

January 2012 Mineral of the Month: Stilbite-Ca

This month we are featuring stilbite-Ca from the Deccan Traps of India. Our write-up details the properties of this Zeolite-group mineral, the Deccan volcanic formations, the many uses of zeolites, and how silicate minerals help shape the surface of the Earth.

OVERVIEW

PHYSICAL PROPERTIES

Chemistry: $(\text{Ca}_{0.5}\text{KNa})_9(\text{Al}_9\text{Si}_{27}\text{O}_{72}) \cdot 28\text{H}_2\text{O}$ Hydrous Calcium Potassium Sodium Aluminum Silicate
(Hydrous Calcium Potassium Sodium Aluminosilicate), usually containing strontium and barium.

Class: Silicates

Subclass: Tectosilicates, Zeolites

Group: Heulandite

Subgroup: Stilbite

Crystal System: Monoclinic

Crystal Habits: Usually in prismatic aggregates of numerous twinned crystals, often pinched in the middle to resemble wheat sheaves or bow ties; also radial, fibrous, globular; rarely as tabular crystals.

Color: Usually colorless, white, gray, yellowish, honey-yellow, or pink; occasionally reddish, orange, or brown.

Luster: Vitreous, pearly on cleavage surfaces

Transparency: Transparent to translucent

Streak: Colorless

Cleavage: Perfect in one direction

Fracture: Conchoidal to uneven, brittle

Hardness: 3.5-4.0

Specific Gravity: 2.1-2.2

Luminescence: None

Refractive Index: 1.48-1.50

Distinctive Features and Tests: Best field-identification marks are wheat-sheaf or bow-tie-shaped crystal aggregates, low density, vitreous luster, lack of striations, solubility in hydrochloric acid, occurrence in basaltic amygdules, and association with other zeolite-group minerals. Lab tests are often necessary to positively distinguish stilbite-Ca from other heulandite group minerals.

Dana Classification Number: 77.1.4.3

NAME The name "stilbite," pronounced STILL-bite, is derived from the Greek *stilbein*, meaning "to glitter," a reference to the mineral's bright, vitreous luster. The formal name of this month's mineral is "stilbite-Ca," in which the "Ca" suffix denotes the calcium-rich member of the stilbite solid-solution series. Stilbite-Ca is pronounced as "stilbite-calcium" or "stilbite-see-aay." Stilbite-Ca has also been called "stilbite," "aedelforsite," and "bundle zeolite." In European mineralogical literature, stilbite appears as *stilbit*, *stilbiet*, *estilbita*, and *desmine*.

COMPOSITION: Stilbite-Ca contains the elements calcium (Ca), potassium (K), sodium (Na), aluminum (Al), silicon (Si), oxygen (O), and hydrogen (H). The molecular weight of stilbite-Ca consists of 5.20 percent calcium, 10.24 percent potassium, 6.10 percent sodium, 7.16 percent aluminum, 22.60 percent silicon, 47.15 percent oxygen, and 1.55 percent hydrogen. Stilbite-Ca is a member of the silicates, the largest of all mineral classes, in which silicon and oxygen combine with one or more metals or semimetals. Stilbite-Ca occurs primarily in basaltic volcanic rocks within amygdaloidal cavities that form as gas bubbles during the solidification of silica-deficient magma. Percolating alkaline groundwater later deposits zeolite minerals that fill these amygdules. Stilbite-Ca also occurs in volcanic tuffs and marine

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sediments that have undergone alkaline alteration, and occasionally in certain pegmatites and metamorphic rocks. Stilbite-Ca is a hydrous (containing attached water molecules) framework silicate or tectosilicate with a modified aluminosilicate radical that forms a porous, sheet-like structure. Spaces and channels within and between the sheets account for its very low specific gravity (density) of only 2.1-2.2; weak, inter-sheet bonding explains its relative softness of Mohs 3.5-4.0. This porous structure enables zeolites to lose and regain water of hydration without any alteration of the crystal structure and to act as filters that pass certain ions, atoms, and molecules while blocking others. When nearly pure, stilbite-Ca is colorless, white, or gray, but impurities, mainly iron and manganese, create a range of pale yellowish, honey-yellow, pink, reddish, orange, or brown colors.

COLLECTING LOCALITIES: Stilbite-Ca is collected in the Jalgaon, Mumbai, Nasik, Puna, and Ahmadnagar districts of the state of Maharashtra in India. Other localities are found in Iceland, Denmark's Faeroe Islands, Germany, Italy, England, Scotland, Norway, Austria, France, Poland, Spain, Switzerland, South Africa, Japan, New Zealand, Australia, Brazil, Canada, and Russia. In the United States, stilbite-Ca is collected in Idaho, Colorado, New Jersey, Oregon, Alabama, Alaska, Arkansas, Connecticut, Georgia, Maryland, Nevada, North Carolina, Pennsylvania, and Utah.

