

## January 2011 Mineral of the Month: Scolecite

This month's mineral, scolecite, is an uncommon zeolite from India. Our write-up explains its origin as a secondary mineral in volcanic host rocks, the difficulty of collecting this fragile mineral, the unusual properties of the zeolite-group minerals, and why mineralogists recently revised the system of zeolite classification and nomenclature.

### OVERVIEW

### PHYSICAL PROPERTIES

Chemistry:  $\text{Ca}(\text{Al}_2\text{Si}_3\text{O}_{10}) \cdot 3\text{H}_2\text{O}$  Hydrous Calcium Aluminum Silicate (Hydrous Calcium Aluminosilicate), usually containing some potassium and sodium.

Class: Silicates

Subclass: Tectosilicates

Group: Zeolites

Crystal System: Monoclinic

Crystal Habits: Usually as radiating sprays or clusters of thin, acicular crystals or Hairlike fibers; crystals are often flattened with tetragonal cross sections, lengthwise striations, and slanted terminations; also massive and fibrous. Twinning common.

Color: Usually colorless, white, gray; rarely brown, pink, or yellow.

Luster: Vitreous to silky

Transparency: Transparent to translucent

Streak: White

Cleavage: Perfect in one direction

Fracture: Uneven, brittle

Hardness: 5.0-5.5

Specific Gravity: 2.16-2.40 (average 2.25)

Luminescence: Often fluoresces yellow or brown in ultraviolet light.

Refractive Index: 1.507-1.521

Distinctive Features and Tests: Best field-identification marks are acicular crystal habit; vitreous-to-silky luster; very low density; and association with other zeolite-group minerals, especially the closely-related minerals natrolite  $[\text{Na}_2(\text{Al}_2\text{Si}_3\text{O}_{10}) \cdot 2\text{H}_2\text{O}]$  and mesolite  $[\text{Na}_2\text{Ca}_2(\text{Al}_6\text{Si}_9\text{O}_{30}) \cdot 8\text{H}_2\text{O}]$ . Laboratory tests are often needed to distinguish scolecite from other zeolite minerals.

Dana Classification Number: 77.1.5.5



Figure 1. Scolecite.

**NAME** The name “scolecite,” pronounced SKO-leh-site, is derived from the German *Skolezit*, which comes from the Greek *skōlēx*, meaning “worm,” an allusion to the tendency of its acicular crystals to curl when heated and dehydrated. Former names of scolecite include “acicular stone,” “ellegite,” “lime mesotype,” “calcium mesotype,” and “weissian.” In European mineralogical literature, scolecite appears as *Skolezit*, *scolecita*, and *espiscolecita*.

**COMPOSITION:** Scolecite is made up of 10.22 percent calcium (Ca), 13.75 percent aluminum (Al), 21.48 percent silicon (Si), 53.01 percent oxygen (O), and 1.54 percent hydrogen (H). As a hydrous mineral, scolecite has three molecules of water attached to each parent molecule. Known as “water of hydration,” these attached water molecules are electrically neutral and do not affect the electrical balance of the parent molecule. Although scolecite is a framework silicate or tectosilicate, its crystal lattice is based on a modified aluminosilicate structure that forms long, aligned chains. These lengthy chains, which are the basis of scolecite’s long, needle- or hair-like prisms, have a parallel arrangement and are separated by open channels that provide space for the ionic bonding of calcium ions and the hydrogen bonding of water

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of hydration. These channels, which account for scolecite's very low specific gravity (density) of 2.16-2.40, are a diagnostic structural feature of all zeolite minerals. Scolecite is a low-temperature, low-pressure mineral that forms primarily within amygdaloidal cavities of basaltic volcanic rocks, often in association with other zeolite minerals and quartz. Smaller amounts of scolecite are also found in contact-metamorphic zones and in cavities within gneisses and amphibolites.

**COLLECTING LOCALITIES:** The finest scolecite specimens come from the basalt formations of India's Deccan Traps in the Nashik, Nagar, Jalgaon, Mumbai, and Pune districts of the state of Maharashtra. Other notable sources are located in Iceland, England, Switzerland, Italy, Germany, Austria, France, Denmark, Northern Ireland, Scotland, Sweden, Russia, Canada, Japan, and Brazil. In the United States, scolecite is collected in New Jersey, Oregon, Alaska, Arizona, California, and Colorado.

