, leaded glass. Today, collector's gems are cut from flawless rock crystal, often in sizes of 100 or more carats and usually in round-brilliant styles. Faceted, 100-carat, rock crystal gems now sell for about \$100.

Over the centuries, rock crystal has been cut into many decorative objects such as drinking glasses, engraved medallions, scepter tips, candle holders, paperweights, figurines, and spheres, the latter for both decorative and metaphysical purposes (see "History & Lore"). The largest-known, flawless rock-crystal sphere, 12.9 inches in diameter and weighing 106.75 pounds, is displayed at the National Museum of Natural History (Smithsonian Institution) in Washington, D.C. Rock crystal has also been carved in the shape of human skulls by both ancient and contemporary stoneworkers (see "How Science Debunked the 'Ancient' Rock-Crystal Skulls"). Three-inch-diameter spheres made from high quality rock crystal now sell for about \$250, and larger spheres can cost much more.

Because of its transparency, brilliance, well-developed crystal form, affordability, and frequent association with other interesting and colorful species, the rock-crystal variety of quartz is widely collected. Depending on size, clarity, and quality, quartz crystals can sell for pennies to thousands of dollars.

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### ***HISTORY & LORE***

Rock crystal has been collected since antiquity. Much of its history and value is based on its visual similarity to diamond [carbon, C]. In their early attempts to explain the difference between rock crystal and diamond, ancient naturalists and alchemists divided colorless gemstones into two groups based generally on hardness. Such gemstones as diamond, beryl [beryllium aluminum silicate,  $\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$ ], and colorless sapphire [corundum, aluminum oxide,  $\text{Al}_2\text{O}_3$ ] were known as *adamas*, the Latin word for “hardest,” while much softer rock crystal was called *kristallos*, the Greek word for “ice.” In *A History of Stones*, the first treatise on gems, written in 315 B.C., Greek philosopher and naturalist Theophrastus (ca 372-ca 287 B.C.) described rock crystal as a type of ice. The Roman scholar Pliny the Elder (Gaius Plinius Secundus, A.D. 23-79) later furthered this belief by describing rock crystal as ice that was frozen so solid that it could never thaw. Other early naturalists classified colorless gems as “ripe” or “unripe.” Diamond was considered “ripe,” while rock crystal was “unripe.” Diamond, which was then obtained almost exclusively from India, was thought to have “ripened” in the warmer Indian climate, while rock crystal, which was collected in much cooler European regions, was thought to have lacked the heat to “ripen.”

As a gem, rock crystal became the “poor man’s diamond.” But as a mineral, it was the “rich man’s glass.” Until the discovery of Brazil’s alluvial diamond deposits in the early 1700s, most European “diamonds” were actually rock crystal that was called “quartz diamond.” When the booming popularity of affordable “quartz diamond” began eroding the value of genuine diamonds, rulers of Austria’s Hapsburg Dynasty, which ruled parts of western Europe during the 1700s, actually banned rock-crystal mining to help maintain diamond values. Much European “quartz diamond” came from the Rhine River sediments, which contained pieces of rock crystal that had washed down from the Alps. These became known as “Rhine diamonds” or “Rhine stones,” the latter name still surviving in the glass “rhinestones” used in modern costume jewelry. During the Middle Ages and the Renaissance, stoneworkers fashioned beautifully engraved drinking glasses, vases, and other objects from rock crystal. These included the likenesses of human skulls, which various cultures believed were endowed with great powers (see “How Science Debunked the ‘Ancient’ Rock-Crystal Skulls”). Rock crystal remained the “rich man’s glass” until the mid-1800s when it was replaced by improved types of glass, which were equally transparent, but softer and thus more workable. By the late 1800s, the cutting of rock crystal was nearly a lost art.

Rock crystal has long been the preferred medium for “crystal balls” for metaphysical use. About 2000 B.C., the Druids, after unifying the Celtic tribes in what is now England, began to use mineral crystals to divine or “see” the future. Later, other cultures fashioned small, polished spheres from colorless beryl for this purpose. By the 15<sup>th</sup> century A.D., divination or “scrying” with crystal balls cut from rock crystal had gained great popularity. Of the many prominent alchemists, seers, psychics, and philosophers who used crystal balls, the most famous is astronomer, mathematician and astrologer Dr. John Dee (1527-ca 1608), who was also a leading advisor to England’s Queen Elizabeth I (1533-1603). The British Museum in London now displays the crystal ball with which Dee divined much of his advice for his queen.

