

February 2009 Mineral of the Month: Heulandite

This month's mineral, heulandite-Ca, is a member of the prolific zeolite group. Our specimens were collected at a newly discovered source in the Deccan Traps in the Republic of India. Our write-up will explain how heulandite-Ca forms, the unique properties and many uses of zeolites, and how the formation of the Deccan Traps is linked to the extinction of the dinosaurs.

OVERVIEW

PHYSICAL PROPERTIES

Chemistry: $(\text{Ca}_{0.5}, \text{Na}, \text{K})_9(\text{Al}_9\text{Si}_{27}\text{O}_{72}) \cdot \sim 24\text{H}_2\text{O}$ Hydrous Calcium Sodium Potassium Aluminum Silicate, usually containing some barium and strontium

Class: Silicates

Subclass: Tectosilicates

Group: Zeolites

Crystal System: Monoclinic

Crystal Habits: Usually as coarse, well-formed, coffin-shaped crystals; single, tabular crystals; or radiating aggregates of nearly parallel crystals. Also in foliated, globular, and granular forms. Prismatic or pinacoidal faces are often modified by small, symmetrical pairs of secondary, triangular faces.

Color: White, grayish, colorless, greenish, peach, pale orange, and red

Luster: Vitreous to pearly

Transparency: Usually translucent, occasionally transparent

Streak: Colorless

Cleavage: Perfect in one direction

Fracture: Uneven, brittle

Hardness: 3.5-4.0

Specific Gravity: 2.1-2.3 (varies with water content)

Luminescence: None

Refractive Index: 1.48-1.52

Distinctive Features and Tests: Best field-identification marks are coffin-shaped crystal form, vitreous-to-pearly luster, low density, and association with other zeolite-group minerals, especially mordenite $[(\text{Na}_2, \text{Ca}, \text{K})_4(\text{Al}_8\text{Si}_{40}\text{O}_{96}) \cdot 28\text{H}_2\text{O}]$. Zeolite-group mineral stilbite $[(\text{Ca}_{0.5}, \text{K}, \text{Na})_9(\text{Al}_9\text{Si}_{27}\text{O}_{72}) \cdot 28\text{H}_2\text{O}]$ is similar in appearance but rarely exhibits coffin-shaped crystals. Laboratory tests are usually necessary to positively distinguish heulandite-Ca from other minerals of the heulandite group.

Dana Classification Number: 77.1.4.1

NAME Pronounced hew-LAND-ite or HEW-land-ite, our mineral is named after the noted British mineral collector and dealer John Henry Heuland (1778-1856). The specific name of this month's mineral is "heulandite-Ca," in which the "Ca" suffix denotes the calcium-analog member of the heulandite series. Heulandite-Ca is pronounced as "heulandite-calcium" or "heulandite-see-aay." Heulandite-Ca has also been called "heulandite," "beaumontite," "calcium heulandite," and "lamellar zeolite."

COMPOSITION: Heulandite-Ca, chemical formula $(\text{Ca}_{0.5}, \text{Na}, \text{K})_9(\text{Al}_9\text{Si}_{27}\text{O}_{72}) \cdot \sim 24\text{H}_2\text{O}$, contains the elements calcium (Ca), sodium (Na), potassium (K), aluminum (Al), silicon (Si), oxygen (O), and hydrogen (H). The molecular weight of heulandite-Ca is made up of approximately 5.06 percent calcium, 1.03 percent sodium, 0.60 percent potassium, 8.96 percent aluminum, 26.54 percent silicon, 55.51 percent oxygen, and 1.86 percent hydrogen. Heulandite-Ca is a member of the silicates, the largest of all mineral classes. Heulandite-Ca occurs primarily in basaltic volcanic rocks within amygdaloidal cavities that form as gas bubbles during the solidification of silica-deficient (mafic) magmas; in marine sediments that have undergone alkaline alteration; and rarely, in certain metamorphic rocks, pegmatites, and volcanic tuffs.

