

Mineral of the Month Club March 2015

CALCITE (var. YELLOW)

Our Mineral of the Month for March is the yellow variety of calcite from a classic locality in South Dakota. Our write-up discusses calcite's mineralogy, and explains why calcite, in the form of limestone, is one of the most important of all mineral resources.

OVERVIEW

PHYSICAL PROPERTIES

Chemistry: CaCO_3 Calcium Carbonate (Yellow calcite contains small amounts of iron or sulfur.)

Class: Carbonates

Subclass: Anhydrous Carbonates

Group: Calcite

Crystal System: Hexagonal (Trigonal Subsystem)

Crystal Habits: Usually as rhombohedrons, scalenohedrons, and prisms; also tabular, acicular, granular, compact, stalactitic, stalagmitic, oolitic, massive, and earthy; twinning common. Numerous and varied crystal habits include many trigonal and pseudo-hexagonal shapes.

Color: The yellow variety of calcite ranges in color from pale yellow to intense yellow and golden yellow; color-zoning is common.

Luster: Vitreous to dull

Transparency: Usually transparent to translucent; occasionally opaque.

Streak: White

Cleavage: Crystals have perfect, three-directional cleavage to form rhombohedrons, but crystal faces do not coincide with cleavage planes; massive, compact, and granular forms have no cleavage.

Fracture: Usually irregular; rarely conchoidal.

Hardness: 3.0

Specific Gravity: 2.7-3.0, increases with the amount of iron present.

Luminescence: Often fluorescent; sometimes thermoluminescent, triboluminescent, and phosphorescent.

Refractive Index: 1.486-1.658; crystals are birefringent (doubly refractive).

Distinctive Features and Tests: Best field indicators are rhombohedral crystal shapes, softness, and vigorous effervescence in acids. Calcite can be confused with the polymorphic calcium-carbonate mineral aragonite, which lacks calcite's perfect, three-directional, rhombohedral cleavage.

Dana Classification Number: 14.1.1.1

NAME: The word "calcite," pronounced KHAL-site, stems from the Latin *calx*, meaning "lime" (calcium oxide) or any white, calcareous mineral. The variety name "yellow calcite" alludes to its yellowish colors. Yellow calcite is also known as "honey calcite," "golden calcite," and

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“honeycomb calcite.” In European mineralogical literature, yellow calcite appears as *gelb Kalcit* and *calcita amarilla*.

COMPOSITION & STRUCTURE: Yellow calcite is not a separate species, but a color variety of the mineral calcite. Calcite, the most abundant of the 192 members of the carbonate class of minerals, is a simple carbonate that consists of 40.04 percent calcium (Ca), 12.00 percent carbon (C), and 47.96 percent oxygen (O). Because it is allochromatic (other-colored), calcite colors are not caused by essential elements or the light-absorption characteristics of its crystal lattice, but by traces of various accessory elements that create a wide range of colors. When pure or nearly pure, calcite is colorless or white. The colors of yellow calcite are most often caused by trace amounts of divalent iron (Fe^{2+}) or by included, microscopic particles of hematite [iron oxide, Fe_2O_3], limonite (an indeterminate mixture of hydrous iron oxides), or sulfur [native element, S]. Calcite, which is found in many different types of rocks in sedimentary, metamorphic and igneous environments, has more forms than any other mineral. Its crystals commonly occur in rhombohedral, scalenohedral, prismatic, and trigonal (pseudo-hexagonal) shapes, and in many complex combinations of these shapes. Frequent twinning in four different twinning types adds to the number of calcite forms. Mineralogists estimate the number of calcite crystal habits at 300, and the total number of calcite forms at more than 800.

COLLECTING LOCALITIES: In the United States, yellow calcite is collected in South Dakota, Colorado, Montana, Nevada, North Carolina, Idaho, Wyoming, Kansas, Missouri, Oklahoma, Tennessee, Ohio, Pennsylvania, New Jersey, New York, Illinois, Florida, Wisconsin, and Utah. Other sources are in Argentina, Peru, Honduras, Mexico, China, Turkey, Australia, Canada, Japan, South Africa, Iceland, Italy, Switzerland, Romania, Slovakia, Austria, Bulgaria, France, Germany, England, and Spain.