Medieval physicians prescribed the ingestion of powdered rock crystal to relieve general pain and specifically to alleviate the symptoms of renal and intestinal ailments. Modern metaphysical practitioners call rock crystal the “universal crystal,” attributing to it the abilities to sharpen insight, enhance spiritual development, improve concentration, refine focus, and energize the mind. Rock crystal has appeared on the 40-centime stamp of Switzerland in 1958, the 400-sucre stamp of Ecuador in 1997, the 1.00-franc stamp of the French Southern & Antarctic Territories in 1998, the 1-cent stamp of Canada in 1963, the 6.00-franc stamp of Monaco in 1990, the 4-bhat stamp of Thailand in 1972, and the 10-cent stamp of the United States in 1974. The rock crystal variety of quartz is the official state mineral of Arkansas and the official state gemstone of Georgia.

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### ***TECHNOLOGICAL USES***

Quartz served as the model for its own laboratory synthesis in 1845. Although this was a major scientific achievement, quartz then had no modern technological uses. French physicists did not discover the remarkable electrical properties of quartz until 1880. By applying mechanical stress to quartz crystals, they generated electrical potential (voltage) across crystal faces, an effect that they named “piezoelectricity,” after the Greek *piezein*, meaning “to press.” The French researchers next discovered that applying electrical current to quartz physically deformed the crystal by slightly changing the angle of the crystal faces. Finally in 1918, they discovered that electrical current applied to bits of thinly sliced quartz caused these “wafers” to vibrate mechanically at a natural resonance frequency later measured at precisely 32,768 cycles per second. Scientists subsequently designed a quartz oscillator to control a clock with unprecedented accuracy, triggering a rush for “electronic-grade” quartz crystals—single (untwinned) crystals with near-perfect, undistorted crystal lattices that were large enough to cut into wafers. Although rare, electronic-grade, natural quartz was obtainable in commercial quantities from sources in Arkansas and Brazil. Natural-quartz wafers were soon regulating time and electrical frequencies in everything from chronometers and radios to radars and bombsights. During World War II, electronic-grade quartz was classified as a strategic material.

By the 1960s, as demand for natural, electronic-grade quartz boomed and supplies dwindled, researchers succeeded in synthesizing “electronically perfect” quartz using a hydrothermal technique that replicated the formation of natural quartz. In quartz synthesis, powdered, high-quality (but non-electronic grade), natural quartz is mixed with an aqueous solution of basic sodium carbonate, then placed in steel autoclaves under high temperature and pressure to form a silica gel. Thin “seed” crystals of electronic-grade, natural quartz are used to initiate the crystallization of synthetic quartz. Synthetic-quartz wafers are now standard in electronic filters, frequency controls, and timers for watches, computers, cellular phones, digital games, televisions, and many other electronic devices. More than 200 tons of synthetic quartz are manufactured each year. One pound of electronic-grade, synthetic quartz costs about \$60.

### ***HOW SCIENCE DEBUNKED THE “ANCIENT” ROCK-CRYSTAL SKULLS***

Rock crystal has been worked into many objects, none of which are more intriguing or controversial than the likenesses of human skulls purportedly fashioned by pre-Columbian stoneworkers in Mexico and Central America. The first Spaniards to contact the Aztecs in 1519 noted that human skulls and skull imagery were important aspects of Aztec art and iconography, and were most dramatically represented by small, rock-crystal skulls.

During the late 19<sup>th</sup> century, when European and American interest in pre-Columbian artifacts had peaked, collectors and artifact dealers suddenly unveiled a number of rock-crystal skulls. Some clearly had been fashioned recently for church use as bases for crucifixes and candles. But others were said by their owners to be of Aztec, Mixtec, or Mayan origin, and therefore extremely valuable. In 1897, George Frederick Kunz (1856-1932), America’s first gemologist, was the gemological advisor to Tiffany & Co., New York City’s most prestigious jeweler. That year, Kunz helped Tiffany & Co. acquire an exquisitely fashioned, life-sized, rock-crystal skull that was supposedly of Aztec origin. According to Kunz, who was convinced of its authenticity, a Mexican army officer had taken the crystal skull out of Mexico prior to the French occupation of early 1860s. The skull, which weighed 36.5 pounds, was then passed on to a British collector, a French antiquities dealer and finally, with Kunz’s help, to Tiffany & Co. The jewelry firm later donated the skull to the British Museum in London, where it remains today.