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Heulandite-Ca is a hydrous (contains 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 heulandite-Ca's very low specific gravity (density) of only about 2.2, while weak, inter-sheet bonding explains its considerable softness of Mohs 3.5-4.0. This network of hollow spaces and channels enables zeolites to lose and regain water of hydration without alteration of the crystal structure and to act as molecular filters that can allow certain ions, atoms, and molecules to pass while blocking others. When nearly pure, heulandite-Ca is colorless or white, but impurities, mainly iron and manganese, create pale yellow, brown, orange, peach, and pink colors.

COLLECTING LOCALITIES: Heulandite-Ca specimens are collected in basalt formations in the Aurangabad, Nasik, Pune, and Ahmadnagar districts in the Indian state of Maharashtra. In Europe, heulandite-Ca occurs at Teigerhorn, Beruford, Iceland; Denmark's Faeroe Islands; the St. Just District of Cornwall, England; and at Hørtekollen in Buskerud, Norway. Canadian specimens are found in the Wasson's Bluff volcanic flow in Cumberland County, Nova Scotia. The most notable collecting locality in the United States is the lava flows near Challis in Custer County, Idaho. Specimens are also collected in lava flows in Colorado, New Jersey, and Oregon.

HISTORY, LORE, & USES: Heulandite-Ca has no use as a gemstone, but is valued by mineral collectors both as single and composite specimens. Heulandite was identified as a distinct mineral species in 1818 and formally named in 1822. Metaphysical practitioners believe that heulandite connects the individual with the universe, enhances general awareness, and aids in recovery from the emotional trauma of loss.

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 virtually all laundry detergents, and as filtration mediums for aquariums and pools. Some five million metric tons of zeolites are mined worldwide each year.

ABOUT OUR SPECIMENS: Our heulandite-Ca specimens were collected at a basalt quarry near Wani south of the city of Aurangabad in the Aurangabad district of the state of Maharashtra in the Republic of India. Aurangabad is situated near the center of the Deccan Traps, a huge volcanic province that consists of basalt formations as thick as 6,000 feet. Our specimens occur in cavities or vesicles formed from gas bubbles in the original magma. Later, these cavities in the basalt filled with mineral-rich groundwater that precipitated crystals of quartz, calcite, and the zeolite minerals. Our specimens were recovered as a by-product of quarrying basalt and consist of pale-orange-to-peach-colored crystals on a matrix of fibrous, white mordenite, another zeolite mineral. Study the specimen closely to observe the flared "shoulders" that typify the coffin-shaped crystals of heulandite-Ca.

10 YEARS AGO IN OUR CLUB: Danburite, Charcas District, San Luis Potosi, Mexico. Putting the write-up together ten years ago made us fall in love with danburite! We love the beautiful, topaz-like crystal forms, translucence, and delicate pinkish tinge of the nicest crystals. It was originally described as a new mineral in 1839 by Charles Upham Shepard, a professor at Amherst College, Amherst, Massachusetts, and named for Danbury, Connecticut, where the first small crystals were found. The quarries where danburite was discovered have long since been built over. Professor Shepard and his colleagues would be blown away by the size and color of the danburite crystals that come from the Charcas District—we have sold more than 180 pounds of small danburite crystals since then, several clusters of large crystals, and one large single crystal at least a foot long and five inches wide, by far the largest we've ever seen.

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COMPREHENSIVE WRITE-UP

COMPOSITION

We have discovered a pipeline to the Zeolite group and other related minerals from the enormous Deccan Traps of India, where we are able to obtain high quality, sizable, undamaged, matrix specimens, and we intend to take advantage of it! Already, we have featured the zeolite group minerals thomsonite (Nov 2007) and stellerite (March 2008), and the not-quite-zeolite-group-but-related minerals cavansite (April 2006) and apophyllite (June 2006). In the future, we hope to feature epistilbite, goosecreekite, okenite, and others!

The chemical formula of heulandite-Ca, $(\text{Ca}_{0.5}\text{Na,K})_9(\text{Al}_9\text{Si}_{27}\text{O}_{72}) \cdot \sim 24\text{H}_2\text{O}$, indicates that it contains the elements calcium (Ca), sodium (Na), potassium (K), aluminum (Al), silicon (Si), oxygen (O), and hydrogen (H). The molecular weight of heulandite-Ca is made up of approximately 5.06 percent calcium, 1.03 percent sodium, 0.60 percent potassium, 8.96 percent aluminum, 26.54 percent silicon, 55.51 percent oxygen, and 1.86 percent hydrogen. These percentages, which apply to *nearly* pure heulandite-Ca, add up only to 99.56. Heulandite-Ca does not occur in pure form and always contains at least 0.44 percent and almost always contains some barium and strontium, along with varying quantities of potassium and sodium.