HISTORY, USES & LORE: Although known since antiquity, calcite’s many complex and confusing crystal habits precluded its recognition as a distinct mineral species until 1845. Some ancient cultures related yellow calcite to the sun. Anthropologists believe that carved amulets of both crystalline and massive yellow calcite were worn to assure the return of the sun in spring. Medieval European physicians prescribed potions of powdered yellow calcite to remedy ailments of the stomach and urinary system. Modern metaphysical practitioners believe that yellow calcite helps alleviate ailments of the stomach and lower back. Yellow calcite is also thought to stimulate intellect, help organize thoughts and information, boost general energy levels, aid in channeling and intuitive awareness, and increase personal power and a sense of self-worth. Although the yellow variety of calcite has no specific technological applications, calcite in the form of limestone, a sedimentary rock of marine origin that contains at least 50 percent calcite, is a major industrial commodity. Calcite has only limited use in jewelry because of its softness, low index of refraction, and perfect, three-directional cleavage that makes cutting difficult. Massive, yellow calcite, a popular decorative stone that is sold as “onyx,” “Mexican onyx,” and “honey onyx,” is fashioned into spheres, figurines, paperweights, and other ornaments.

ABOUT OUR SPECIMENS: Our specimens of the yellow variety of calcite were collected at the Elk Creek locality in Meade County, South Dakota, a short distance west of the confluence of Elk Creek and the Cheyenne River. This area, which is part of the high plains of western South Dakota, is approximately 40 miles east-northeast of Rapid City and 20 miles north of the Wasta

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exit of Interstate 90. The topography consists of gently rolling, grass-covered hills and deeply eroded streambeds and riverbeds. Most of the land is private and occupied by cattle ranches. Access is by a limited number of county roads and numerous unmarked and unpaved ranch roads. Our specimens of yellow calcite are sections of concretions that formed within the Pierre (pronounced “peer”) Shale Formation. Pierre Shale, a distinctive, crumbly, laminated, gray shale that makes up the regional bedrock, was deposited as sediments by the Western Interior Seaway, a warm, shallow sea that existed 70-to-80-million years ago. The calcite-containing concretions formed soon after deposition and before the sediments lithified. The Elk Creek concretions are fossiliferous, septarian, and partially hollow. Calcite crystals formed when calcium-rich seawater contacted sulfur-rich, organic remains. Some concretions contain central cavities that provided space for the growth of well-developed calcite crystals. To recover concretions that contain yellow calcite crystals, collectors search the banks along the rivers, creeks, intermittent streams, gullies, and dry washes that cut through the Pierre Shale bedrock. Collecting is difficult because most ranchers do not grant access to their land, and also because the concretions themselves are hard and extremely durable. Breaking open the concretions is a laborious process that is done manually with sledges, bars, and chisels. We acquired our specimens of yellow calcite from one of the few commercial collectors working the Elk Creek locality.

COMPREHENSIVE WRITE-UP

COMPOSITION & STRUCTURE

Club members may recall that we featured the red variety of massive calcite as our Mineral of the Month in November 2014. This time, our featured calcite specimens are a crystalline form of the yellow variety. It would be almost impossible to feature every type of calcite because, as mineralogists point out, calcite occurs in hundreds of different forms—more than any other mineral.

Calcite is the trigonal form of calcium carbonate (CaCO_3). The term “yellow calcite” refers to a color variety of the calcite, not to a distinct mineral species. As the most abundant of the 192 members of the carbonate class of minerals, calcite is a simple carbonate that consists of the elements calcium (Ca), carbon (C), and oxygen (O) in the proportions of 40.04 percent calcium, 12.00 percent carbon, and 47.96 percent oxygen. Carbonate minerals basically consist of metallic elements combined with the carbonate radical (CO_3)²⁻. Radicals are groups of atoms of different elements that act as entities in chemical reactions. The carbonate radical, the fundamental structural unit of all carbonate minerals, has a flat, triangular shape. Within this triangle, a central carbon ion C^{4+} is covalently bound by shared electrons to three equidistant oxygen ions 3O^{2-} . The +4 charge of the carbon ion C^{4+} and the collective -6 charge of the three oxygen ions 3O^{2-} provide the carbonate radical with a total -2 charge. Carbonate minerals form when negatively charged carbonate radicals bond ionically to positively charged metal ions. As a simple carbonate, calcite consists of a single metal ion bound to a single carbonate radical. Like all molecules, the calcite molecule consists of a positively charged cation and a negatively charged anion. The calcite cation is a single, divalent calcium ion Ca^{2+} ; the anion is a single carbonate radical (CO_3)²⁻. The calcite molecule is electrically stable because the +2 cationic charge balances the -2 anionic charge.