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In 1992, another rock-crystal skull unexpectedly arrived by mail at the National Museum of Natural History (Smithsonian Institution) in Washington, D.C. An anonymous note explained that this skull, cut from slightly milky rock crystal and supposedly of Aztec origin, had been purchased in 1960 in Mexico City. The appearance of this skull invited questions about its authenticity and also refocused interest on the skull in the British Museum. In 1996, the Smithsonian and the British Museum formed a joint research group to positively determine the authenticity of the two rock-crystal skulls by answering two key questions: How were the skulls carved and where did the rock crystal originate? The investigation first focused on the carving methods used to fashion the skulls. Researchers examined details of the faint "tool marks" on the highly polished skulls under the high magnification of a scanning electron microscope, then compared them with those on authentic, pre-Columbian rock-crystal objects. The marks on the two museum skulls were distinctly unlike the hand-made marks on the authentic objects. Furthermore, the marks were shown to have been made using wheels and abrasives that were much harder than quartz itself. The researchers noted that rotary cutting wheels did not exist in the Western Hemisphere prior to the arrival of the Spanish, and that harder-than-quartz abrasives did not become available until the mid-1800s.

Researchers then addressed the source of the rock crystal in the two museum skulls. Spectroscopic analysis revealed that solid inclusions within the rock crystal of both skulls consisted primarily of an iron-rich chlorite mineral (a basic magnesium iron aluminosilicate) that is consistent with quartz from mesothermal and granitic occurrences—mineralogical environments which are not known to exist within the Aztec or Mayan trading networks. Furthermore, the inclusions in the skulls are consistent with those found in rock crystal occurring only in Brazil and Madagascar. Interestingly, German immigrants had discovered large blocks of high-quality rock crystal in Brazil in the 1830s, which they shipped to stoneworkers in Germany. And in the late 1800s, French colonists found large blocks of nearly flawless rock crystal in Madagascar, which they also sent to Europe for cutting.

Lastly, investigators noted that neither of the museum skulls had actually been recovered in documented, professional archaeological excavations. Their unanimous conclusion was that neither of the museum skulls represented pre-Columbian craftsmanship. The rock crystal in both skulls had likely been mined in the late 1800s in Brazil or Madagascar and cut using modern, mechanical methods. With the help of electron microscopes and spectrographic analysis, even rock crystal can tell remarkable tales!



Figure 1. Crystal skull in British Museum. Image courtesy of britishmuseum.org



Figure 2. Profile of crystal skull in British Museum. Image courtesy of britishmuseum.org



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## ***ABOUT OUR SPECIMENS***

Our specimens of compound-stalactitic quartz were collected in the Jalgaon District of the state of Maharashtra in the Republic of India. Maharashtra occupies the west-central part of the Indian subcontinent, borders the Arabian Sea, and is roughly half the size of the state of Texas. Maharashtra's capital is the coastal city of Mumbai (formerly Bombay). Jalgaon, one of Maharashtra's 34 administrative districts, is 240 miles northeast of Mumbai. About the size of the state of Connecticut, Jalgaon has a population of 4.2 million. Thanks to a subtropical climate and a rich volcanic soil that covers Jalgaon's broad valleys and low hills, the region is an important agricultural district.

Maharashtra is part of the Deccan (DEH-kenn) Traps, one of the world's largest volcanic regions. The Deccan Traps formed some 65 million years ago at the end of the Mesozoic Era when magma rose through long, narrow, crustal fissures to extrude onto the surface to create basalt formations thousands of feet thick. Basalt is an extrusive (volcanic) igneous rock that forms from the solidification of low-silica magma at or near the surface. Basalt contains very little quartz; its dark color is due to large amounts of iron and magnesium minerals. Because it is hard, durable, dense, and largely inert, basalt makes an excellent construction and fill material and is quarried extensively throughout Maharashtra. Basalt often contains vesicles (cavities) and amygdules (mineral-filled cavities). Vesicles form from gas bubbles within solidifying magma, usually near the top of lava flows where steam and gases expand in reduced pressure. When magma solidifies, vesicles are devoid of secondary mineralization. But upon final cooling, basalt contracts and fractures to create a network of fissures through which groundwater later circulates. As this groundwater percolates downward, it dissolves various minerals. This mineral-rich groundwater then fills many vesicles where it precipitates crystals of quartz, calcite [calcium carbonate,  $\text{CaCO}_3$ ], and zeolite minerals (a group of complex, hydrous sodium, calcium aluminosilicates). Commercial collecting of these crystals has become an important, secondary aspect of basalt quarrying throughout Maharashtra.