While heulandite-Ca's chemical formula $(\text{Ca}_{0.5}\text{Na,K})_9(\text{Al}_9\text{Si}_{27}\text{O}_{72}) \cdot \sim 24\text{H}_2\text{O}$ can seem imposing, it can be explained simply. Remember that all molecules are composed of positively charged cations and negatively charged anions. In heulandite-Ca, both the cation and anion are radicals, groups of ions of different atoms that behave as single entities in chemical reactions. The heulandite-Ca cation is the radical $(\text{Ca}_{0.5}\text{Na,K})_{9+}$, in which the calcium ion has a +2 charge and both the sodium and potassium ions have a +1 charge. The " $_{0.5}$ " quantifier for calcium indicates that one calcium ion participates in 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, providing that the net collective cationic charge remains +9. The anion of the heulandite-Ca molecule 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 ion has a +4 charge, and each oxygen ion has a -2 charge, resulting in a collective -9 charge. This -9 anionic charge balances the +9 cationic charge to provide the heulandite-Ca molecule with electrical stability.

The " $\sim 24\text{H}_2\text{O}$ " in heulandite-Ca's chemical formula shows that it is a hydrous (or hydrated) mineral with as many as 24 molecules of water (H_2O) attached to each parent molecule (the symbol " \cdot " indicates attachment and " \sim " indicates "as many as"). Attached water molecules are collectively called "water of hydration" and consist of electrically neutral water molecules that do not affect the electrical balance of the parent molecule. An unusual atomic configuration in which two hydrogen ions are grouped together on one side of a large oxygen ion enables water molecules to attach to certain other molecules. 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 polarity enables water molecules to behave as tiny dipole magnets and to attach themselves to other molecules by a weak attraction called "hydrogen bonding."

Heulandite-Ca is a member of the silicates, the largest of all mineral classes, 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);

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double tetrahedral silicates (sorosilicates); single- and double-chain silicates (inosilicates); ring silicates (cyclosilicates); sheet silicates (phyllosilicates); and framework silicates (tectosilicates).

Although heulandite-Ca is classified as a framework silicate or tectosilicate, its crystal lattice is actually based on a modified aluminosilicate radical that forms a sheet-like structure. 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 are positioned so that the rings in each sheet align in stacks to form open channels throughout the lattice. Together with spaces between the sheets, these channels provide room for the attachment of heulandite-Ca's water of hydration and account for its very low specific gravity (density) of only about 2.2. Because the sheets are widely separated, the covalent atomic bonding that joins them is relatively weak—the reason for heulandite-Ca's perfect, one-directional cleavage. Weak inter-sheet bonding also explains why heulandite-Ca is one of the softest of all silicate minerals at Mohs 3.5-4.0.

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

The Dana mineral-classification number 77.1.4.1 identifies heulandite-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. Heulandite-Ca is then assigned to the heulandite group (4) as the first (1) of 12 members. The heulandite group includes five members of the heulandite sub-group, three members of the clinoptilolite group, two members of the stilbite group, stellerite, and barrerite, all of which have similar chemistries. The five very closely related members of the heulandite sub-group include:

77.1.4.1 Heulandite-Ca ($\text{Ca}_{0.5}, \text{Na}, \text{K}$)₉($\text{Al}_9\text{Si}_{27}\text{O}_{72}$)·~24H₂O
77.1.4.1a Heulandite-Na ($\text{Na}, \text{Ca}_{0.5}, \text{K}$)₉($\text{Al}_9\text{Si}_{27}\text{O}_{72}$)·~24H₂O
77.1.4.1b Heulandite-K ($\text{K}, \text{Ca}_{0.5}, \text{Na}$)₉($\text{Al}_9\text{Si}_{27}\text{O}_{72}$)·~24H₂O
77.1.4.1c Heulandite-Sr ($\text{Sr}_{0.5}, \text{Ca}_{0.5}, \text{Na}, \text{K}$)₉($\text{Al}_9\text{Si}_{27}\text{O}_{72}$)·~24H₂O
77.1.4.1d Heulandite-Ba ($\text{Ba}_{0.5}, \text{Ca}_{0.5}, \text{Na}, \text{K}$)₉($\text{Al}_9\text{Si}_{27}\text{O}_{72}$)·~24H₂O