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Most carbonate minerals exhibit a three-fold, crystalline symmetry that reflects the triangular shape of the carbonate radical. Calcite and most other simple carbonates crystallize in the hexagonal system, the characteristic, six-sided, external, hexagonal shape of which is a multiple of three-fold symmetry. In chemically complex carbonates, this basic structure is distorted, causing crystallization to occur in either the orthorhombic or monoclinic systems. Calcite and most other simple carbonates, however, crystallize in the trigonal subsystem, which is a division of the hexagonal system. The trigonal subsystem is characterized by three axes of equal length with angles between them of *other* than 90 degrees. The basic trigonal shape is the rhombohedron, a six-sided polygon with parallelogram sides. Because of the many possible variations in this basic shape, calcite has an estimated 300 habits and more than 800 distinct sub-habits and forms. It also exhibits four types of twinning. Calcite crystals commonly occur in rhombohedral, scalenohedral, prismatic, and trigonal (pseudo-hexagonal) habits—along with many complex combinations of these shapes. Twinning increases the number of calcite forms. Calcite also forms pseudomorphs, replacing other minerals, but retaining the crystal form of the original mineral.

The calcite crystal lattice is often compared with that of halite [sodium chloride, NaCl], a mineral which crystallizes in the cubic system. Halite has a cubic habit and perfect, right-angle cleavage in three directions. The carbonate radicals in the calcite lattice occupy exactly the same positions as the chlorine ions in the halite lattice. But the triangular shape of the carbonate radicals distorts the lattice along one axis. Calcite therefore has perfect cleavage in three directions, but not at right angles. This explains why calcite cleaves into rhombohedrons, while halite cleaves into cubes.

Within the calcite crystal lattice, six oxygen ions of the carbonate radicals completely surround and shield each calcium ion, explaining why calcite exhibits no metallic properties. The relatively weak ionic bonding between the calcium ions and the carbonate radicals accounts for calcite's minimal hardness of Mohs 3.0. Despite its close atomic packing, calcite has a low specific gravity of 2.7-3.0, only a bit higher than that of quartz [silicon dioxide, SiO₂]. Its low density is due to the relatively low atomic weights of its essential components calcium (40.08), carbon (12.01), and oxygen (16.00). Calcite's most important diagnostic feature is a vigorous effervescence in acids, a reaction that is due to its weak ionic bonding. Using hydrochloric acid (HCl) as an example, calcite effervesces when the acid's highly reactive chlorine ion Cl¹⁻ breaks the weak ionic bond and replaces calcite's carbonate radical. This reaction proceeds according to the formula $\text{CaCO}_3 + 2\text{HCl} = \text{CaCl}_2$ (calcium chloride) + H₂O (water) + CO₂ (carbon dioxide). The resulting, rapid release of carbon-dioxide gas creates the diagnostic bubbles of effervescence.

Calcite forms in many mineralogical environments, most commonly in shallow conditions where carbonic acid (H₂CO₃) can react with various metal salts. Carbonic acid forms when atmospheric carbon dioxide (CO₂) dissolves in water (H₂O) according to the formula $\text{H}_2\text{O} + \text{CO}_2 = \text{H}_2\text{CO}_3$. Under proper conditions of temperature, pressure, and chemistry, free metal ions then bond ionically with carbonate ions from the carbonic acid to form carbonate minerals. This reaction is especially common in chemical-sedimentary environments and results in the formation of limestone, a marine sedimentary rock consisting primarily of calcite. Calcite also occurs in nepheline-syenite pegmatites, metamorphic rocks, basaltic volcanic rocks, high- and

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low-temperature hydrothermal veins, disseminated replacement deposits, carbonatites (carbonate-rich igneous rocks), and, in the case of our yellow-calcite specimens, as the linings of concretions within sedimentary deposits.

The Dana mineral-classification number 14.1.1.1 identifies calcite as a simple, anhydrous carbonate (14) with the general formula $A^{2+}CO_3$, in which “ A^{2+} ” can be divalent ions of calcium, magnesium, iron, manganese, cobalt, zinc, nickel, or cadmium. The subclassification (1) defines calcite as crystallizing in the trigonal subsystem of the hexagonal system. Calcite is then assigned to the calcite group (1) as the first (1) of eight members. Other calcite-group members, which vary only in their cationic chemistries, include such familiar and collectible minerals as magnesite [magnesium carbonate, $MgCO_3$], siderite [iron carbonate, $FeCO_3$], rhodochrosite [manganese carbonate, $MnCO_3$], and smithsonite [zinc carbonate, $ZnCO_3$].

As an allochromatic (other-colored) mineral, calcite’s colors are not caused by essential elements or the light-absorption properties of its crystal lattice, but by traces of accessory elements that create a wide range of colors. When pure or nearly pure, calcite is colorless or white. But the presence of manganese, as an example, creates pink manganoan calcite, while that of cobalt creates purplish cobaltoan calcite. In these minerals, traces of manganese and cobalt distort the crystal lattice to alter its color-absorption and color-reflection characteristics. In our specimens of yellow calcite, the color is most often caused by trace amounts of divalent iron (Fe^{2+}). Calcite colors can also be caused by inclusions of accessory elements or minerals. Some yellow calcite contains inclusions of microscopic particles of sulfur [native element, S]; other types of yellow calcite contain particles of hematite [iron oxide, Fe_2O_3] and limonite (an indeterminate mixture of hydrous iron oxides). A black color in calcite is due to included, microscopic particles of carbon [native element, C].