**HISTORY, LORE, & GEMSTONE/TECHNOLOGICAL USES:** German mineralogists identified scolecite as a new mineral species in 1813. Scolecite received its modern name in 1823; X-ray diffraction revealed its atomic structure in 1923. Because of the thinness and fragility of its acicular prisms, scolecite crystals have no use in jewelry. Massive scolecite, however, is sometimes tumbled and polished for use as pendants worn for metaphysical purposes. As one of the few zeolite minerals that can be faceted, scolecite collector gems are in great demand. Mineral collectors value scolecite both as single and composite specimens, the latter in association with quartz and other zeolite minerals. Perfect (undamaged) scolecite specimens are costly because of the great difficulty in removing them intact from basalt cavities. Zeolites are used to purify water and gases, catalyze petrochemical and chemical processes, remove radioactive wastes in nuclear processes, and control nutrient-release times in agricultural fertilizers. Because scolecite is uncommon, it has only minimal industrial importance. Modern metaphysical practitioners believe that scolecite promotes inner peace, deep relaxation, and meditation; enhances the dream state; and facilitates both dream recall and restful sleep.

**ABOUT OUR SPECIMENS:** Our scolecite specimens were collected at a basalt quarry near the city of Sangamner, Ahmadnagar District, in the state of Maharashtra in west-central India. The topography of Maharashtra, one of the world's largest volcanic regions, is dominated by the massive basalt formations of the Deccan Traps. Basalt is an extrusive (volcanic) igneous rock with a fine grain and characteristic dark color. The basalt of the Deccan Traps contains numerous amygdules--cavities originating as gas bubbles in the original lava. These cavities later became filled by secondary minerals when alkaline groundwater percolated downward, dissolved aluminum and silica-bearing minerals in the basalt, then precipitated zeolite minerals. Basalt is quarried extensively throughout Maharashtra for use as ballast, fill for roads and rail beds, foundations for buildings and dams, and as a gravel additive for cement. Basalt quarrymen, excavators, and commercial specimen collectors now work together with dealers to satisfy the booming, international demand for zeolite specimens. Specimen miners utilize special techniques to extract the fragile zeolite specimens intact from cavities in the tough basalt.

**10 YEARS AGO IN OUR CLUB:** Dolomite, Vulcan Quarry, Lawrence County, Arkansas. You may see these specimens occasionally at shows, as they were quite abundant then, but we don't recall seeing much around lately. Another locality that is not producing as it once was! We remember these being especially large and heavy matrix pieces with a good coating of the pick dolomite crystals, some with minute chalcopyrite crystals perched on the dolomite! The crystals were slightly curved, and the reason for the curvature was explained in the write-up. Remarkable too was the full name of the French professor for whom it was named: Déodat Guy Silvain Tancredé Gratet de Dolomieu (1750-1801). Now that is a mouthful! We traveled to more than twenty shows in 2001 (we've only participated in twelve the last few years), and our Club was approaching its fifth anniversary and sixtieth featured mineral. Our web site was beginning to take shape--since 2000 we have had our own web site with photos of our featured minerals.

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## **COMPREHENSIVE WRITE-UP**

### *COMPOSITION*

This is the second time we have featured scolecite from India, the first coming in May 1997, when we sent Club members clusters of spiky, needle-like scolecite crystals on a matrix of pale green apophyllite crystals. They were even more delicate and fragile than these current specimens are! We had about 220 members then. Perhaps some of you still have your specimen—how different it is from this month's!

The chemical formula of scolecite,  $\text{Ca}(\text{Al}_2\text{Si}_3\text{O}_{10})\cdot 3\text{H}_2\text{O}$ , shows that it contains the elements calcium (Ca), aluminum (Al), silicon (Si), oxygen (O), and hydrogen (H). The ideal molecular weight of scolecite is made up of 10.22 percent calcium, 13.75 percent aluminum, 21.48 percent silicon, 53.01 percent oxygen, and 1.54 percent hydrogen. Like all molecules, those of scolecite are composed of positively charged cations and negatively charged anions. In scolecite, the simple cation consists of one calcium ion  $\text{Ca}^{2+}$  with its +2 charge. The scolecite anion, however, is a radical or group of ions of different atoms that behave as a single entity in chemical reactions. The scolecite anion is the aluminosilicate radical  $(\text{Al}_2\text{Si}_3\text{O}_{10})^{2-}$ , which consists of two aluminum ions  $2\text{Al}^{3+}$ , three silicon ions  $3\text{Si}^{4+}$ , and ten oxygen ions  $10\text{O}^{2-}$ . This aluminosilicate radical has a collective anionic charge of -2 that balances the cationic charge of +2, thus providing the scolecite molecule with electrical stability.