Notice that the group chemistry differs only in quantities or in the substitution of the cationic elements, and that in heulandite-Sr and heulandite-Ba, strontium and barium, respectively, substitute for some of the calcium, sodium, and potassium. Cationic substitution enables these minerals to form graded, continuous, solid-solution series. All share similar physical properties and require laboratory analysis for positive differentiation. Of all these minerals, heulandite-Ca is by far the most abundant.

Heulandite-Ca is a low-temperature, low-pressure mineral that occurs primarily in basaltic volcanic rocks within amygdaloidal cavities that form as gas bubbles during the solidification of silica-deficient (mafic) magmas. In subsequent low-grade, hydrothermal metamorphism, percolating alkaline groundwater deposits zeolite minerals, often as well-developed crystals associated with other zeolite minerals, along with quartz [silicon dioxide, SiO₂], and calcite [calcium carbonate, CaCO₃]. Heulandite-Ca also occurs in marine sediments that have undergone alkaline alteration; smaller quantities are found in certain metamorphic rocks, pegmatites, and volcanic tuffs.

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Heulandite-Ca is an allochromatic mineral, meaning that color-causing impurities called chromophores can impart to it a wide range of colors. When nearly pure, heulandite-Ca is colorless or white. But impurities, mainly iron and manganese, can create a wide range of pale yellow, brown, orange, peach, and pink colors. Greenish hues in heulandite-Ca are caused by inclusions of chlorite minerals (a group of basic magnesium iron aluminum silicates).

COLLECTING LOCALITIES

Our heulandite-Ca specimens represent a new find, collected at a basalt quarry at Wani near the city of Aurangabad in the Aurangabad district of the state of Maharashtra in the Republic of India. Other Indian sources of heulandite-Ca include quarries in the Nasik, Pune, and Ahmadnagar districts.

In Europe, heulandite-Ca occurs at the classic locality at Teigerhorn, Berufjord, Iceland; the lava flows on Denmark's Faeroe Islands; the Schann and Jean quarries at Kusel in Rhineland-Palatinate, Germany; the Fassio Valley in Trento Province, Trentino-Alto Adige, Italy; the Botallack Mine in the St. Just District of Cornwall, England; and at Hørtkollen near Lier in Buskerud, Norway.

Other notable localities include Mount Puiva near Saranpaul in the Tyumenskaya Oblast' in the Urals Region of Russia; the Cairnwood quarries near Durban in the KwaZulu-Natal Province of South Africa; the Wasson's Bluff volcanic flow in Cumberland County, Nova Scotia, Canada; and quarries at Yugawara in Kanagawa Prefecture in the Kanto Region of Honshu Island, Japan.

The United States has several heulandite-Ca localities, the most notable being the Rat's Nest claims on the lava flows near Challis in Custer County, Idaho, our Mineral of the Month for November 2002. We obtained those specimens due to the efforts of collector and author Lanny Reem, former publisher of the *Mineral News*. After seeing a reference in a 1924 National Museum article published by the Smithsonian Institution that mentioned heulandite, mordenite, and other minerals found in the low hills south of Challis, Idaho, he searched out and found the source of the marvelous minerals. Collector John Cornish worked the find, and gave us a sweetheart deal so that we could bring them to you in 2002.

Other sources of fine American specimens include the North Table Mountain and South Table Mountain lava flows at Golden in Jefferson County, Colorado; the Prospect Park and Sowerbutt traprock quarries at Prospect Park in Passaic County, New Jersey; and the lava flows near Edwards in Tillamook County, Oregon.