Calcite is a polymorphic mineral and one of three natural forms of calcium carbonate. The other polymorphic forms are aragonite and the rare mineral vaterite. These three minerals share identical chemistries, but calcite crystallizes in the trigonal subsystem of the hexagonal system, aragonite in the orthorhombic system, and vaterite in the hexagonal system.

COLLECTING LOCALITIES

Our specimens of yellow calcite are from the Elk Creek locality in Meade County, South Dakota. Other sources in the United States are the Rico Argentine Mine at Rico in Dolores County, the Idarado Mine at Telluride in San Miguel County, and Stoneham in Weld County, all in Colorado; the Alice Mine at Walkerville, Silver Bow County, Montana; the North Aurora Mine in the White Pine district, White Pine County, Nevada; the Bald Knob deposit near Sparta, Allegheny County, North Carolina; the Friday Mine in the Westview district in Boise County and the Rat’s Nest Claim near Challis in Custer County, both in Idaho; Mammoth Hot Springs, Yellowstone National Park, Wyoming; the Tri-State Mining District of Kansas, Missouri, and Oklahoma; the Sweetwater Mine in the Viburnum Trend, Reynolds County, Missouri; the Elmwood Mine at Carthage, Smith County, Tennessee; the Pugh Quarry at Custar, Wood County, Ohio; the Roosevelt (York) Quarry at York, York County, Pennsylvania; the Prospect Park basalt formations, Passaic County, New Jersey; the Black River Mine at Antwerp, Jefferson County,

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New York; the Annabel Lee Mine in the Hardin Creek district, Hardin County, Illinois; and Ruck's Pit near Fort Drum, Okeechobee County, Florida. Wisconsin's sources include the Montreal, Jupiter, Bourne, and Moore mines in the Gogebic Iron Range, Iron County; the Linden and Mineral Point mines in Iowa County; the Valderes area of Manitowoc County; and Shullsburg in Lafayette County. In Utah, yellow calcite is found in the Uinta Mountains near Hanna in Duchesne County, and at the Sioux-Ajax Mine in Tooele County.

Notable Central and South American sources are the Farallón Negro Mine at Farallón Negro, Belen Department, Catamarca, Argentina; the Casapalca Mine at Casapalca in Huarochiri Province in Lima Department, and the Pachapaqui district mines at Pachapaqui in Bolognesi Province in Ancash Department, both in Peru; and the El Mochito Mine at El Mocho, Santa Barbara Department, Honduras. Mexican sources include the Portillo, Potosí, and West Camp sections of the Santa Eulalia district at Aquiles Serdán, and the Gibraltar Mine at Naica, all in Chihuahua; and the La Sirena Mine at Veta Madre, Guanajuato.

Chinese sources include the Manaoshan Mine in the Dongpo ore field, Chenzhou, Chenzhou Prefecture, Hunan Province; and the Tuanshangou Mine, Huangpi District, Wuhan Prefecture, Hubai Province. Yellow calcite is also found at the Dokuztepe iron-manganese deposit at Ceyhan, Adana Province, Mediterranean Region, Turkey; the Broken Hill mines in Yancowinna County, New South Wales, Australia; the Sulphurets district in the Skeena Mining Division, British Columbia, Canada; the Toyoguchi Mine at Yamagata, Iwate Prefecture, Tohoku Region, Honshu Island, Japan; and the Wessel Mine at Hotazel in the Kalahari Manganese Field, Northern Cape Province, South Africa.

In Europe, yellow calcite is collected at Helgustadir Mine at Reydarfjörður in the Eastern Region of Iceland; the Scrove Mine at Reppia in the Graveglia Valley, Genova Province, Liguria, Italy; the Gonzen Mine at Sargans, St. Gallen, Switzerland; the Cavnic and Boldut mines at Cavnic, Maramures County, Romania; the Banská Štiavnica district mines in Banská Bystrica Region, Slovakia; the Martis and Felixbau mines at Hüttenberg, Freisach-Hüttenberg area, Carinthia, Austria; the Stevanof Mine at Zlatograd, Smolyan Oblast', Bulgaria; the Rivet Quarry near Tarn, Midi-Pyrénées, France; the Seben Gots Mine in the Freiburg District, Erzgebirge, Saxony, Germany; the Botallack Mine, Botallack, St. Just District, Cornwall, England; and Sierra de Aracina, Huelva, Andalusia, Spain.

