

September 2005 Mineral of the Month: Prehnite

We are delighted to present this month's mineral, prehnite, the first mineral to be named for an individual, and also the first to be assigned a South African type locality. We also attempt to explain its extremely complex crystal-lattice structure and the details of this exciting recent find in the African nation of Mali.

PHYSICAL PROPERTIES

Chemistry: $\text{Ca}_2\text{Al}_2\text{Si}_3\text{O}_{10}(\text{OH})_2$ Calcium Aluminum Silicate Hydroxide, often containing some iron.
Class: Silicates Subclass: Phyllosilicates (with complex structure)
Crystal System: Orthorhombic
Crystal Habits: Usually as short, tabular, or prismatic crystals with slightly curved faces; well-formed, sharp crystals rare. Most often occurs as botryoidal or mammillary masses with distinctively ridged surfaces that are the edges of curving crystals; also as reniform, stalactitic, radiating, and fibrous masses. Sometimes forms epimorphs (crystal growth over the surfaces of other minerals).
Color: Pale to dark green, also yellow-green, yellow, gray, white, or colorless; occasionally subtle shades of pink and blue.
Luster: Vitreous to waxy, pearly on fresh cleavage surfaces.
Transparency: Translucent to sub-transparent
Streak: Colorless
Refractive Index: 1.61-1.64
Cleavage: Good in one direction
Fracture: Uneven; brittle
Hardness: 6.0-6.5
Specific Gravity: 2.80-2.95, increases with iron content.
Luminescence: None
Distinctive Features and Tests: Best field marks are color, crystal habits, cleavage, hardness, and association with calcite and zeolite minerals.
Dana Classification Number: 72.1.3.1

NAME

"Prehnite," correctly pronounced PRENN-ite, is named after Dutch military officer Hendrik von Prehn. Prehnite's alternative names often derive from its early confusion with other silicate minerals. Originally named "chrysotile," it was later referred to as "Cape emerald," "prehnit," "prehnita," "adelite," "aedelite," "chiltonite," "cougholite," "faux-zeolite," and "anchi-zeolite."

COMPOSITION

Prehnite's chemical formula, $\text{Ca}_2\text{Al}_2\text{Si}_3\text{O}_{10}(\text{OH})_2$, indicates that it contains the elements calcium (Ca), aluminum (Al), silicon (Si), oxygen (O), and hydrogen (H). By weight, prehnite consists of 20.27 percent calcium, 13.65 percent aluminum, 21.31 percent silicon, 44.51 percent oxygen, and 0.26 percent hydrogen. Within the prehnite molecule, the collective +10 cationic charge of two calcium ions (Ca^{2+}) and two aluminum ions (Al^{3+}) balances the collective -10 anionic charge of the silicate ion $[(\text{Si}_3\text{O}_{10})^{8-}]$ and the two hydroxyl ions $[(\text{OH})^{1-}]$.

Prehnite is a member of the silicates, the largest and most abundant class of minerals. Silicates are subdivided by crystal-lattice structure into seven groups. Prehnite is classified as a phyllosilicate, or sheet silicate, because its molecules join together in flat, two-dimensional sheets to form layers. But because it also exhibits characteristics of two other structural groups, prehnite is more precisely classified as a "silicate of complex structure," as explained in the box on page 2.

September 2005 Mineral of the Month: Prehnite

COMPLEX SILICATE STRUCTURES

Silicates are combinations of silicon and oxygen with one or more metals. The building blocks of all silicates are silica tetrahedra $[(\text{SiO}_4)^4^-]$, which consist of a central silicon atom surrounded by four equidistant oxygen atoms in a tetrahedral shape. Silicates, which consist of metal cations (positively charged ions) and silica anions (negatively charged ions), form seven distinct structures: independent tetrahedral silicates (nesosilicates); double tetrahedral silicates (sorosilicates); framework silicates (tectosilicates); single- and double-chain silicates (inosilicates); ring silicates (cyclosilicates); and phyllosilicates (sheet silicates). Because of its layered structure, prehnite is a phyllosilicate. But because its characteristics include those of both chain silicates and ring silicates, prehnite is also considered to be one of the few complex silicates that combine the structural features of two or more silicate groups.