HISTORY, LORE, & GEMSTONE/TECHNOLOGICAL USES: Stilbite was determined to be a distinct mineral species and formally named in 1822. Mineralogists recognized stilbite-Ca and stilbite-Na as individual species in 1997. Although stilbite-Ca has only minimal use as a gemstone, it is among the most collectible of all zeolite minerals and is valued by mineral collectors both as single and composite specimens. Because zeolite minerals can exchange metal cations and absorb and filter particulates, they are superb mediums for absorption, filtration, ion-exchange, chemical catalysis, and molecular sieving. Zeolites are used in water- and gas-purification systems, as catalysts in the petrochemical and chemical industries, as radioactive-waste-removal mediums in the nuclear industries, and as "slow-nutrient-release" mediums for agricultural fertilizers. They are also used to purify medical oxygen, as "filtration-capture" mediums in laundry detergents, and as filtration mediums for aquariums and pools. About three million metric tons of zeolites were mined worldwide in 2010. Stilbite-Ca makes up only a small part of overall zeolite production. According to modern metaphysical practitioners, stilbite helps to heal the soul, enhance intuition, and promotes restful sleep and vivid dreaming. In the 1700s, the wearing of stilbite was thought to counteract poisons; modern metaphysical practitioners believe it helps to cleanse the body of toxins.

ABOUT OUR SPECIMENS: Our stilbite-Ca specimens were collected at basalt quarries in the Jalgaon District in the state of Maharashtra in the Republic of India. Jalgaon is located within the Deccan Traps, a huge volcanic province that formed some 65 million years ago and consists of basalt formations as thick as 6,000 feet. Our specimens were extracted from vesicles that formed from gas bubbles in the original magma. Later, these cavities filled with mineral-rich groundwater that precipitated crystals of quartz, calcite, and various zeolite minerals. Basalt quarrying is an important industry throughout the Deccan Traps region of India. Crushed basalt is used as ballast and fill for roads, rail beds, foundations for buildings and dams, and cement additives. Our stilbite-Ca specimens were recovered by professional specimen miners who contract with quarry managers for permission to extract zeolite specimens when they are exposed by quarrying operations.

10 YEARS AGO IN OUR CLUB: Barite, Long Point, Rancho Palos Verdes, Los Angeles County, California. Our specimens were different from most found along the Palos Verdes cliffs—they had a unique growth of sugary-white barite crystals on top of the tan-colored crystals normally found at this classic barite locality. The white crystals fluoresced creamy white under shortwave UV light, while the tan crystals gave off a similar tan color, and phosphoresced for several seconds after the light was turned off. This was the first of three times so far that we have featured Barite, in 3 completely different colors and forms!

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COMPREHENSIVE WRITE-UP

COMPOSITION

When we first featured stilbite-Ca as our Mineral of the Month in May 1999, mineralogical literature had not quite caught up with the major revision of zeolite nomenclature that took place in late 1997. Accordingly, we then used the old name “stilbite” rather than stilbite-Ca.

Stilbite-Ca's chemical formula, $(\text{Ca}_{0.5}, \text{K}, \text{Na})_9(\text{Al}_9\text{Si}_{27}\text{O}_{72}) \cdot 28\text{H}_2\text{O}$, shows that it contains the elements calcium (Ca), potassium (K), sodium (Na), aluminum (Al), silicon (Si), oxygen (O), and hydrogen (H). The molecular weight of pure stilbite-Ca consists of 5.20 percent calcium, 10.24 percent potassium, 6.10 percent sodium, 7.16 percent aluminum, 22.60 percent silicon, 47.15 percent oxygen, and 1.55 percent hydrogen. Stilbite-Ca usually contains small amounts of strontium and barium, which replace calcium within the crystal lattice.

Stilbite-Ca's lengthy chemical formula, $(\text{Ca}_{0.5}, \text{K}, \text{Na})_9(\text{Al}_9\text{Si}_{27}\text{O}_{72}) \cdot 28\text{H}_2\text{O}$, is easily understood when we remember that all molecules are composed of positively charged cations and negatively charged anions. In stilbite-Ca, both the cation and anion are radicals, or groups of ions of different atoms that behave as single entities in chemical reactions. The stilbite-Ca cation is the radical $[(\text{Ca}_{0.5}, \text{K}, \text{Na})_9]^{9+}$, in which the calcium ion has a +2 charge and the sodium and potassium ions each have a +1 charge. The “_{0.5}” quantifier for calcium indicates that one calcium ion is bonded to two molecules, thus reducing its effective charge by half. The comma-separation within this formula indicates that the amounts of calcium, sodium, and potassium are variable, provided that the net collective cationic charge remains +9. The stilbite-Ca anion is the aluminosilicate radical $(\text{Al}_9\text{Si}_{27}\text{O}_{72})^{9-}$, in which each aluminum ion has a +3 charge, each silicon has ion a +4 charge, and each oxygen ion a -2 charge, resulting in a collective -9 charge. This -9 anionic charge balances the +9 cationic charge to provide the stilbite-Ca molecule with electrical stability.