JEWELRY & DECORATIVE USES

Because of its minimal hardness (Mohs 3.0), low index of refraction (1.486-1.658), and perfect, three-directional cleavage that makes cutting difficult, calcite has limited use in jewelry. Yellow calcite crystals are sometimes wrapped with silver wire as pendants. Massive forms of yellow calcite, especially tufa and travertine, are fashioned into beads, drilled, and strung into necklaces. Because of its softness, massive yellow calcite is easily shaped and carved by mechanical means into such decorative objects as ashtrays, candleholders, jewelry boxes, spheres, bookends, figurines, spheres, small tabletops, and paperweights. Yellow massive calcite is often sold as "onyx," "Mexican onyx," and "honey onyx."

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HISTORY & LORE

Calcite, in its many forms that include the rocks limestone and marble, has been known since antiquity. Calcite was named *calx*, meaning “lime,” in 77 A.D. by the Roman scholar Pliny the Elder (Gaius Plinius Secundus, 23-79 A.D.) in his *Historia Naturalis*. But because of its many varied and confusing crystal habits, calcite was not recognized as a distinct mineral species until 1845, when Austrian mineralogist Wilhelm Karl von Hardinger (1795-1871) formally named it after the Latin *calx*.

Calcite forms some of the largest crystals of all minerals. The largest known calcite crystal, which measured 21x21x6 feet and weighed an estimated 250 tons, was found at the Helgustadir Mine at Reydarfjörður in the Eastern Region of Iceland, a mine once famed for its production of Iceland spar—transparent, colorless, optical-quality calcite crystals.

Some ancient cultures related yellow calcite to the sun and carved amulets of both crystalline and massive yellow calcite that anthropologists believe were worn to assure the return of the sun in spring. Medieval European physicians prescribed potions of powdered yellow calcite to remedy ailments of the stomach and urinary system. Modern metaphysical practitioners believe that yellow calcite is valuable in alleviating discomfort of the stomach and lower back. Yellow calcite is also thought to stimulate intellect, help to organize thoughts and information, boost general energy levels, aid in channeling and intuitive awareness, and increase personal power and a sense of self-worth.

CALCITE & LIMESTONE

Our Mineral of the Month—calcite—is a favorite among collectors for its wide range of colors and extraordinary number of forms (see “Composition & Structure”). Calcite, the most abundant of all carbonate minerals, makes up about four percent of the weight of the Earth’s crust and ten percent of the weight of all sedimentary rocks. It occurs in many different mineralogical environments and is often a major component of sedimentary, metamorphic, and igneous rocks. In sedimentary rocks, calcite occurs in crystalline, oolitic, fossiliferous, and massive forms, and is often the cementing agent that binds the particles in sandstone and shale. It is also the primary mineral component of massive formations of limestone, a rock which, by petrological definition, consists of at least 50 percent calcite. Recrystallized calcite is the primary component of marble, a metamorphic rock that forms when heat and pressure alter limestone. Calcite also occurs in hydrothermal veins and is a major component of carbonatite rocks (carbon-rich, igneous rocks). Because calcite dissolves readily in weakly acidic water, it is easily transported and redeposited in fractures, faults, and fissures in all three rock types. Calcite also makes up most stalactites and stalagmites in caves around the world..

Calcite is a major industrial commodity and one of the most extensively mined of all mineral resources. Each year, an estimated 28 pounds of calcite are quarried for each of the seven billion people living on Earth. Most of this calcite is quarried as limestone, a sedimentary rock of marine origin. Limestone contains most of the calcite in the Earth’s crust as microcrystals. In its

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mineralogical and petrological definitions, limestone is any sedimentary rock consisting of at least 50 percent calcite. In its industrial context, limestone is any sedimentary rock containing at least 80 percent calcite. In practice, most quarried limestone consists of at least 90 percent calcite.

Limestone forms from seawater that is rich in calcium ions Ca^{2+} and bicarbonate ions $(\text{HCO}_3)^{1-}$. Corals, bivalve mollusks, plankton, and many other marine organisms of all sizes use these two materials to create calcite and aragonite to build protective shells and exoskeletons. When these organisms die, the shells and exoskeletons fall to the sea bottom, mix with other sediments, and eventually lithify into limestone.

Limestone has been vital to construction throughout history. Some of the world's earliest, freestanding, still-surviving buildings are constructed of limestone. Limestone was used to build such notable structures as Egypt's Giza pyramids; Rome's Colosseum; London Bridge and the Palace of Westminster in the United Kingdom; and the Empire State Building and the Pentagon in the United States.