The “ $3\text{H}_2\text{O}$ ” in scolecite's chemical formula indicates that it is a hydrous (or hydrated) mineral with three molecules of water ( $3\text{H}_2\text{O}$ ) attached to each parent molecule. Known as “water of hydration,” these attached water molecules are electrically neutral and do not affect the electrical balance of the parent molecule. Water molecules have an unusual atomic configuration with two hydrogen ions grouped together on one side of a large oxygen ion. These grouped 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 resulting polarity enables water molecules to behave as tiny dipole magnets and to attach themselves to other molecules by a weak attraction called “hydrogen bonding.” In scolecite, hydrogen bonding occurs when the positive polarity of water molecules is attracted (opposite charges attract) to the negative charges of the oxygen ions within the aluminosilicate radicals.

Scolecite 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).

Scolecite is a framework silicate or tectosilicate with its crystal lattice based on a modified aluminosilicate structure. In scolecite, this structure consists of aligned chains in which alternate oxygen ions in each silica tetrahedra are bound to either an aluminum ion within their own tetrahedra or to silicon ions in adjacent tetrahedra. These lengthy chains, which explain scolecite's long, needle- or hair-like prisms, have a parallel arrangement with open channels between them. These hollow channels, which are diagnostic structural features of all zeolite minerals, provide space for the ionic bonding of calcium ions and the hydrogen bonding of water of hydration and account for scolecite's very low specific gravity (density) of 2.16-2.40. These features account for many unusual zeolite properties, including the ability to lose and regain water of hydration without altering the crystal structure. These hollow channels also function as molecular filters that pass certain ions, atoms, and molecules, while blocking others. Because the weak

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ionic bonding of the metal cations within these channels is easily broken, other metal ions can easily substitute in a phenomenon called “ion exchange.” With their unusual properties, zeolite minerals have many industrial, scientific, and consumer applications (see “Technological Uses”).

Predominant, strong, covalent oxygen-oxygen and oxygen-aluminum bonding throughout its crystal lattice explains scolecite’s substantial hardness of Mohs 5.0-5.5. Within the scolecite lattice, the separation of the aluminosilicate chains is greatest along the single plane where inter-ionic distances are greatest, and thus the bonding strength weakest—the reason that scolecite exhibits perfect, one-directional cleavage. Because scolecite crystals are rarely more than a quarter-inch in thickness and usually much less, this perfect, one-directional cleavage can be difficult to observe. Contact- and penetration-type twinning is common in scolecite and produces its characteristic slanted terminations.

The Dana mineral-classification number 77.1.5.5 first places scolecite in the tectosilicate-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. Scolecite is then assigned to the natrolite group (5) as the fifth (5) of 11 members. Within the natrolite-group minerals, metal cations can be sodium, calcium, barium, strontium, or beryllium, either singularly or in paired combinations. The two natrolite-group members most closely related to scolecite are natrolite and mesolite:

Scolecite	Hydrous calcium aluminosilicate $\text{Ca}(\text{Al}_2\text{Si}_3\text{O}_{10})\cdot 3\text{H}_2\text{O}$	Monoclinic
Natrolite	Hydrous sodium aluminosilicate $\text{Na}_2(\text{Al}_2\text{Si}_3\text{O}_{10})\cdot 2\text{H}_2\text{O}$	Orthorhombic
Mesolite	Hydrous sodium calcium aluminosilicate $\text{Na}_2\text{Ca}_2(\text{Al}_6\text{Si}_9\text{O}_{30})\cdot 8\text{H}_2\text{O}$	Orthorhombic

These three natrolite-group minerals, called the “chain” or “needle” zeolites, often occur together and are difficult to distinguish visually because of their similar colors and radiating, acicular crystal habits. Natrolite tends to form thin crystals with pyramidal terminations. Mesolite forms the thinnest crystals, while those of scolecite are the thickest and most durable. Although all contain varying amounts of both sodium and calcium, they do not form complete solid-solution series.

Scolecite is an allochromatic (other-colored) mineral with a narrow range of pale colors that are caused by chromophoric (color-causing) impurities. When nearly pure, scolecite is colorless or white. Trace impurities of ferrous iron ( $\text{Fe}^{2+}$ ) create pale brownish or yellowish hues; traces of divalent manganese ( $\text{Mn}^{2+}$ ) create pale, pinkish hues. Scolecite exhibits both pyroelectric and piezoelectric properties. Pyroelectricity (from the Greek *pyr*, or “fire”) is electrical voltage that has been generated by heat; piezoelectricity (from the Greek *piezein*, “to press”) is electrical voltage that has been generated by mechanical pressure. Both pyroelectricity and piezoelectricity are caused when heat or mechanical pressure displaces electrons from their normal orbits within the lattice, thus generating an electrical differential (voltage) across certain crystal faces.