The “ $\cdot 28\text{H}_2\text{O}$ ” in stilbite-Ca's chemical formula indicates that it is a hydrous (or hydrated) mineral with 28 molecules of water (H_2O) attached to each parent molecule. Attached water molecules, collectively called “water of hydration,” consist of electrically neutral water molecules that do not affect the electrical balance of the molecule. Water molecules have an unusual atomic configuration, with two hydrogen ions grouped together on one side of a large oxygen ion. These hydrogen ions retain a small positive charge, while the opposite side of the molecule, dominated by the large oxygen ion, retains a small negative charge. This polarity enables water molecules to behave as tiny dipole magnets and to attach themselves to other molecules by a weak attraction called “hydrogen bonding.”

Stilbite-Ca is a member of the silicates, the largest mineral class, in which silicon and oxygen combine with one or more metals. The basic structural unit of all silicates is the silica tetrahedron $(\text{SiO}_4)^{4-}$, in which a silicon ion is surrounded by four equally spaced oxygen ions positioned at the four corners of a tetrahedron (a four-faced polyhedron). In the silicates, silica anions and metal cations join together 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).

Stilbite-Ca is classified as a framework silicate or tectosilicate, but its crystal lattice is actually based on a modified aluminosilicate radical that forms sheet-like structures. Within the crystal lattice, each oxygen ion is connected to either a silicon ion or an aluminum ion in a 1:2 ratio. Each sheet contains alternating arrangements of eight- and ten-sided open rings and is positioned so that the rings in each sheet align in stacks to form open channels throughout the lattice. These channels and the inter-sheet spaces provide

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room for the attachment of stilbite-Ca's water of hydration and also explain its very low specific gravity (density) of only 2.1-2.2. This slight variation in specific gravity is due to interchangeable amounts of calcium, potassium and sodium, and to the presence of small quantities of the heavy metals strontium and barium. Because the sheets are widely separated, the relatively weak, covalent bonding between them provides stilbite-Ca with perfect, one-directional cleavage. Weak inter-sheet bonding also explains why stilbite-Ca, at Mohs 3.5-4.0, is among the softest of all silicate minerals.

The characteristic wheat-sheaf or bow-tie shape of stilbite crystal aggregates, in which termination ends are thicker than their "pinched" or narrow middles, is caused by crystal-growth rates that are faster at the ends. Mineralogists believe that this occurs because stilbite-Ca "crystals" are actually aggregates of many individual crystals, and that the slight separation of these crystals at the terminations of the aggregates provides a greater surface area to accommodate more rapid crystal growth. Stilbite-Ca crystals are almost always twinned, usually by penetration twinning in which two or more crystals appear to interpenetrate each other. In certain minerals, such as, staurolite [acid iron magnesium zinc oxyaluminosilicate, $(\text{Fe,Mg,Zn})_{3-4}(\text{Al,Fe})_{18}(\text{Si,Al})_8\text{O}_{48}\text{H}_{2-4}$], our Mineral of the Month for May 2010, twinning sometimes occurs at 90 degrees to produce prominent, cross-like, crystal structures. In stilbite-Ca, however, the angle of twinning is very subtle, usually only about one degree. Crystallographers have recently determined that the typical, twinned stilbite-Ca crystal actually consists of eight sectors, some of which exhibit orthorhombic crystal symmetry, while others exhibit monoclinic crystal symmetry.

The channels and spaces within the stilbite-Ca crystal lattice are diagnostic structural features of all zeolite minerals and account for many unusual properties, including the ability to lose and regain water of hydration without alteration of the crystal structure. The network of hollow spaces and channels also functions as molecular filters that pass certain ions, atoms, and molecules, while blocking others. Finally, the weak cationic bonding within zeolite molecules is easily broken to enable substitution by other metal cations in a phenomenon called "ion exchange." Because of these properties, stilbite-Ca and other zeolite minerals have many industrial applications (see "Technological Uses").