Phyllosilicates are divided into two-layer silicates and three-layer silicates. As a three-layer silicate, prehnite consists of two layers of silica tetrahedra that “sandwich” a third, octahedral layer of oxygen and hydroxyl ions. Within the silica layers, positively charged metal ions balance the negative charges of the tetrahedra. The octahedral layer consists of oxygen ions on the apices of the tetrahedral layers along with the hydroxyl ions that occupy the hexagonal holes between them.

The three-layer phyllosilicates include such subgroups as the talcs, micas, and brittle micas, in which physical properties are determined by the nature of their “sandwiched” layer. Because the talc-group minerals have no metal ions in this layer, their silica layers are joined only by a very weak electrostatic attraction called “van der Waals” forces. In the mica-group minerals, potassium ions in the “sandwiched” layer provide only a slightly stronger electrostatic attraction. In both the talc and mica subgroups, this weak, interlayer bonding accounts for perfect, one-directional cleavage. But in prehnite, closely related in structure to members of the brittle-mica subgroup, aluminum ions (Al^{3+}) sometimes substitute for silicon ions (Si^{4+}), thus creating a negative charge in the silica sheets which is balanced by calcium ions (Ca^{2+}) in the “sandwiched” layer. Because the electrostatic attraction of the calcium ions for the adjacent silica layers increases interlayer bonding strength, prehnite, unlike the micas, lacks perfect, one-directional cleavage.

Although prehnite is classified as a sheet silicate, its sheets consist largely of single-chain and ring structures. In single- and double-chain silicates (inosilicates), each tetrahedron shares two of its oxygen ions with adjacent tetrahedra to covalently link the chain together. Covalent electron-sharing reduces the number of oxygen ions in each tetrahedron by one to form a chain of $(\text{SiO}_3)^{2-}$ tetrahedral units. The negative charges of these tetrahedra are balanced within the lattice by calcium ions (Ca^{2+}).

Closely related ring silicates (cyclosilicates) are essentially closed chains. In prehnite, the chains consist of four-membered (four-tetrahedra) rings held together by the ionic attraction of calcium cations to silica anions. These weak, omnidirectional ionic bonds further reduce prehnite’s cleavage tendency and impart rigidity, hardness, and brittleness to the sheets. This combination of sheet-, chain-, and ring-structure characteristics with weak, complex, electrostatic, ionic, and covalent bonding is typical of prehnite and of the “brittle mica” phyllosilicate subgroup. Unlike the mica-group minerals which have perfect one-directional cleavage and tough, soft, elastic sheets, prehnite and the brittle micas, have brittle sheets, greater hardness, and good (but not perfect), one-directional cleavage.

The temperatures and pressures that existed when prehnite formed determine the proportion of chain and ring structures within the sheets. Proportional variations explain the formation of prehnite polymorphs (different crystallographic forms of the same mineral). Prehnite usually crystallizes in the orthorhombic system, but has at least two monoclinic polymorphs. Most prehnite crystals contain two structural polymorphs in a complex and somewhat confused lattice, which explains the rarity of well-developed, sharp prehnite crystals. This multi-structural character is also important in mineralogical classification. Prehnite’s Dana classification number, 72.1.3.1, first identifies it as a phyllosilicate with a structure consisting of two-dimensional, infinite sheets with other than six-membered rings (72). The subclassification (1) specifies that its structure contains four-membered rings. Prehnite is then assigned to its own group (3) as the first (1) and only member.

September 2005 Mineral of the Month: Prehnite

As an allochromatic, or “other-colored,” mineral, prehnite’s colors are created not by its essential mineral components or the nature of its crystal structure, but by the presence of nonessential impurities called chromophores (literally, “color carriers”). Pure prehnite is colorless, but limited quantities of ferric iron (Fe^{3+}) often substitute for aluminum (Al^{3+}) to impart green colors. Other chromophoric ions create subtle blue, yellow, and pink hues.