Scolecite is a low-temperature, low-pressure mineral that occurs primarily within amygdaloidal cavities of basaltic volcanic rocks. Cavities form as gas bubbles during the solidification of mafic (silica-deficient, iron- and magnesium-rich) magmas. In subsequent low-grade, hydrothermal metamorphism, percolating alkaline groundwater deposits zeolite minerals within these cavities, often as well-developed crystals. Scolecite is often deposited along with other zeolite minerals, especially natrolite and mesolite, and also such non-zeolite minerals as quartz [ $\text{SiO}_2$ ], prehnite [ $\text{Ca}_2\text{Al}_2\text{Si}_3\text{O}_{10}(\text{OH})_2$ ], and calcite [calcium carbonate,  $\text{CaCO}_3$ ]. Scolecite is usually the last mineral to form, and often grows atop crystals of such previously deposited zeolite minerals as stilbite-Ca [hydrous calcium potassium sodium aluminum silicate,  $(\text{Ca}_{0.5}, \text{K}, \text{Na})_9(\text{Al}_9\text{Si}_{27}\text{O}_{72})\cdot 28\text{H}_2\text{O}$ ], heulandite-Ca [hydrous calcium sodium potassium aluminosilicate,  $(\text{Ca}_{0.5}, \text{Na}, \text{K})_9(\text{Al}_9\text{Si}_{27}\text{O}_{72})\cdot \sim 24\text{H}_2\text{O}$ ], and epistilbite [ $\text{Ca}_3(\text{Al}_6\text{Si}_{18}\text{O}_{48})\cdot 16\text{H}_2\text{O}$ ]. To a lesser extent, scolecite also

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occurs in contact-metamorphic zones and in cavities within formations of gneisses and amphibolites.

### ***COLLECTING LOCALITIES***

Scolecite is a widely distributed, but uncommon zeolite mineral. Few localities provide good specimens. The finest scolecite specimens come from the basalt formations of India's Deccan Traps. Our specimens were collected at a basalt quarry near the city of Sangamner, Ahmadnagar District, state of Maharashtra in the Republic of India. Other important scolecite sources in Maharashtra are located in the districts of Nashik, Nagar, Jalgaon, Mumbai, and Pune.

Europe's scolecite localities include Osfjall, Breiðdalsvík, Suður-Múlasýsla, Iceland; the Dean Quarry at St. Taeverne, Lizard Peninsula, Cornwall, England; the Forno quarries in the Bregaglia Valley, and the Arvigo gneiss quarries in the Mesolcina Valley, both in Grischun, Switzerland; the Lierskogen Quarry at Lier, Buskerud, Norway; the Fasso Valley quarries in Trento Province, Trentino-Alto Adige, Italy; the Kaiserstuhl Quarry at Kaiserstuhl, Baden-Württemberg, Germany; the Kreuzkogel Massif, Nassfeld Valley, Hohe Tauern Mountains, Salzburg, Austria; the Bussiol Quarry, Puy-de-Dôme, Auvergne, France; Denmark's Faeroe Islands lava flows; Lanford Lodge, Dunseverick, County Antrim, Northern Ireland; Trotternish, Isle of Skye, North West Highlands, Scotland; and the Leveäniemi Mine at Svappavaara, Kiruna district, Lapland, Sweden. Other notable localities are Dal'negorsk, Primorskiy Kray, Kamchatka Oblast', Far-Eastern Region, Russia; the Palabora Mine at Loolekop, Limpopo Province, South Africa; Gates Mountain, Kings County, Nova Scotia, Canada; the Hokizawa quarries, Yamakita, Kanto Region, Honshu Island, Japan; the Campos Novos region in Brazil's Santa Catarina state; and the Rodaito Mine, Coquimbo, Elqui Province, Coquimbo Region, Chile.

U.S. localities include the Prospect Park and Sowerbutt traprock quarries at Prospect Park, Passaic County, New Jersey; the Edwards lava flow in Tillamook County, Oregon; the Hound Island breccia formation, Kuiu Island, Sitka Borough, Alaska; the Bunker Hill district in the Galiuro Mountains, Pinal County, Arizona; the Genesee Valley copper prospects, Plumas County, and the Crestmore Quarry at Crestmore, Riverside County, in California; the Upper Slate Lake area, Summit County, Colorado; Malison Falls near Windham, Cumberland County, Maine; the Hanover-Fierro district, Grant County, New Mexico; the Station Quarry in Haverford Township, Delaware County, Pennsylvania; the Dexter and Conklin quarries at Lincoln, Providence County, Rhode Island; and Clayton Peak in Wasatch County, Utah.