The major types of limestone include:

Chalk, a soft limestone with a very fine texture, usually white or light gray in color, that forms from the calcareous shell remains of microscopic organisms or the calcareous remains of algae;

Coquina, a poorly-cemented limestone composed of broken shell debris that forms from beach sediments;

Lithographic limestone, a dense limestone of fine, uniform grain size that occurs in thin, easily separated strata with smooth surfaces. In the 1700s, a pioneering lithography technique employed lithographic limestone plates bearing oil-based, ink images to create multiple copies when pressed on paper;

Block limestone, a dense, gray, medium-grained limestone suited for architectural purposes. Marble, or metamorphosed limestone, has similar architectural uses and also serves as a sculpting medium;

Fossiliferous limestone, which contains abundant and prominent shell and skeletal fossils of the organisms that created the limestone;

Oolitic limestone, a limestone that is composed mainly of spherical "oolites," forms from the concentric precipitation of calcite on sand particles or shell fragments;

Tufa and travertine, types of very fine-grained limestone, form when calcite precipitates from hot-spring or lakeshore water.

Limestone is the source of the calcite used to manufacture lime (also known as quicklime, burnt lime, and caustic lime). Lime, or calcium oxide (CaO), is produced by calcining (heating nearly to fusion to remove volatile substances) ground limestone to drive off carbon dioxide from calcium carbonate in the reaction $\text{CaCO}_3 = \text{CO}_2 + \text{CaO}$. Lime is used to manufacture glass, paper, masonry mortar, whitewash, water-softeners, soil conditioners, high-calcium animal feeds, and leather-tanning and sugar-refining agents. Large amounts of limestone are also used as rock, either crushed for construction applications or as blocks (dimension stone) for architectural purposes.

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Most quarried limestone is used to manufacture portland cement, the most widely used, affordable, and durable construction material. Portland cement is a mixture of tricalcium silicate ($3\text{CaO}\cdot\text{SiO}_2$), tricalcium aluminate ($3\text{CaO}\cdot\text{Al}_2\text{O}_3$), and dicalcium silicate ($2\text{CaO}\cdot\text{SiO}_2$). It is made from limestone and a source of silica and alumina such as clay, shale, or blast-furnace slag. These raw materials are ground together and fed into long, continuous, rotary kilns. First, heat calcines the calcium carbonate into calcium oxide. Then, at about $2,800^\circ\text{F}$., the mixture fuses and reacts chemically to form “clinker,” a chunky, gray-brown mixture of calcium aluminates and silicates which, when ground to a powder, becomes ready-to-mix cement.

The Romans developed the first modern, lime-based cement. Interestingly, the formula for Roman cement was lost for 1,400 years before being replicated in England in the early 1800s. This English cement became known as “portland cement,” because its concrete matched the color, hardness, and durability of the gray Jurassic Period limestone of England’s Portland Peninsula. Today, 3.4 *billion* tons of portland cement are manufactured worldwide each year. China accounts for half of that production, followed by the United States and India. Worldwide, more than 100 million tons of limestone containing about 90 million tons of calcite are mined annually.

TECHNOLOGICAL USES

Although the yellow variety of calcite itself has no specific technological uses, calcite, quarried as limestone, is of great industrial importance (see “Calcite & Limestone”).

ABOUT OUR SPECIMENS

Our specimens of yellow calcite were collected at the Elk Creek locality in Meade County, South Dakota, a short distance west of the confluence of Elk Creek and the Cheyenne River. This area is approximately 40 miles east-northeast of Rapid City and 20 miles north of the West exit of Interstate 90. Its high-plains topography consists of gently rolling, grass-covered hills and deeply eroded streambeds and riverbeds that sustain groves of cottonwood trees. Cattle ranchers own most of the land. Access is limited to a few county roads and a network of private ranch roads.

The regional bedrock is the Pierre (pronounced “peer”) Shale Formation, which consists of a distinctive, crumbly, laminated, gray shale. It was first described in 1862 as a “dark-gray shale, fossiliferous, with veins and seams of gypsum and concretions of iron oxide,” and is named for an exposure near Fort Pierre on the Missouri River in central South Dakota. Pierre Shale is of marine origin and was deposited as sediments by the Western Interior Seaway, a warm, shallow sea that existed 70-80-million years ago and stretched from the Arctic to the Gulf of Mexico, bisecting the North American continent. These sediments eventually lithified into shale formations that were later uplifted to form the bedrock in large parts of what are now the High Plains.