JEWELRY & DECORATIVE USES

Because of its relative softness (Mohs 3.5-4.0), low index of refraction (1.48-1.52), perfect, single-directional cleavage that makes cutting difficult, and tendency to be at least partially translucent, heulandite is not used as a gemstone. Heulandite has long been valued by mineral collectors both as single and composite specimens, the latter most often in association with other zeolite minerals.

HISTORY & LORE

Swedish mineralogist Axel Fredrick Cronstedt (1722-1765) pioneered the study of zeolite minerals in 1756 by identifying the first zeolite mineral, stilbite-Ca [hydrous calcium potassium sodium aluminum silicate, $(\text{Ca}_{0.5}\text{KNa})_9(\text{Al}_9\text{Si}_{27}\text{O}_{72}) \cdot 28\text{H}_2\text{O}$]. Observing how stilbite-Ca specimens vibrated as heat drove off their water of hydration, Cronstedt coined the word "zeolite," literally "stone that boils," from the Greek *zein*, meaning "to boil," and *lithos*, or "stone." Most scientists initially assumed that heulandite and stilbite, which

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often occur together, were actually the same mineral. But British mineral dealer and collector John Henry Heuland (1778-1856) may have been the first to suspect otherwise and took a special interest in zeolites minerals. Heuland came from a family of mineral dealers. His father Christian Heuland collected minerals in the late 1790s in what is now Peru and Chile, while two of his uncles were also prominent mineral collectors and dealers. In 1816, Heuland visited the classic locality at Teigerhorn, Beruford, Iceland, to build the first significant collection of the mineral that would later be named in his honor.

In 1818, the German mineralogist August Johann Friedrich Breithaupt (1791-1873) studied Heuland's Iceland specimens and differentiated them from stilbite, naming the new mineral "euzeolite," meaning "beautiful zeolite." Then in 1822, British crystallographer Henry James Brooke (1771-1857) confirmed Breithaupt's findings and formally named "euzeolite" after John Henry Heuland—heulandite. In the 1830s, Heuland acquired the first significant shipment of heulandite specimens ever sent to England from India's Deccan Traps. He instilled much interest in the mineral by distributing the specimens to other collectors, scientists, museums, and universities. Heuland greatly influenced mineral collecting in 19th century England by importing a steady supply of fine mineral specimens from around the world, publishing mineral-specimen catalogues, and conducting specimen auctions. Many of Heuland's finest specimens are now displayed in major British museums.

Although X-ray diffraction techniques revealed the crystal structure of heulandite in the late 1920s, mineralogists nevertheless would consider heulandite to be a single mineral species for another 70 years. But in the early 1990s, mineralogists using advanced quantitative-analysis methods learned that heulandite was actually a mineral group that consisted of a solid-solution series based on the nearly complete cationic substitution of calcium, potassium, strontium, and sodium. In 1997, the Zeolites Committee of the Commission on New Minerals and Mineral Names of the International Mineralogical Association (IMA) reorganized the zeolite-minerals group. The committee recognized many new zeolite species, renamed heulandite as heulandite-Ca, and recognized heulandite-Na, heulandite-K, and heulandite-Sr as distinct mineral species. In 2004, the committee also recognized the barium analog of the heulandite group as heulandite-Ba. Prior to 1997, the IMA had recognized just 51 zeolite minerals; today, it recognizes 87 zeolite species and the list continues to grow.

According to modern metaphysical lore, heulandite (metaphysical practitioners do not differentiate between members of the heulandite group) connects the individual with the universe, enhances general awareness, and aids in recovery from the emotional trauma of loss. Physically, heulandite is thought to assist with weight loss and alleviate problems with the inner ear, feet, and lungs.

An artist's representation of heulandite crystals appeared on the 1.50 króna stamp of Iceland in 1999.

TECHNOLOGICAL USES

Because the structure of channels and spaces in the zeolite minerals enables them to exchange metal cations and absorb and filter particulates, they are superb mediums for absorption, filtration, ion-exchange, chemical catalysis, and molecular sieving. Today, zeolites are the foundation of a multi-billion-dollar industry that mines and synthesizes more than five million metric tons of zeolites each year. China, the leading producer of natural zeolites, mines more than 3.5 million metric tons annually. The United States mines 55,000 tons of natural zeolites each year.