In most amygdules within the basalt of the Deccan Traps, mineral-rich fluids are static and have no directional movement. This enables quartz and other minerals to crystallize in a geodic pattern, developing equally from all interior cavity surfaces and orienting toward the center of the cavity. Our quartz specimens are rare because of their stalactitic habit. They were collected from a cavity in which quartz crystals hung from the roof and projected downward in the form of stalactites. The word "stalactite" is derived from the Greek *stalaktos*, meaning "dripping." Stalactites are defined as mineral formations resembling icicles that hang from the roofs of caves or cavities and that formed from the crystallization of dripping, mineral-rich solutions. This definition assumes, of course, that stalactite formation took place in an atmospheric environment. But our specimens of compound-stalactitic quartz formed in a *fluid* environment.

Our specimens formed when with a hollow vesicle in basalt filled with a flow of silica-rich groundwater that entered continuously from the roof and exited through the floor. Conditions of chemistry, low temperature, and low pressure within the vesicle caused the immediate precipitation of quartz at the vesicle's roof. The groundwater, now deficient in silica, continued its slow, downward migration, precipitating its remaining silica as small quantities of quartz on the walls and floor of the developing amygdule. As new, downward-flowing, silica-rich solutions continued to enter the amygdule from the roof, additional quartz immediately precipitated to continue the development of stalactites. This eventually resulted in the creation of a generally spherical amygdule that was several feet in diameter, the roof of which was covered with hanging stalactites of quartz. Unlike the uniform, microcrystalline nature of stalactites that form from dripping in atmospheric environments, our stalactites formed in a fluid environment and consist of aggregates of individual quartz macrocrystals and are known as *compound* stalactites.

As you examine your specimen, note first its compound-stalactitic form, in which the stalactite consists of many individual quartz macrocrystals. The broken surface is the contact point from which the stalactite

## March 2012 Mineral of the Month: Stalactitic Quartz



Figures 3 -6. Some of the strange shapes of our Platinum- and Gold-level specimens.



hung from the roof of the amygdule. The three-section, concentric cross section of the stalactite is a record of the crystallization sequence. The small, dark center core consists mainly of iron minerals that crystallized first to “seed” the secondary crystallization of quartz. The first quartz to crystallize did so in microcrystalline form and appears as a concentric, internal ring of bright, white chalcedony. The large, outer section of the stalactite represents the final phase of quartz crystallization and consists of well-developed quartz macrocrystals of the rock-crystal variety. Some of the strange shapes our compound-stalactitic quartz formed in are seen in the photos above! Most crystals exhibit various degrees of natural surface frosting which, in some cases, may appear to diminish the transparency of the quartz. The basic hexagonal structure of each quartz crystal is apparent in its six-sided cross section and termination.

In the past, we have seen similar compound-stalactitic amethyst from Brazil. It seems quite likely that they formed in a similar way to our pieces this month, from the downward migration of silicon-rich fluids through amygdules in basalt. The Brazilian amethyst compound-stalactites are often cut into thin slices and polished, and sold for use in jewelry. Some of our composite stalactite pieces could also be cut and polished for use in one-of-a-kind jewelry. Your specimen of compound-stalactitic quartz is an example of one of the rarest forms of the most common mineral on Earth!

References: *Dana's New Mineralogy*, Eighth Edition; *Encyclopedia of Minerals*, Second Edition, Roberts, et al, Van Nostrand Reinhold Company; *2008 Fleischer's Glossary of Mineral Species*, J. A. Mandarino and Malcolm E. Back; *Mineralogy*, John Sinkankas, Van Nostrand Reinhold Company; *Gems and Jewelry*, Joel Arem, Geoscience Press; *Gemstones of the World*, Walter Schumann, Sterling Publishing Company; *Complete Guide to Rocks & Minerals*, John Farndon, Heritage House, 2007; *The Mystical Lore of Precious Stones*, George Frederick Kunz, Newcastle Gem & Crystal Classics (reprint), 1986; “A More Perfect Quartz,” Steve Voynick, *Rock & Gem*, November 2011; “The Origin of Two Purportedly Pre-Columbian Mexican Crystal Skulls,” M. Sax, J. M. Walsh, I. C. Freestone, A. H. Rankin, and N. D. Meeks, *Journal of Archaeological Science*, 2008; “Rock Crystal Quartz,” David Federman, *Modern Jeweler*, January 2011.