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Our yellow-calcite specimens originated as linings of concretions that occur in the Pierre Shale sediments. These concretions formed within layers of sedimentary strata soon after deposition and prior to lithification. Sedimentary geologists define “concretion,” a term that derives from the Latin *con*, “together,” and *crescere*, “to grow,” as a volume of sedimentary rock in which mineral cement fills the pores between the sediment grains. Concretions can be spherical, ovoid, elongated, or irregular in shape, and can range in size from microscopic to many feet in diameter. Concretions are most common in such sedimentary rock as shale, siltstone, and sandstone. Common concretionary cements include calcite; apatite-(CaF) [calcium fluorophosphate, $\text{Ca}_5(\text{PO}_4)_3\text{F}$]; siderite [iron carbonate, FeCO_3]; gypsum [hydrated calcium sulfate, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$]; barite [barium sulfate, BaSO_4], and silica [quartz, silicon dioxide, SiO_2]. Depending upon conditions, concretions can undergo either concentric or pervasive growth. In concentric growth, the concretion grows slowly, usually around an organic nucleus, as a succession of concentric layers accrete to its surface. In pervasive growth, cementing minerals fill all the pore spaces simultaneously within a limited volume of sediment.

The calcite concretions at Elk Creek developed by concentric growth and are fossiliferous, septarian, and partially hollow. They are fossiliferous because organic matter acted as the “seed” that initiated the precipitation of calcite. This calcite precipitated when circulating seawater containing high levels of calcium contacted sulfur-rich, organic remains. Septarian concretions are roughly spherical and contain angular cavities or cracks called “septaria,” a term that stems from the Latin *septem*, meaning “seven,” in reference to the internal crack pattern which often, but not always, has seven primary branches. When cut in cross section to exhibit the intricate, internal patterns, septarian nodules make interesting and attractive decorative objects. Finally, the Elk Creek concretions developed a central cavity that provided space for the growth of well-developed calcite crystals. Other minerals present in the Elk Creek concretions include barite; gypsum; marcasite [the orthorhombic polymorph of iron disulfide, FeS_2]; and the rare mineral whewellite [hydrated calcium oxalate, $\text{Ca}(\text{C}_2\text{O}_4) \cdot \text{H}_2\text{O}$].

The Pierre Shale Formation covers several thousand square miles of central and western South Dakota and in places is more than 2,000 feet thick. It does not form a contiguous bedrock, but occurs in irregular sections bounded by other types of bedrock. Pierre Shale is rarely visible on the surface. Because it weathers so quickly, Pierre Shale is usually covered, often deeply, by its own derivative soils and gravels. To recover concretions that contain yellow calcite, collectors search for unweathered exposures of Pierre Shale along the rivers, creeks, intermittent streams, gullies, and dry washes that cut through the bedrock. These exposures usually form steep, unstable banks devoid of vegetation where concretions are prominently visible amid the otherwise fine-grained, gray shale.

The concretions are hard and durable; breaking them open is a slow, laborious process that is done manually with sledges, bars, and chisels. In recent years, some commercial collectors have used mechanized equipment, but with only limited success. Breaking the hard concretions often damages the interior crystals of yellow calcite. Commercial collectors consider it a “miracle” that undamaged specimens are recovered at all. Although the resource—the number of calcite-containing concretions that exist within the Pierre Shale in the Elk Creek area—is undoubtedly very large, relatively few specimens have been collected in recent years. Most ranchers at Elk Creek do not allow collectors on their land, and those who do usually charge a fee. Many