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

Because of the thinness and fragility of its acicular prisms, scolecite crystals have no use in jewelry. However, massive scolecite is sometimes tumbled and polished for use as pendants worn for metaphysical purposes. Despite its brittleness and perfect, one-directional cleavage that makes cutting difficult, scolecite is among the few zeolite minerals that can be faceted and scolecite collector gems are in high demand. Scolecite collector gems rarely weigh more than five carats and are always faceted in elongated emerald cuts to maximize cutting retention of the thin, acicular crystals. Because of scolecite's very low density (average specific gravity 2.25), a two-carat scolecite gem is about the size of a four-carat diamond (specific gravity 3.5) gem. Four-carat scolecite collector gems are about one inch long, but only one-fifth of an inch thick.

Mineral collectors value scolecite both as single and composite specimens, the latter in association with quartz, calcite, or other zeolite minerals. Because they are very difficult to remove intact from basalt cavities, perfect (undamaged) scolecite specimens can be quite costly. Single scolecite specimens are sometimes found mounted atop crystals of stilbite-Ca [hydrous calcium potassium sodium aluminum

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silicate,  $(\text{Ca}_{0.5}, \text{K}, \text{Na})_9(\text{Al}_9\text{Si}_{27}\text{O}_{72}) \cdot 28\text{H}_2\text{O}$ ] or fluorapophyllite [basic hydrous potassium calcium fluorosilicate,  $\text{KCa}_4\text{Si}_8\text{O}_{20}(\text{F}, \text{OH}) \cdot 8\text{H}_2\text{O}$ ], as our 1997 pieces were. Because these zeolite minerals are often found with scolecite, they provide not only a secure base to display the fragile scolecite crystals, but a “natural” mineralogical association as well. The National Museum of Natural History (Smithsonian Institution) in Washington, D.C., exhibits the largest and finest known scolecite specimen—a spectacular, radiating spray of colorless, acicular crystals measuring 20 inches across and 11 inches high.

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

Although scientists knew of zeolite minerals in the mid-1700s, they could not begin to chemically distinguish them until the early 1800s. German mineralogist Abraham Gottlieb Werner (1747-1817) first categorized the minerals now known as scolecite, natrolite, and mesolite as *Faserzeolithen* (fibrous zeolites). In 1801, the French mineralogist and crystallographer René-Just Haüy renamed this group “mesotype.” Although Haüy identified the calcium-rich member of the mesotype group, he did not recognize it as a distinct species. After observing the tendency of its long, thin crystals to curl in the dehydrating heat of a blowpipe, Haüy informally named this calcium-rich member *Skolezit*, from the Greek *skôlōx*, meaning “worm.” The true chemistries of the mesotype group began to emerge in 1805 when researchers identified natrolite, the sodium-rich mesotype member, as a distinct mineral species.

In 1813, German mineralogists Johann Nepomuk Fuchs (1774-1856) and Adolph Ferdinand Gehlen (1775-1815), working mainly with specimens collected at Kaiserstuhl, Baden-Württemberg, Germany, demonstrated that *Skolezit*, the calcium-rich mesotype member, was also a new mineral species. But because Fuchs and Gehlen had also studied specimens from other localities, Kaiserstuhl was not recognized as the scolecite type locality. Researchers identified the last mesotype member, a sodium-calcium mineral, as a new species in 1816 and named it “mesolite.” In 1823, the name *Skolezit* was changed to “scolecite.” In the 1880s, German chemist Johann Theodor Lemberg (1842-1902) used scolecite to demonstrate the zeolitic property of ion exchange. Also, by immersing scolecite in basic soda solutions and applying heat and pressure, Lemberg substituted sodium for all or part of its calcium cations, in effect converting scolecite to natrolite and mesolite, thus confirming the process of zeolitic ion exchange and clarifying the chemical relationship between scolecite, natrolite, and mesolite. The atomic structure of scolecite was determined by X-ray diffraction methods in 1923.

Modern metaphysical practitioners believe that scolecite promotes inner peace, deep relaxation, and meditation; enhances the dream state; and facilitates both dream recall and restful sleep.

### ***TECHNOLOGICAL USES***

Because of their unique, open-channel structure and ability to exchange metal cations, zeolites are effective mediums for chemical and physical absorption, filtration, ion-exchange, chemical catalysis, and molecular sieving. Zeolites have many applications in science, industry, agriculture, and the manufacture of consumer products and are used to purify water and gases, catalyze petrochemical and chemical processes, remove radioactive wastes in the nuclear, medical and power-generation processes, and control nutrient-release times in agricultural fertilizers. Zeolite minerals serve as the models for their own laboratory synthesis. The production of natural and synthetic zeolites is a multi-billion-dollar industry. Each year, 2.5 million metric tons of synthetic zeolites are produced, while 5 million metric tons of natural zeolites are mined. China, the leading producer, mines more than 3.5 million tons of natural zeolites each year. Other important producers of natural zeolites are, in order, Jordan, the Republic of Korea, Japan, and Turkey. The United States ranks sixth, producing 60,000 tons of natural zeolites each year from open-pit mines in California and Nevada. Because scolecite is uncommon, it has minimal industrial importance.