Zeolites are regularly 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. Zeolites are also used for purification of medical oxygen, as "filtration-capture" mediums in virtually all laundry detergents, as additives to improve the

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workability and reduce the density of asphalt and cement, and as filtration mediums for aquariums and pools. The study of natural zeolites has led to the development of commercially important synthetic zeolites, which now make up half of all zeolites used by industry.

THE DECCAN TRAPS AND THE END OF THE DINOSAURS

The Deccan Traps, one of the Earth's largest volcanic provinces and the source of our heulandite-Ca specimens, are part of the Deccan Plateau that covers much of central and southern India. The name "Deccan," pronounced DEH-cann, is an anglicized form of the Prakrit dakkhin, which stems from the ancient Sanskrit daksina, meaning "south," referring to the southern part of the Indian subcontinent. The term "traps" is derived from trappa, Swedish for "stairs" and a reference to the step-like hills and valleys that dominate the Deccan topography.

The Deccan volcanic formations cover nearly 200,000 square miles, an area nearly equal to that of Texas. The Deccan Traps are as thick as 6,000 feet and cover virtually all of the Indian state of Maharashtra and small, adjoining sections of the states of Madhya Pradesh to the north and east, Andhra Pradesh to the east, and Karnataka and Tamil Nadu to the south.

Scientists theorize that the Deccan Traps were created by a lengthy, massive series of volcanic eruptions between 68 million and 60 million years ago during the late Cretaceous Period. To understand the origin of the Deccan Traps, it is important to remember that, because of tectonic-plate drift, the Indian Subcontinent was not always in its present geographic location.

Tectonic plate movement began with the breakup of the ancient, "universal" continent of Pangaea. About 200 million years ago, after Pangaea had begun separating into a mosaic of sub-plates, its southern part broke off into the proto-continent of Gondwanaland, which included both the modern-day plates of Africa and India. Some 80 million years ago, the Indian Plate (actually the Indo-Australian Plate) and the African plate began to separate. Driven by thermal convection currents in the Earth's mantle, the Indian plate drifted to the northeast where it collided and continues to collide with the Eurasian plate, generating the stresses that uplifted the Himalayan Massif.

The Indian plate is 24 miles thick and consists of a lower basalt crust 11 miles thick, an overlying granitic crust about 13 miles thick, and a very thin, uppermost layer of sediments. The leading theory of the origin of the Deccan Traps focuses on the "Réunion hotspot," a mantle plume that now underlies the island of Réunion in the Indian Ocean. Mantle plumes or "hotspots" are columns of magma that extend nearly from the Earth's molten core through the mantle almost to the surface. Pressure sometimes causes magma within these hotspots to extrude onto the surface in massive volcanic events. When the Indian plate, fractured by its separation from the African plate, drifted over the Réunion hotspot, enormous quantities of basaltic magma erupted onto the surface. Basalt is an extrusive igneous (volcanic) rock that forms from the solidification of magma at or near the surface. Volcanic rocks usually cool quickly and have generally smooth textures with no visible crystals (aphanitic texture) or very small crystals scattered throughout a dense groundmass (porphyritic texture). Both extrusive and intrusive igneous rocks are categorized chemically by their silica content. Basalt is a low-

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silica rock that contains little quartz, but has large amounts of iron and magnesium minerals that impart a very dark color.

The Deccan Traps eruptions began about 68 million years ago and reached their peak of intensity 65 million years ago. For the next five million years, an estimated 300,000 square miles of basaltic magma was extruded onto the surface, not in violent eruptions, but in phases of massive lava floods that formed countless superposed, individual layers of basalt, each from 3 to 400 feet thick. Most lava in the Deccan Traps is of the tholeiitic type that forms from aluminum-rich, potassium-deficient magma originating deep in the Earth's mantle. Finally, some 60 million years ago, as the Indian plate continued its northeasterly drift, the fractured section of the plate through which the magma had erupted passed over the Réunion hotspot. A stronger section of the plate then took its place, "capping" the mantle plume and ending significant volcanic activity.