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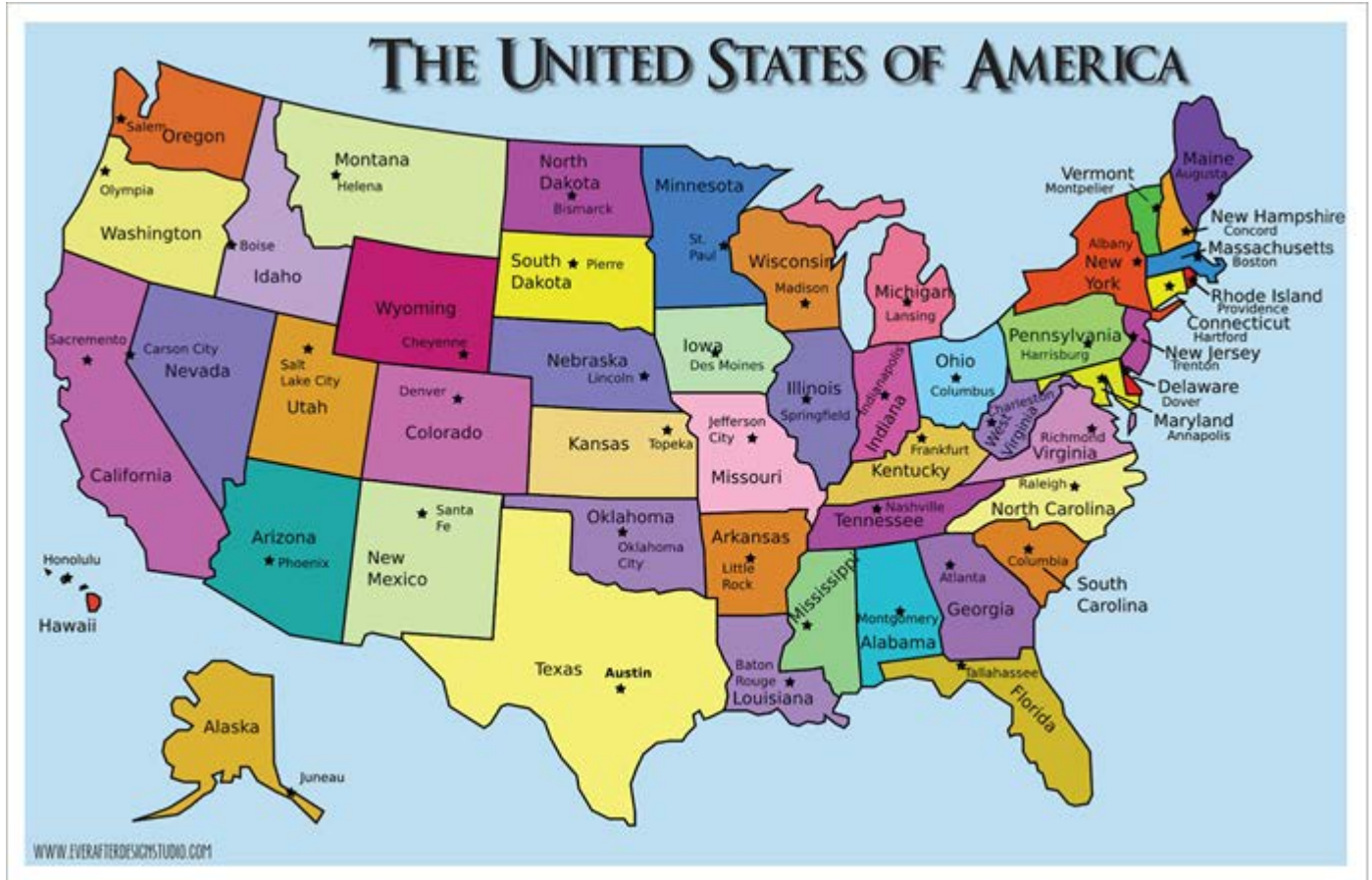
yellow-calcite specimens available today come from the marketing of older, private collections. We acquired our specimen of yellow calcite from one of the few commercial collectors working the Elk Creek locality.

The yellow-calcite crystals in your specimen are translucent and have a yellow-to-yellow-orange color that is caused by trace amounts of divalent iron Fe^{2+} . The crystals are terminated rhombohedrons that are distorted and exhibit slightly curved, terminal and prism faces. Many specimens also exhibit a number of well-developed, monoclinic rhombohedrons. These crystals, which are colorless and have a water-clear transparency, are selenite, the crystalline variety of gypsum. In your specimen, the clusters of yellow-calcite crystals appear atop a matrix of massive brown calcite, which formed the outer “shell” of the original concretion.

Elk Creek, South Dakota, was one of 50 American localities featured in the “American Mineral Treasures Exhibit” at the 2008 Tucson (Arizona) Gem & Mineral Show and in the corresponding book (see “References”). This exhibit and book recognize what are, in the opinion of many experts, the top 50 classic, mineral-specimen localities in the United States.

References: *Dana's New Mineralogy*, Eighth Edition; *Encyclopedia of Minerals*, Second Edition, Roberts, et al, Van Nostrand Reinhold Company; *2008 Fleischer's Glossary of Mineralogical Species*, Malcolm E. Back and Joseph A. Mandarino, The Mineralogical Record, Inc.; *Mineralogy*, John Sinkankas, Van Nostrand Reinhold Company; *Gemstone and Mineral Data Book*, John Sinkankas, Geoscience Press; *The Complete Guide to Rocks & Minerals*, John Farndon, Hermes House, 2007; *Gemstones of the World*, Walter Schumann, Sterling Publishing Company; “The Origin of Color in Minerals,” Kurt Nassau, *American Mineralogist*, Volume 63, 1978; “Cement,” Hendrik van Oss, *Mineral Commodity Summaries*, United States Geological Survey, 2013; “Lime,” M. Michael Miller, *Mineral Commodity Summaries*, United States Geological Survey, 2013; *American Mineral Treasures*, various authors, Gloria Stabler, Wendell Wilson, Janet Clifford, et al, editors, Lithographie LLC, 2008; “Famous Mineral Localities: Elk Creek, South Dakota,” Thomas Campbell, Donald Campbell, and Willard Roberts, *The Mineralogical Record*, March-April 1987.

Mineral of the Month Club March 2015



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