The Dana mineral-classification number 77.1.4.3 identifies stilbite-Ca as a tectosilicate member of the general zeolite group (77). The subclassification (1) defines it as a true zeolite, a group of hydrous aluminosilicates that can lose and regain water of hydration without altering their crystal structures. Stilbite-Ca is then assigned to the heulandite group (4) as the third of three subgroups (3). These are divided into the five-member heulandite subgroup, the three-member clinoptilolite subgroup, and the four-member stilbite subgroup. The four closely related members of the stilbite subgroup include:

77.1.4.3 stilbite-Ca $(\text{Ca}_{0.5}, \text{K}, \text{Na})_9(\text{Al}_9\text{Si}_{27}\text{O}_{72}) \cdot 28\text{H}_2\text{O}$

77.1.4.3a stilbite-Na $(\text{Na,K,Ca}_{0.5})_9(\text{Al}_9\text{Si}_{27}\text{O}_{72}) \cdot 28\text{H}_2\text{O}$

77.1.4.4 stellerite $\text{Ca}_4(\text{Al}_8\text{Si}_{27}\text{O}_{72}) \cdot 28\text{H}_2\text{O}$

77.1.4.5 barrerite $\text{Na}_8(\text{Al}_8\text{Si}_{27}\text{O}_{72}) \cdot 28\text{H}_2\text{O}$

The chemistry of the stilbite subgroup members differs only in the quantities or substitution of the cationic elements. In stilbite-Ca, calcium is the dominant cationic element; in stilbite-Na, which is much less abundant than stilbite-Ca, sodium is the dominant cationic element. Because these two minerals are nearly identical in appearance and properties, laboratory analysis is necessary for positive differentiation. In stellerite, calcium is the single cationic element; in barrerite, sodium is the single cationic element. Partial or complete solid-solution series exist between all four stilbite-subgroup members.

Stilbite-Ca is a low-temperature, low-pressure mineral that occurs primarily in basaltic rocks within amygdaloidal cavities that initially formed as gas bubbles during the solidification of silica-deficient

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magmas. In subsequent low-grade, hydrothermal metamorphism, percolating alkaline groundwater deposited zeolite minerals, often as well-developed crystals in association with other zeolite minerals, along with quartz [silicon dioxide, SiO₂] and calcite [calcium carbonate, CaCO₃]. Stilbite-Ca also occurs in volcanic tuffs and marine sediments that have undergone alkaline alteration; smaller quantities are found in certain pegmatites and metamorphic rocks.

Stilbite-Ca is an allochromatic (other-colored) mineral, meaning that color-causing impurities called chromophores impart a range of colors. When nearly pure, stilbite-Ca is colorless or white. But traces of impurities, mainly iron and manganese, can create a wide range of pale yellowish, honey-yellow, pink, reddish, orange, or brown colors.

COLLECTING LOCALITIES

The finest stilbite-Ca specimens occur in the huge basalt formations of the Deccan traps in the Republic of India. Our specimens were collected in the Jalgaon District in the state of Maharashtra in the Republic of India. Other Maharashtra sources include the Mumbai, Nasik, Puna, and Ahmadnagar districts.

Stilbite-Ca specimens are also found in Iceland at Digritindur, Fásskrúdfjörð; Gaesadalur, Mjoifjörður; and Teigarhorn, Suður-Múntlasýsla. Other European localities include Denmark's Faeroe Islands, notably the islands of Bordoy, Eysturoy, Kunor, Nolsoy, Streymoy, and Vágur; the Schann and Jean quarries at Kusel in Rhineland-Palatinate, and the Zufurt Quarry at Tröstau, Franconia, Bavaria, both in Germany; the Fasso Valley in Trento Province, Trentino-Alto Adige, Italy; the Botallack Mine in the St. Just District of Cornwall, England; Hørtekollen near Lier in Buskerud, and the Konnerudkolien mines at Drammen, Buskerud, both in Norway; the Bieler Höhe Pass area in Vorarlberg, Austria; the Aure Valley lava flows at Hautes-Pyrénées, Midi-Pyrénées, France; the Nowa Ruda Mine at Nowa Ruda, Klodzko District, Lower Silesia, Poland; the Cillarga Quarry at Pontevedra, Galicia, Spain; Schwartzhorn Mountain near Geisspfad, Valais, Switzerland; and the Isle of Mull, Strathclyde, Scotland.

Other notable localities are the Cairnwood quarries near Durban, KwaZule-Natal Province, South Africa; the Yugawara quarries at Kanagawa Prefecture, Kanto Region, Honshu Island, Japan; the Flat Top Quarry near Auckland, North Island, New Zealand; the Burnley and Council quarries at Richmond near Melbourne, Victoria, Australia; and Serra de Botucatu at Botucatu, São Paulo, Brazil. Canadian specimens come from the King and British Canadian mines at Black Lake, Thetford Mines, Chaudière-Appalaches, Québec; and from the Wasson's Bluff volcanic flow in Cumberland County, Nova Scotia. In Russia, stilbite-Ca specimens are collected at Dal'negorsk, Primorskiy Kray, Far-Eastern Region; and Mount Puiva near Saranpaul, Tyumenskaya Oblast', Urals Region.