The Réunion hotspot, which is stable relative to the mass of the Earth, is located beneath the French island of Réunion east of Madagascar, Africa. However, the Deccan Traps region of India is now 3,000 miles to the northeast, the result of 60 million years of tectonic drift. Because of weathering and surface erosion, the Deccan Traps today are an altered remnant only about one-quarter of their original size.

The Deccan Traps have great geological significance. Along with the Columbia Plateau in the western United States, the Stromberg Formation in South Africa, and the Paranna volcanic formation in southern Brazil, it is among the world's largest volcanic provinces. Also, the formation of the Deccan Traps coincided very closely with the Cretaceous-Tertiary (K-T) extinction that decimated life on Earth and wiped out the dinosaurs. Most researchers now believe that the Deccan eruptions are linked to the extinction of the dinosaurs; some even think that these eruptions actually caused the K-T extinction by releasing vast volumes of volcanic gases that catastrophically altered worldwide ecosystems.

The main phase of the Deccan eruptions also occurred simultaneously with the Chicxulub (CHICK-shoo-loob) meteor impact in Mexico's Yucatán Peninsula and the adjacent Gulf of Mexico 65 million years ago. This impact generated worldwide clouds of sunlight-blocking, climate-altering dust and debris. Ever since the 120-mile-wide Chicxulub crater was discovered in 1991, many scientists have considered it to be the "smoking gun" of the K-T extinction. But based on the latest radiometric dating of the Deccan rocks, growing numbers of scientists are now suggesting that the Deccan eruptions had already set the K-T extinction in motion before the Chicxulub meteor impact.

Paleontologists note that in the three million years that followed the start of the Deccan eruptions, the numbers of biological species worldwide had rapidly declined, ostensibly because of the release of large volumes of climate-altering volcanic gases. The Chicxulub meteor seems to have impacted nearly simultaneously with the start of the main Deccan eruptive phase 65

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million years ago. Current theory postulates that the dramatic global warming caused by the early Deccan eruptions had already doomed the dinosaurs, and that the effects of the Chicxulub impact simply pushed them over the edge into extinction. Another intriguing theory is that, since the Deccan eruptions were already in progress, the powerful, worldwide shock waves generated by the Chicxulub impact could have further weakened sections of the Indian plate and triggered the most intensive phases of the Deccan eruptions.

ABOUT OUR SPECIMENS

Our heulandite-Ca specimens were collected at a basalt quarry near the town of Wani just south of the city of Aurangabad in the Aurangabad district of the state of Maharashtra in the Republic of India. Maharashtra, one of India's largest states, borders the Arabian Sea in west-central India. Mumbai (formerly Bombay) is the capital of Maharashtra, and Aurangabad is one of Maharashtra's 34 administrative districts. The city of Aurangabad, the capital of the Aurangabad district, is located 160 miles east of Mumbai. With a population of almost one million, Aurangabad is one of India's fastest-growing cities and a manufacturing center for silk and cotton fabrics, automotive and electronic components, and pharmaceuticals. Wani is one of the many small towns that surround the city.

Geologically, Aurangabad is situated near the center of the Deccan Traps, the huge volcanic province that covers most of Maharashtra. Consisting of basalt formations as thick as 6,000 feet, the Deccan Traps were created by magmatic eruptions between 68 and 60 million years ago (see "The Deccan Traps"). Hard, durable, and dense, basalt is widely used as a cement additive and as ballast-fill material for general construction purposes. Like most districts in Maharashtra, Aurangabad has thousands of basalt quarries of all sizes. Many of these quarries, including those at Wani, are located near the city of Aurangabad, where the rapidly growing population and economy have created a strong demand for basalt.

Basalt sometimes contains cavities that are filled with mineral crystals. These cavities or vesicles formed from gas bubbles when the original magma solidified. Vesicles, which range in size from less than an inch to many feet, are initially barren and devoid of secondary mineralization. But fissures and fractures in the basalt conduct circulating groundwater that often becomes alkaline and dissolves certain aluminum and silica-bearing minerals. Eventually, this water fills the vesicles and precipitates such minerals as quartz, calcite, and a variety of zeolites, the latter often in well-developed botryoidal, spherical, and radiating crystal forms. When filled with secondary minerals, vesicles are correctly termed "amygdules."