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### **RECLASSIFYING THE ZEOLITES**

Scolecite is one of 83 zeolite-mineral species that all share unique physical properties (see “Composition”). But the zeolites have another claim to mineralogical notoriety—their system of nomenclature and classification has undergone the greatest recent revision of any mineral group. This revision reflects mineralogists’ efforts to assimilate and interpret the huge volumes of zeolite chemical and structural data being produced by advanced analytical methods.

The study of zeolites dates to 1756, when Swedish mineralogist Axel Fredrick Cronstedt (1722-1765) pioneered the study of zeolite minerals by identifying stilbite-Ca [hydrous calcium potassium sodium aluminum silicate,  $(\text{Ca}_{0.5}, \text{K}, \text{Na})_9(\text{Al}_9\text{Si}_{27}\text{O}_{72}) \cdot 28\text{H}_2\text{O}$ ]. At the time, stilbite-Ca was known as “stilbite.” Observing how stilbite vibrated when 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.” Mineralogists had recognized 19 zeolite minerals by 1842, and 29 species by 1920. By the mid-1970s, using data obtained from advanced analytical techniques, mineralogists had recognized 41 distinct zeolite species and were proposing new species at rate of one per year.

During the 1970s, the rapid increase in the number of new zeolite species was due mainly to refinements in two analytical tools—the X-ray diffractometer and the electron-beam microprobe. X-ray diffraction analysis is a method of determining atomic and molecular structure by measuring the “scatter” patterns of X rays after they pass through mineral crystals or other crystalline materials. Mineralogists first used X-ray diffraction to define the atomic structures of minerals in the 1920s. By the 1970s, advanced X-ray diffractometers were providing remarkably detailed “views” of atomic structures that revealed the most subtle crystallographic differences, even in minerals of similar chemistries. Meanwhile, electron microprobes (electron-probe microanalyzers) were providing extremely detailed compositional data. Electron microprobes, which were commercially introduced in the 1950s, employ a sharply defined electron beam to cause mineral specimens as small as one square micrometer ( $1/25,000^{\text{th}}$  of a square inch) to emit characteristic X rays. Because these secondary X rays have frequencies that are diagnostic for specific elements, X-ray diffractometers can positively identify most elements in mineral samples, even when present in trace amounts of only 100 parts per million.

During the 1970s, the flood of zeolite data generated by government and university scientists was supplemented by that from industrial researchers working with both natural and synthetic zeolites. Mineralogists became concerned that the traditional definition of zeolite minerals had become restrictive or even obsolete. Another concern was the increasingly rapid acceptance, classification, and naming of new zeolite minerals. In 1979, the International Mineralogical Association (IMA), the global organization of mineralogical scholars and researchers who formally recognize new mineral species, classify minerals, and approve new mineral names, agreed that revision of the zeolite-classification system was necessary. The IMA’s Commission on New Minerals and Mineral Names (CNMMN) appointed a subcommittee to study the issue. When this subcommittee filed its report in 1987, the number of zeolite species had grown to 48. When this number surpassed 50 in 1993, the IMA appointed another CNMMN subcommittee, this one with a priority mandate to revise the zeolite-classification system. Its report, accepted and published in 1997, redefined zeolite minerals as follows:

*A zeolite mineral is a crystalline substance with a structure characterized by a framework of linked tetrahedra, each consisting of four O atoms surrounding a cation. This framework contains open cavities in the form of channels and cages. These are usually occupied by  $\text{H}_2\text{O}$  molecules and extra-framework*

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cations that are commonly exchangeable. The channels are large enough to allow passage of guest species. In the hydrated phases, dehydration occurs at temperatures mostly below about 400 °C., and is largely reversible. The framework may be interrupted by (OH,F) groups; these occupy a tetrahedron apex that is not shared with adjacent tetrahedra.

The CNMMN's 1997 report also established rules for the classification and nomenclature of zeolites. The five most important rules follow in abbreviated form:

Rule 1: Zeolite minerals having a topologically distinctive tetrahedral framework and a composition typical of zeolites shall constitute separate *species*; these minerals, when displaying a substantial range in composition in which differing extra-framework cations are more abundant in atomic proportions shall constitute a *series*.

Rule 2: Differences in space-group symmetry and order-disorder relationships do not provide adequate ground for recognition of separate species. Chemical composition must also be considered.