In the United States, stilbite-Ca localities include the Rat's Nest claims near Challis in Custer County, Idaho—we featured Heulandite from a new find at this locality in November 2002; North Table Mountain and South Table Mountain at Golden in Jefferson County, Colorado; the Prospect Park and Sowerbutt traprock quarries at Prospect Park, Passaic County, New Jersey; and the lava flows at Edwards in Tillamook County, Oregon. Other localities are the West Point Dam at Standing Rock, Chambers County, Alabama; the Jumbo Copper Mine at Copper Mountain, Prince of Wales Island, Prince of Wales-Outer Ketchikan Borough, Alaska; the Granite Mountain and Big Rock quarries near Little Rock, Pulaski County, Arkansas; the Thomaston Dam railroad cut at Thomaston, Litchfield, County, Connecticut; the Tyrone Quarry at Tyrone, Fayette County, Georgia; the Milford Quarry at Bare Hills near Baltimore, Baltimore County, Maryland; the Fernley zeolite deposit at Fernley, Lyon County, Nevada; the Stokesdale, Pomona, and Jamestown basalt quarries of Guilford County, North Carolina; the Hay Creek Quarry at Birdsboro, Berks County, Pennsylvania; and the Elbow Ranch zeolite deposit near Marysville, Piute County, Utah.

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JEWELRY & DECORATIVE USES

Stilbite-Ca rarely forms large, single crystals that are suitable for faceting. It is also relatively soft (Mohs 3.5-4.0) and has a low index of refraction (1.48-1.50), as well as perfect, single-directional cleavage that makes cutting difficult. Not surprisingly, it has only minimal gemstone use. Faceted collector gems are unusual and rarely larger than one carat. Globular and radiating forms of stilbite-Ca are occasionally tumble-polished and drilled for wear as pendants or cut into cabochons, usually for metaphysical purposes. Stilbite-Ca specimens are considered among the most collectible of all zeolite species. Collectors value stilbite-Ca as both single and composite specimens, the latter in association with other zeolite minerals, calcite [calcium carbonate, CaCO_3], and quartz [silicon dioxide, SiO_2].

HISTORY & LORE

Swedish mineralogist Axel Fredrick Cronstedt (1722-1765) identified the first zeolite mineral in 1756—a mineral that would much later be named stilbite-Ca. Observing how this mineral vibrated as heat drove off its water of hydration, Cronstedt coined the word “zeolite,” literally “stone that boils,” from the Greek *zein*, meaning “to boil,” and *lithos*, or “stone.” Because of their similar, complex chemistries, differentiating the zeolite minerals initially was quite difficult. The zeolite minerals that we now know as stilbite-Ca and heulandite-Ca [hydrous calcium sodium potassium aluminosilicate, $(\text{Ca}_{0.5}\text{Na,K})_9(\text{Al}_9\text{Si}_{27}\text{O}_{72}) \cdot \sim 24\text{H}_2\text{O}$] were first thought to be the same mineral. In 1801, the French crystallographer René Just Haüy (1743-1822) described several varieties of stilbite-like minerals, applying such names as “stilbite anamorphique” and “stilbite octoduodecimale” in reference to their crystal structures. But British mineral dealer and collector John Henry Heuland (1778-1856), who specialized in zeolite minerals, suspected that some assumed zeolite minerals were actually several individual species. In 1818, the German mineralogist August Johann Friedrich Breithaupt (1791-1873) studied Heuland’s specimens and confirmed that stilbite did indeed consist of two distinct mineral species. Breithaupt named the mineral that we now know as heulandite-Ca “euzeolite,” meaning “beautiful zeolite”; the mineral that we now know as stilbite-Ca, he named “desmine.” In 1822, British mineralogist and crystallographer Henry James Brooke (1771-1857) independently confirmed Breithaupt’s findings. Brooke also showed that Haüy’s “stilbite anamorphique” and “stilbite octoduodecimale” were entirely different species. Brooke then formally assigned the modern names “stilbite,” from the Greek *stilbein*, meaning “to glitter,” and “heulandite,” in honor of John Henry Heuland. German mineralogists, however, refused to recognize the name “stilbite”—the reason that stilbite-Ca is still known as “desmine” in Germany today.

In 1909, researchers determined that a calcium-rich variety of stilbite was a distinct mineral species that they named “stellerite” [hydrous calcium aluminosilicate, $\text{Ca}_4(\text{Al}_8\text{Si}_{27}\text{O}_{72}) \cdot 28\text{H}_2\text{O}$], after the German explorer and zoologist Georg Wilhelm Steller (1709-1746). X-ray diffraction techniques revealed the crystal structure of stilbite and stellerite in the late 1920s. Although stilbite was first thought to crystallize in the orthorhombic system, crystallographers now realized that it actually crystallized in the monoclinic system. Mineralogists considered stilbite to be a single mineral species until 1975, when they learned that it included another distinct species, which they named barrerite [hydrous sodium aluminosilicate, $\text{Na}_8(\text{Al}_8\text{Si}_{27}\text{O}_{72}) \cdot 28\text{H}_2\text{O}$], after the New Zealand chemist and zeolite researcher Richard Maling Barrer (1910-1996). Finally in the early 1990s, advanced quantitative-analysis methods confirmed that stilbite itself actually consisted of a solid-solution series of two distinct minerals based on the nearly complete cationic substitution of calcium, potassium, and sodium (see “Composition”). In 1997, as part of a major reorganization and nomenclatural revision of the entire zeolite group, these species were formally named stilbite-Ca and stilbite-Na. Prior to 1997, mineralogists recognized just 51 zeolite minerals; today, the list includes 87 species and continues to grow. We featured stellerite in March 2008, and would love to feature barrerite sometime in the future!