Prehnite occurs most commonly in mafic (magnesium- and iron-rich) volcanic rocks, notably basalt, where it forms as a secondary mineral in veins and cavities from hydrothermal metamorphism. In basaltic environments, prehnite is associated with zeolites (complex, hydrated aluminum silicates), calcite (calcium carbonate, CaCO_3), and pectolite (basic sodium calcium silicate [$\text{NaCa}_2\text{Si}_3\text{O}_8(\text{OH})$]). Prehnite also occurs in impure, partially metamorphosed limestone; granite gneisses, syenites, and gabbros through low-grade regional metamorphism; and low-grade, contact metamorphic environments associated with hot springs.

Although prehnite is not a member of the zeolite mineral group, whose best-known members include analcime, natrolite, and three that we have featured, (scolecite [May 1997], stilbite [May 1999], and heulandite [November 2002]), it does have a zeolitic property. Zeolites have attached water molecules called “water of hydration,” which can be driven from the crystal lattice and replaced without altering the crystal structure. Similarly, prehnite gives off water when heated (because of the rearrangement of its hydroxyl radicals) without altering its crystal structure—the reason it was once confused with zeolites and given such names as “anchi-zeolite” and “faux-zeolite.” But unlike zeolites which can regain their water, prehnite cannot regain its hydroxyl ions.

COLLECTING LOCALITIES

Although not abundant, prehnite is widely distributed. Prehnite’s type locality in the Creadock District in South Africa’s Eastern Cape Province still provides specimens. South African sources also include the Premier kimberlite pipe, a famed diamond source, in Gautang Province; Farm Geode Hoop and the Kalahari manganese field near Kuruman in Northern Cape Province; and the Palabora Mine in the Transvaal’s Messina District. Other African sources are the Brandburg Hills near Brandburg, Namibia; Djbel Melh at Bou-Arfa, Morocco; and the recent find from Mali, as we will describe in detail.

Europe’s many prehnite localities include Motta Naiara, Graubunden, Switzerland; Edelfors, near Uppsala, Sweden; and Renfrewshire and Dumbartonshire in Scotland. In Germany, fine specimens come from Oberscheld and Uckersdorf in Nassau, Joachimsthal in Bohemia, Freiburg in Baden, Schwarzenburg in Saxony, and Adreasburg in Harz. In Australia, Wave Hill in the Northern Territory and Prospect Hill in New South Wales yield excellent prehnite specimens. Numerous quarries in the Deccan traps near Poona in Maharashtra, India, provide fine, composite prehnite-zeolite specimens. In Brazil, prehnite occurs at Bagé in Rio Grande do Sul.

Canadian prehnite specimens include sharp, two-inch crystals from the Jeffrey Mine at Asbestos, Quebec. In British Columbia’s Bonaparte River Valley, small prehnite crystals are found in narrow fissures in peridotite (an igneous rock derived from ferromagnesian-silicate magma), while a five-foot-thick layer of white prehnite occurs at Gold Bridge in the Lilloet District. The shore of Lake Superior in Ontario (and also in upper Michigan in the United States) has numerous prehnite occurrences. In the United States, prehnite is found in the Cole Shaft near Bisbee in Cochise County, Arizona; the contact metamorphic rock along Park Creek in Custer County, Idaho; the vugs in quarried gneiss formations at Athens in Clarke County, Georgia; and Vesper Peak in Snohomish County, Washington. Fine specimens are collected from zeolite pockets in trap-rock quarries in Passaic, Essex, and Hudson counties in northern New Jersey. Prehnite is found also in quarries at Centreville in Fairfax County and at Gainesville in Prince William County, Virginia.

September 2005 Mineral of the Month: Prehnite

JEWELRY & DECORATIVE USES

Prehnite, mostly in green colors, is a minor gemstone that was once sold as “Cape emerald,” a reference to its type locality. Polished prehnite has a superb luster and a soft, jade-like glow. Prehnite’s refractive index of 1.61-1.64 roughly equals that of topaz. But because it is sub-transparent and often included, prehnite is faceted only occasionally into collector’s gem that resemble peridot. Prehnite is usually fashioned into cabochons for mounting as pendants or tumbled and drilled for use in necklaces, bracelets and earrings. Carved into small figurines, prehnite is sometimes mistaken for chrysoprase and jade. Because heat can produce cloudiness in prehnite, jewelry-makers must exercise care when soldering prehnite jewelry.