The zeolite-crystal-filled amygdules of the Deccan Traps have been known since basalt was first quarried in the region centuries ago. But because these specimens then had no intrinsic value, they received little if any attention. The first written reports of zeolite specimens in the Deccan Traps that appeared in the 1820s described finely developed crystals of quartz, calcite, and certain zeolite minerals that occurred within amygdules in the basalt. British surveyors, military men, and engineers collected limited numbers of specimens, but the quantity and beauty of the zeolite minerals were not realized until the 1830s, when tunnels were constructed on a railroad between Bombay and Puna, and workers encountered numerous cavities as large as six feet that were filled with superb crystals. These became known as "Jewel Tunnels."

The current international trade in zeolite specimens began in the 1960s, then picked up rapidly in the 1970s when detailed articles about these minerals appeared in western mineral-collecting publications. Since then, the collecting and marketing of zeolite-mineral specimens from the Deccan Traps has become big business both in India and abroad. The Deccan Traps are now the world's leading source of zeolite

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specimens, all of which are recovered as by-products of well-digging, road construction, and basalt quarrying. The quarry at Wani, the source of our heulandite-Ca specimens, is one of Aurangabad's newest quarries. At Wani, as at other quarries, workers break the basalt by drilling and blasting, then haul it by truck to crushers to be sized for specific uses. With zeolite specimens now a valuable by-product of basalt quarrying, quarry managers contract with professional specimen miners who expertly remove the crystals as they are exposed by quarrying operations.

Our heulandite-Ca specimens consist of pale-orange-to-peach-colored crystals on a matrix of fibrous, white mordenite [hydrous sodium calcium potassium aluminum silicate, $(\text{Na}_2, \text{Ca}, \text{K}_2)_4(\text{Al}_8\text{Si}_{40}\text{O}_{96}) \cdot 28\text{H}_2\text{O}$]. Also a zeolite group mineral, mordenite has a chemistry similar to that of heulandite-Ca and forms in similar conditions. Mordenite is a collectible mineral in its own right when it occurs in characteristic clusters of needle-thin, radiating prisms. In our specimens, both the heulandite-Ca and the mordenite formed simultaneously, but in specific conditions that favored the development of heulandite-Ca crystals, while limiting the mordenite growth to a fibrous crust. The mordenite crust formed directly against the wall of the basalt vesicle. This crust tends to separate from the basalt, thus enabling collectors to recover the heulandite crystals on small plates of mordenite, as seen in our specimens.

When you examine your heulandite crystals, keep in mind that heulandite crystallizes in the monoclinic system, which along with the triclinic system tends to have the least amount of easily observable crystal symmetry. By looking closely at the crystals, we can get an idea of the crystal form, if we keep in mind that crystals of the monoclinic system have three axis of unequal length, with two at right angles to each other, the third axis being inclined to their plane. You may be able to notice the flared "shoulders" that typify the coffin-shaped crystals of heulandite-Ca, but again this not terribly obvious in these Wani specimens.

One final thought: As you may know from previous write-ups and newsletters, the committee of experts responsible for naming and classifying minerals have taken to adding prefixes and suffixes to many long-accepted mineral names lately, to more accurately reflect differentiations in chemical make-up and crystal structure. We have been trying to use these new names in our labels and write-ups. We will continue to highlight these changes in the body of our write-ups, but will no longer use them in our labels and titles. For example, when we featured apophyllite a couple of years ago, we followed the protocol established by the committee and labeled it and called the write-up "Fluorapophyllite," to include the prefix they had added. However, in just the short span of time since we featured it, the committee has removed the prefix "fluor" and added a suffix, renaming it "apophyllite-(KF)"! Therefore, should we feature it again, we will simply call it by its longtime name of "apophyllite," and will explain in the write-up the use of the prefixes and suffixes then in vogue. As Shakespeare wrote: "What's in a name? That which we call a rose by any other name would smell as sweet!" This month's featured mineral was originally named "euzeolite," meaning "beautiful zeolite," and that is just as descriptive as its modern, official name of Heulandite-Ca!

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