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According to modern metaphysical practitioners (who do not differentiate between stilbite-Ca and stilbite-Na), stilbite helps to heal the soul, enhance intuition, and promotes restful sleep and vivid dreaming. In the 1700s, the wearing of stilbite was thought to counteract poisons; modern metaphysical practitioners believe it helps to cleanse the body of toxins. Stilbite was featured on the 35-króna stamp of Iceland in 1992 and on the 3.70-króna stamp of Denmark's Faeroe Islands in 1998.

TECHNOLOGICAL USES

Because their open structures make zeolite minerals capable of exchanging metal cations and absorbing and filtering particulates, they are superb mediums for absorption, filtration, ion-exchange, chemical catalysis, and molecular sieving. Zeolites are standard mediums in water- and gas-purification systems, and are also used as catalysts in the petrochemical and chemical industries, radioactive-waste-removal mediums in the nuclear industries, and "slow-nutrient-release" mediums in agricultural fertilizers. Zeolites are also used to purify medical oxygen; as "filtration-capture" mediums in laundry detergents, aquariums, and pools; and as additives to improve the workability and reduce the density of asphalt and cement.

The study of natural zeolites has led to the development of synthetic zeolites, which now account for half of all the zeolites used in industry. Today, zeolite production is a multi-billion-dollar industry. About five million metric tons of zeolites are mined or synthesized each year. China, the leading producer of natural zeolites, mined more than two million metric tons in 2010. That same year, the United States produced 61,000 tons of natural zeolites from mines in Arizona, California, Idaho, Nevada, New Mexico, Oregon, and Texas. All commercial zeolite deposits have formed from the alteration of volcanic tuffs in alkaline, lacustrine environments and do not produce collectible specimens. Stilbite-Ca makes up a small part of the overall production of natural zeolites. After washing and concentrating, the average price of natural zeolites is about \$160 per metric ton.

HOW SILICATES SHAPE THE EARTH'S CRUST

Stilbite-Ca is one of approximately 2,000 silicate minerals, most of which consist of one or more metals in combination with silicon and oxygen. (A major exception is quartz [silicon dioxide, SiO₂], because silicon is classified as a semimetal.) Silicon and oxygen are the most abundant elements in the Earth's crust, comprising about 75% of the Earth's crust. As major components of igneous, metamorphic, and sedimentary rocks, silicates correspondingly make up about three-quarters of the weight of the Earth's crust. Quartz is the crust's most abundant mineral, accounting for about 20 percent of its weight. All common rock-forming minerals are silicates; such important rock-forming mineral groups as the feldspars, micas, amphiboles, pyroxenes, olivines, and clays all contain between 40 and 70 percent silica by weight. Quartz and the other silicate minerals have a profound effect on rock coloration, the Earth's topography, and the nature of volcanism.

Magma, the molten rock that underlies the Earth's crust and is the direct source of all igneous rocks, is categorized by its silica content. Basaltic magma consists of roughly 50 percent or less silica, 10 percent iron and magnesium, and 40 percent other elements. Granitic magma, however, contains about 70 percent silica, only 2 percent iron and magnesium, and 28 percent other elements. The amount of silica in magma determines its viscosity, flow properties, and volcanic behavior, as well as the coloration of its derived igneous rocks. Because low-silica, basaltic magmas have little covalent bonding between the corners of their silica tetrahedrons, they have low viscosity and thus flow readily and solidify very slowly. In contrast, granitic magmas have high viscosity, a resistance to flowing, and solidify much faster.

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When low-silica, low-viscosity, basaltic magmas extrude, they cannot readily build gas pressure and tend to flow steadily and “quietly” onto the surface. This type of volcanism created such massive basalt formations as India’s Deccan Traps, as well as those in southern Brazil and in the American states of Oregon and Washington. Low-silica magma also created Hawaii’s broad, “dome” volcanoes. In high-silica magmas, however, the greater concentration of silica tetrahedrons results in a great deal of covalent bonding that produces high viscosity and flow-resistance. When these thick, high-silica magmas reach the surface, flow resistance enables them to build great gas pressures that often cause explosive eruptions, such as those that created the steep-sided cinder cones typical of Italy’s Mt. Vesuvius.