Chatoyant, or “cat’s-eye,” prehnite is rare and quite valuable. The chatoyancy effect, caused by tiny, fibrous inclusions that reflect light in a pattern reminiscent of the shape of the pupil of a cat’s eye, occurs mainly in yellow prehnite. Because prehnite crystals are doubly refractive, they are also pleochroic, exhibiting tricolor shifts with changes in angles of viewing or incident light, an optical phenomenon caused by differences in the angular absorption of light by the crystal lattice.

Mineral collectors value both individual and composite prehnite specimens for their subtle colors, unusual crystal habits, ridged surface textures, and pleasing luster.

HISTORY & LORE

Prehnite was discovered by Dutch colonial governor Colonel Hendrik von Prehn (1733-1785) at the type locality, the Karoo dolerite (gabbro) formations in the Creadock District in South Africa’s Eastern Cape Province. In 1777, von Prehn brought specimens to Europe where they were studied and described by French chemist and mineralogist Balthazar Georges Sage (1740-1824). Believing that von Prehn’s mineral was closely related to chrysoprase, Sage named it “chrysotile.” Then, in 1789, German mineralogist Abraham Gottlob Werner (1750-1817), after determining its chemical composition and crystal structure, confirmed the mineral as a new species and named it prehnite—the first mineral with a South African type locality. Prehnite is also the first mineral named for an individual. In naming prehnite for von Prehn, Werner established a mineral-naming precedent that remains popular today. Nearly a century later, Scottish mineralogist and geologist Matthew F. Heddle (1828-1897) would study the complex structure of prehnite in his pioneering work with thin-section and polarizing microscopy.



Figure 1 Local farmers near Bendoukou.

According to modern metaphysicists, prehnite guards its wearer against unsettling and disruptive forces, enhances meditation, and is a powerful dream stone that encourages lucid and memorable dreams.

TECHNOLOGICAL USES

Although prehnite has no technological uses, studies of its complex lattice structure have contributed to the advancement of crystallography. Prehnite is also a valuable indicator of low-temperature metamorphism in mineral deposits.

September 2005 Mineral of the Month: Prehnite



Figure 2 Map of Mali and surrounding nations.

ABOUT OUR SPECIMENS

Our pretty specimens come from the small, landlocked nation of Mali, in the heart of West Africa, as seen on the map in Figure 2. Its northern half consists of the virtually uninhabited Saharan Desert, while its southern half is a fertile savanna (a flat grassland of tropical or subtropical regions), irrigated by the Niger River. Most of Mali's population of ten million ekes out a living by farming in the southern half. A thousand years ago, the empire of Mali ruled western Africa, reaching its zenith in the early fourteenth century. Since then, Mali has come under domination by the Songhai Empire of Gao, and then the Muslim leader Umar Tal. In 1904 Mali was colonized by France as the French Sudan, finally gaining independence in 1960. Its capital is Bamako, and Tombouctou (Timbuktu) is known as an intellectual and spiritual capital and a center for the propagation of Islam throughout Africa in the 15th and 16th centuries, whose restored great mosques are currently under threat from desertification. Mineral resources include gold, salt, phosphate rock, iron ore, diamonds, tungsten, and uranium.

Our research for details on the exact locality of our prehnite took us to Bill Dameron, president of the Friends of Mineralogy, who was serving as U.S. Ambassador to Mali in 1994 when minerals began to

September 2005 Mineral of the Month: Prehnite

come out of the Sandaré area. He writes to us: "I didn't get to the site: it is very remote, a long journey, and even more so during the rainy season. Plus it is rather wild territory! The 'commercants,' or traders, who specialized in the area would come by the residence because they knew I was interested and dump a bag of banged-up garnets from a flour sack and haggling would begin. There was very little prehnite at the time, and their surfaces were always quite weathered."