Rule 3: Zeolite mineral species shall not be distinguished solely on the basis of widely variable framework silicon-to-aluminum ratios.

Rule 4: Dehydration, rehydration or overhydration, whether reversible or irreversible, are not sufficient grounds for recognition of separate species.

Rule 5: Individual species in a zeolite series with varying extra-framework cations are named by attaching to the series name a suffix consisting of the chemical symbol of the predominant extra-framework element.

The application of these rules sharply increased the number of zeolite species. The greatest impact came from the application of Rule 5, concerning the predominant extra-framework cation. Under the new guidelines, 13 previously accepted zeolite species were reclassified into 13 new compositional series consisting of 35 new species. An example of this nomenclatural reclassification is heulandite-Ca (our Mineral of the Month for April 2009). Prior to 1997, heulandite, a hydrous calcium sodium potassium aluminosilicate, was considered a single zeolite species with such extra-framework cations as calcium, sodium, potassium, and strontium present in varying proportions. Under the new rule, heulandite became the heulandite *series*, which includes the original calcium-dominant heulandite along with three new separate species, all with chemical-symbol suffixes to indicate the predominant extra-framework element:

**Heulandite-Ca**  $(\text{Ca}_{0.5}, \text{Na}, \text{K})_9(\text{Al}_9\text{Si}_{27}\text{O}_{72}) \cdot \sim 24\text{H}_2\text{O}$  hydrous calcium sodium potassium aluminosilicate

**Heulandite-Na**  $(\text{Na}, \text{Ca}_{0.5}, \text{K})_9(\text{Al}_9\text{Si}_{27}\text{O}_{72}) \cdot \sim 24\text{H}_2\text{O}$  hydrous sodium calcium potassium aluminosilicate

**Heulandite-K**  $(\text{K}, \text{Ca}_{0.5}, \text{Na}, \text{Mg}_{0.5}, \text{Sr}_{0.5})_9(\text{Al}_9\text{Si}_{27}\text{O}_{72}) \cdot \sim 24\text{H}_2\text{O}$  hydrous potassium calcium sodium magnesium strontium aluminosilicate

**Heulandite-Sr**  $(\text{Sr}_{0.5}, \text{Ca}_{0.5}, \text{Na}, \text{K})_9(\text{Al}_9\text{Si}_{27}\text{O}_{72}) \cdot \sim 24\text{H}_2\text{O}$  hydrous strontium calcium sodium potassium aluminosilicate

Also, several minerals not previously accepted as distinct species (or even as zeolites) were recognized as zeolites under the new definition. As a result, the IMA now recognizes 83 zeolite species. This revision has made several important points. First, the zeolite-mineral group exhibits levels of chemical and structural complexity that had not previously been understood. Second, the number of approved zeolite minerals can be expected to increase in the future. And finally, mineralogy is not a static pursuit, but a continuously evolving science that must respond to new compositional and structural data by revising, as necessary, any and all mineral nomenclature and classification systems.



## ***January 2011 Mineral of the Month: Scolecite***

### ***ABOUT OUR SPECIMENS***

Our scolecite specimens were collected at a basalt quarry near the city of Sangamner, Ahmadnagar District, state of Maharashtra, in the Republic of India. Maharashtra is located in west-central India and borders the Arabian Sea; its capital is the coastal city of Mumbai (formerly Bombay). With 118,000 square miles, Maharashtra is nearly half the size of the state of Texas. Ahmadnagar, one of Maharashtra's 34 administrative districts, is in west-central part of the state. About the size of the state of New Jersey, the Ahmadnagar District has a population of 4.5 million. Sangamner, population 600,000 and the district's second largest city, is located 80 air miles east-northeast of Mumbai. Sangamner, named for its location at the confluence (*sangam*) of the Pravara, Mhalungi, and Mahanuti rivers, has an elevation of 1,800 feet, enjoys a warm climate, and is a busy trading center for the surrounding agricultural region that produces sugar, tobacco, and cotton.

In the state of Maharashtra, the districts of Ahmadnagar, Nashik, Nagar, Jalgaon, Mumbai, and Pune are the world's leading sources of fine zeolite-mineral specimens. The host rock of these specimens is the basalt of the Deccan (DECK-kenn) Traps, one of the world's largest volcanic regions. This huge formation covers 200,000 square miles (more than the combined areas of the states of Washington and Oregon) and includes most of Maharashtra and the entire Ahmadnagar district. The Deccan Traps were formed by a massive extrusion of magma at the late Cretaceous Period some 65 million years ago. This magma rose through long, narrow fissures and faults in the crust, extruded onto the surface, and spread in horizontal sheets to form basalt formations thousands of feet thick. Although the Deccan Traps contain no commercial mineral deposits, the hard, durable, dense, inert basalt itself makes a fine construction material. As the only regionally available rock, basalt serves as ballast, fill for roads and rail beds, and foundations for buildings and dams. When finely crushed, it is a gravel additive for cement. Basalt quarrying is a major industry in Maharashtra, with thousands of individual quarries.