Igneous rocks with different silica content also have very different properties. Because of their high iron-magnesium content and low silica content, basaltic volcanic rocks are characterized by dark to near-black colors, while high-silica volcanic rocks such as rhyolite are much lighter in color and somewhat harder than basalt. Intermediate phases of volcanic rock, which progressively grade from low- to high-silica, include basalt, andesite, dacite, trachyte, and rhyolite. Silica content also determines the properties of intrusive igneous rocks. Intrusions of low-silica magma will form gabbro, which contains less than 10 percent quartz and has a dark gray color. But intrusions of high-silica magma will form granite, which is generally light in color and contains about 35 percent quartz. The intermediate phases of intrusive igneous rock, which progressively grade from low-silica to high-silica, include gabbro, syenite, nepheline, monzonite, grandiorite, and granite.

Because silica is hard and extremely resistant to erosion, the silica content of surface rocks has largely determined much of the Earth’s present-day topography. Most prominent outcrops of igneous rock consist of hard, high-silica granite. The world’s highest mountains and most impressive mountain ranges consist of high-silica rock, whether igneous, metamorphic, or sedimentary. Silica content also largely governs the rate of erosion of sedimentary deposits. Zones of sedimentary rock with higher silica content than that in adjacent rock tend to form mesas and pinnacles, such as those in Arizona’s Monument Valley. And beaches worldwide consist primarily of quartz sand, because the quartz particles contained in igneous, metamorphic, and sedimentary rocks are most resistant to chemical weathering and physical erosion.

ABOUT OUR SPECIMENS

Our stilbite-Ca specimens were collected in the Jalgaon District of the state of Maharashtra in the Republic of India. Maharashtra is located in the west-central part of the Indian subcontinent and borders the Arabian Sea, as seen in the map in Figure 1. With an area of 118,000 square miles, it 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 located in the north-central part of the state about 240 miles northeast of Mumbai. The Jalgaon District is about the size of the state of Connecticut and has a population of 4.2 million. Its topography is one of broad valleys and low hills. With its subtropical climate and rich volcanic soil, Jalgaon is an important producer of bananas, cotton, and sugarcane.

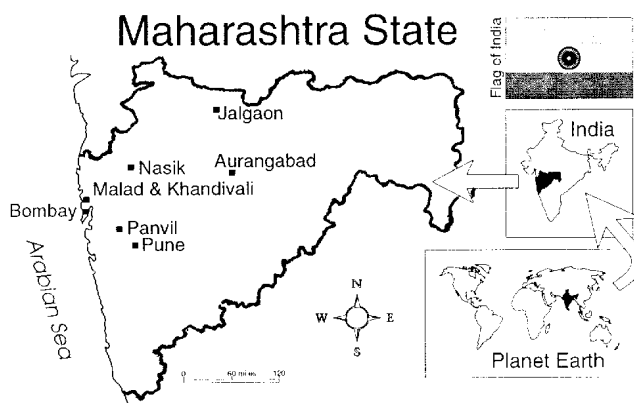


Figure 2. Mineral localities in Maharashtra State, India

Figure 1. Map from our May 1999 Stilbite write-up.

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Maharashtra and the Jalgaon District are famed sources of zeolite-mineral specimens. These zeolites occur in the basalt of the Deccan (DEH-kenn) Traps, one of the world's largest volcanic regions. This huge formation, also called the Deccan Plateau, covers 200,000 square miles (the approximate combined area of the states of Washington and Oregon) and includes the entire Jalgaon District and most of Maharashtra. The Deccan Traps were formed by massive extrusions of magma some 65 million years ago at the end of the Mesozoic Era. After rising through long, narrow, crustal fissures, this magma extruded onto the surface and spread in nearly horizontal sheets to form basalt formations many thousands of feet thick. Originally, the Deccan Traps covered three times its present area, but weathering and erosion have since reduced its size. The volume of the basalt in the Deccan Traps is now estimated at 12,000 cubic miles.

Basalt is an extrusive (volcanic) igneous rock that forms from the solidification of magma at or near the surface. Volcanic rocks cool quickly and have smooth textures with no visible crystals (aphanitic texture) or very small crystals scattered throughout a dense groundmass (porphyritic texture). As a low-silica rock, basalt contains little quartz, but large amounts of iron and magnesium minerals that impart a very dark color. Prominent structures in basalt include flow banding, vesicles (cavities), and amygdulites (mineral-filled cavities). Vesicles form from gas bubbles within solidifying magma, usually near the top of the flows where steam and gases can expand in reduced pressure. When magma solidifies, vesicles are barren, that is, devoid of any secondary mineralization. But upon final cooling, contraction of the basalt created a network of fissures and fractures through which groundwater later circulated. As this water percolated downward through the basalt, it became alkaline and dissolved various aluminum and silicate minerals. This mineral-laden groundwater then filled many vesicles in which it precipitated an array of zeolite minerals, often in well-developed crystal forms.