The first garnets found in the area were written up in "What's New in Minerals" in the May-June 1995 *Mineralogical Record*, as dodecahedrons, trapezohedrons, and combinations of the two, with concentrically zoned colors, ranging from black-brown on the outside progressing to light green centers, which we being faceted into gemstones resembling peridot in color. Also mentioned from the site are epidote, vesuvianite, and this month's featured mineral.



Figure 3 Large prehnite and epidote specimen.

The find is mentioned again in September-October 1995 and January-February 1996 *Mineralogical Record*, the March 2002 *Mineral News*, and the September-October 2002 *Rocks & Minerals*, all commenting on this exceptional new find, highlighting the garnet crystals coming out. The May-June 2005 *MR* mentions the new flow of prehnite, stating that a major museum collection had already reserved the best of the striking specimens, and mentions the potential for further specimen production.

A number of localities are mentioned in the articles, including the Sadiola gold mine, near Kayes. The administrative divisions used also differ quite a bit in the articles. Evidently, the former French administrators of Mali used terms like "arondissements" and "cercles" in dividing the country into administrative units, and this has led to some of the confusion over the best way of expressing the name of the locality. We have left these out in order to focus on the best, most accurate locality information. Evidently, there are several sites producing prehnite and the other minerals, centered south of the city of Sandaré, as seen on the map. Our specimens come from in or near a little town called Bendoukou, in surface diggings done by local farmers in their spare time. The minerals formed in skarn, a term used for rocks containing calcium-bearing silicates derived from nearly pure limestones and dolomites into which large amounts of silicon, aluminum, iron, and magnesium have been introduced.

Examination of your specimen with a loupe or microscope will reveal the curved nature of the prehnite crystals, allowing you to see the curved edges. These curves, and the resulting ball-shaped clusters they form, are due to the extremely complex nature of the crystal lattice. What a fascinating mineral!

References: *Dana's New Mineralogy*, Eighth Edition; *Encyclopedia of Minerals*, Second Edition, Roberts, et al, Van Nostrand Reinhold Co.; 2004 *Fleischer's Glossary of Mineral Species*, Joseph Mandarino and Malcolm Back, The Mineralogical Record Company; *Mineralogy*, John Sinkankas, Van Nostrand Reinhold Co.; *Manual of Mineralogy*, Cornelius Hurlbut and Cornelis Klein, Twenty-first Edition, John Wiley & Sons; *Minerals of the World*, Walter Schumann, Sterling Publishing Co.; *Gemstones of the World*, Walter Schumann, Sterling Publishing Co.; *Handbook of Mineralogy: Silica and Silicates*, Vol. Two, J. W. Anthony, et al, Mineral Data Publishing; *Structural Chemistry of Silicates*, F. Liebau, Springer-Verlag Publishing Co.; "An Occurrence of Prehnite in the Red Mountain Mining District, Ouray County, Colorado," Tom Rosemeyer, *Rocks & Minerals*, September-October 1994; "Connoisseur's Choice: Prehnite, Brandenburg, Namibia," Robert Cook, *Rocks & Minerals*, May-June 1999; "Prehnite from La Combe de la Selle, Saint Christophe-en-Oisans, Isere, France," Laurent Gautron and Nicolas Meisser, *The Mineralogical Record*, May-June 2001; "Prehnite From the Kalahari Manganese Field, South Africa, and Its Implications," B. Cairncross, H. Tsikos, and C. Harris, *South African Journal of Geology*, December 2000. "What's New in Minerals? Tucson Show 1995," Thomas Moore, *Mineralogical Record*, May-June 1995; "World Review of Mineral Discoveries- 1993-1994," George W. Robinson, Vandall T. King, Jeffrey Scovil, Forrest Cureton, *Mineralogical Record*, September-October 1995; "What's New in Minerals? Denver Show 1995," Thomas Moore, *Mineralogical Record*, January-February 1996; "The Shows of Tucson 2002 Part II," Lanny Reem, *Mineral News*, March 2002; "Connoisseur's Choice: Epidote," Robert B. Cook, *Rocks & Minerals*, September-October 2002; "What's New in Minerals? Tucson Show 2005," Thomas Moore, *Mineralogical Record*, May-June 2005; Special thanks to Bill Dameron and Rock Currier.