As an extrusive (volcanic) igneous rock, basalt forms when magma solidifies at or near the surface. Basalt is a fine-grained rock containing little quartz, but large amounts of iron and magnesium minerals that impart a characteristic dark color. Its prominent structures are vesicles (cavities) and amygdules. Vesicles form from gas bubbles within the flowing magma, usually near the top of the flow where reduced pressure enables expansion of steam and gases. Amygdules are vesicles that later became filled with secondary minerals such as quartz and zeolites. Because of the broad, flat nature of the Deccan Traps lava flows, much surface and near-surface basalt has a vesicular texture. When the lava solidified, these vesicles were barren or hollow. But contraction of the basalt formations created networks of fissures and fractures through which groundwater later circulated. As this water percolated downward through the basalt, it became alkaline and dissolved aluminum- and silica-bearing minerals. After filling many vesicles, these solutions precipitated zeolite minerals in an array of well-developed crystal forms.

In the 1820s, British surveyors, military men, and engineers working in the Deccan Traps collected finely developed crystals of quartz, calcite, and zeolite minerals from amygdules within the basalt. The abundance of these specimens became apparent in the 1830s, when the construction of railroad tunnels between Bombay and Pune exposed many large amygdules filled with beautiful crystals. Workers called these mineral-laden pockets "Jewel Tunnels." At first, these crystals had only scientific interest, until they gained popularity among European and American mineral collectors in the late 1960s. After receiving considerable attention in western mineralogical and mineral-collecting publications during the 1970s, the international trade in Indian zeolite specimens boomed. Since then, collecting and marketing zeolite-mineral specimens from the Deccan Traps has become big business both in India and abroad. Most every gem-and-mineral show contains vendors proudly displaying large, well-crystalized specimens of zeolite-group minerals like scolecite, mesolite, heulandite, stilbite, and thomsonite, along with the non-zeolite

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minerals (apophyllite, okenite, calcite, quartz) that often form on and with them!

Today, Indian zeolite specimens are recovered mainly from basalt quarries and to a lesser extent from canal, well, and building excavations. Because zeolite specimens have become a valuable by-product of basalt quarrying, dealers and specimen miners contract with individual quarries for exclusive recovery rights. Specimen miners utilize special techniques to extract intact zeolite specimens from amygdules in the tough basalt. At the Sangamner municipal quarries, the source of our scolecite specimens, workers break the basalt by drilling and blasting, then truck the rock to crushers to be sized for specific uses. When zeolite-filled amygdules are encountered, supervisors move operations to other parts of the quarries, providing time for commercial collectors to recover specimens.

Our scolecite specimens consist of radiating clusters or sprays of colorless-to-white, acicular crystals. When studying your specimen, be sure to handle it carefully as scolecite is brittle and its long, acicular crystals are fragile. Note first the crystal shape itself, in which the long, thin crystals are an external manifestation of the internal structure of long, aluminosilicate chains. A loupe or magnifying glass is helpful in observing two of scolecite's characteristic features—slanted crystal terminations and lengthwise striations. Most terminations—the unbroken ends of the crystals—are steeply slanted; the striations appear as faint, parallel lines running lengthwise along the prisms. Note also that although some crystals may appear to be thick, single prisms, these actually consist of many, much thinner (some even hair-like) prisms grown together as a cluster.

The base of the specimen—the point from which the prisms radiate outward—was once attached to another massive zeolite mineral, probably natrolite, that covered the wall of an amygdule within the basalt. This amygdule was generally spherical in shape, one or two feet in diameter, and partially filled with scolecite crystals. Considering the extraordinary durability of the surrounding basalt, it is remarkable that commercial collectors were able to recover these fragile crystals at all.

Scolecite can sometimes give off yellow or brown fluorescence in ultraviolet light. We checked some of our pieces under both short and long wave light, and the only fluorescence we noted was a yellow color coming from tiny crystals on a very few of the scolecites. Examination with our handy 10x power loupe reveals the tiny crystals to be calcite, judging by their clarity and luster, and their fluorescence. Examining and marveling at the delicate beauty of our scolecite crystals, we cannot help but think of the tremendous wealth of zeolite-group minerals and related species found in India's vast Deccan Traps! Every time a new quarry or tunnel is dug, another amazing new find may be made! Each find will have unique properties. Truly, India will be a source of wonderful specimens for many, many years to come!

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