Hard, durable, dense, and largely inert, basalt makes a superb construction and fill material. As the only rock available throughout most of Maharashtra, basalt is quarried in great quantities for use as ballast and fill for road and rail beds, foundation material for buildings and dams, and gravel for cement mixtures. Because it is an inexpensive, low-profit commodity, it is quarried as near as possible to where it will be used. As in other Maharashtra districts, virtually every town and city in the Jalgaon district has at least one basalt quarry.

The first reports of zeolite specimens in the Deccan Traps appeared in the 1820s, when British surveyors, soldiers, and engineers collected finely developed crystals of quartz, calcite, and zeolite minerals from amygdulites in the basalt. While quite spectacular, these zeolite specimens had little value until they became popular among mineral collectors in the late 1960s. Most Indian zeolite specimens are collected in basalt quarries, and to a lesser extent in excavations for irrigation canals, wells, and building and dam foundations. Quarrymen and professional specimen miners now work together to satisfy the booming demand for zeolite specimens. Zeolite specimens have become a valuable by-product of basalt quarrying, and specimen miners are proficient in the techniques necessary to extract—intact—the delicate zeolite specimens from the amygdulites in the tough basalt. Quarry workers break the basalt by drilling and blasting, then truck it to crushers to be sized for specific uses. Our stilbite-Ca specimens were recovered by professional specimen miners who contract with quarries for permission to extract specimens when they become exposed by quarrying operations.

As you examine your specimen, note that its color is honey-yellow with subtle hints of pink, which is typical of stilbite-Ca from India's Deccan Traps. With backlighting, the specimen will appear translucent; only small, thin, tabular crystals will exhibit semi-transparency. Remember that the name "stilbite" is derived from the Greek *stilbein*, meaning "to glitter," a reference to your specimen's bright, vitreous luster. Using intense backlighting, notice the longitudinal patterns and lines in each long "crystal." These are not striations, but the edges of individual crystals within a crystalline aggregate. Further evidence of

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aggregate-crystal development appears on the aggregate terminations, which actually consist of the multiple terminations of many individual crystals. Some specimens will also have small, thin, transparent, tabular crystals. These are single crystals, which are unusual in stilbite-Ca. Your specimen may also exhibit penetration twinning, which is common in stilbite-Ca. The angle of twinning is very subtle and is most easily seen as a “double edge” on the sides of the thin, tabular crystals. In your specimen, the pronounced projection of certain crystals from the sides of others does not represent orderly twinning, but only the random intergrowth of crystals.

This is how we explained stilbite-Ca's twinning in our May 1999 write-up: “You may wonder about this phenomenon in stilbite, as it is reported that all stilbite crystals are twinned. What we have in stilbite are cruciform penetration twins in which the angle of penetration is about as slight as possible, and the two individual crystals are about as close to parallel as two things can be and still intersect! In staurolite, the angle between the two crystals can be close to 90°, while in stilbite, it is probably about 1° or less. Needless to say, this twinning is nearly impossible to observe in stilbite with the unaided eye, but it is present! Interestingly, a similar cruciform penetration twinning is found in two other zeolite group minerals, phillipsite and harmotome.”

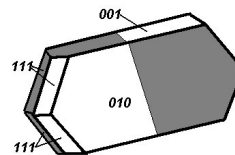


Figure 2. Stilbite twin. Shaded area is crystal A; clear area, crystal B, from our May 1999 write-up.

Our specimens were collected from amygdaloidal cavities in basalt that also contained calcite, quartz, and several other zeolite minerals. Within these cavities, stilbite-Ca was the last mineral to crystallize, and thus grew while attached to other minerals. See if you can locate the slightly rough section where this attachment occurred. At this point you may find small areas of other zeolite minerals. Green crystals are fluorapophyllite [hydrous basic potassium calcium fluorosilicate, $\text{KCa}_4\text{Si}_8\text{O}_{20}(\text{F},\text{OH})\cdot 8\text{H}_2\text{O}$]. Mordenite [hydrous sodium calcium potassium aluminosilicate, $(\text{Na}_2,\text{Ca},\text{K}_2)_4(\text{Al}_8\text{Si}_{40}\text{O}_{96})\cdot 28\text{H}_2\text{O}$] appears as delicate, white fibers. As always, each specimen has its own unique features and tells its own unique story!

Over the years, we have had the privilege of featuring many Zeolite group minerals from India, along with many gorgeous, closely-related minerals from these same geological environments, such as cavansite and fluorapophyllite. These comprise some of the best finds from India's massive Deccan Traps, source of an incredible abundance of exceptional mineral specimens!

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