

## August 2011 Mineral of the Month: Dolomite

This month's mineral is dolomite from a classic locality in China. Our write-up details dolomite's mineralogy, its importance as a major source of magnesium, and the interesting properties of this remarkable, lightweight metal.

### OVERVIEW

### PHYSICAL PROPERTIES

Chemistry:  $\text{CaMg}(\text{CO}_3)_2$  Calcium Magnesium Carbonate, sometimes containing small amounts of manganese, iron, lead, zinc, and chromium.

Class: Carbonates

Subclass: Anhydrous Carbonates

Group: Dolomite

Crystal System: Trigonal

Crystal Habits: Usually as blocky, rhombohedral crystals with curved faces; also compact, granular, massive, stalactitic, and stalagmitic. Twinning common.

Color: Usually white or colorless; also gray, pink, green, lilac, yellow, or brownish-white. Transparent, colored varieties can appear nearly colorless in transmitted light.

Luster: Pearly to vitreous

Transparency: Transparent to translucent

Streak: White

Cleavage: Perfect in three directions, forming rhombohedrons

Fracture: Conchoidal, brittle

Hardness: 3.5-4.0

Specific Gravity: 2.8-2.9

Luminescence: Rarely fluorescent; sometimes triboluminescent

Refractive Index: 1.679-1.723

Distinctive Features and Tests: Best field identification marks are curved crystal faces and pearly-to-vitreous luster; powdered dolomite effervesces slowly in hydrochloric acid. Dolomite can be confused with calcite [calcium carbonate,  $\text{CaCO}_3$ ], which is less dense and effervesces vigorously in hydrochloric acid.

Dana Classification Number: 14.2.1.1

**NAME** Dolomite, pronounced DOUGH-low-mite, is named for the French geologist Déodat de Dolomieu. Other names for dolomite are "coddazite," "compound spar," "magnesian lime," "magnesio-calcite," "pearl spar," "rhomb spar," "ridolphte," and "tharandite." In European mineralogical literature, dolomite appears as *dolomie*, *Dolomit*, and *dolomita*. Dolomite varieties that form from cationic substitution are cobalt-rich "cobaltoan dolomite," iron-rich "ferroan dolomite," manganese-rich "manganoan dolomite," lead-rich "plumbodolomite," and zinc-rich "zincian dolomite." The terms "dolomite rock" and "dolostone" refer to sedimentary rock that consists primarily of the mineral dolomite.

**COMPOSITION:** Dolomite consists of 21.73 percent calcium (Ca), 13.18 percent magnesium (Mg), 13.03 percent carbon (C), and 52.06 percent oxygen (O). Dolomite is a member of the carbonates, a class of nearly 100 minerals in which metallic elements combine with the carbonate radical ( $\text{CO}_3$ )<sup>2-</sup>. The flat, triangular carbonate radical, the fundamental structural unit of all carbonates, consists of a central carbon ion C<sup>4+</sup> covalently bound to three equidistant oxygen ions 3O<sup>2-</sup>. As an allochromatic mineral, dolomite's colors are created by color-causing, metallic impurities called chromophores. When pure or nearly pure, dolomite is colorless or white, but traces of impurities create a range of pale colors. Soft pink, purple, and lilac hues are due to manganese; yellows and browns are caused by iron. An unusual, bright-pink color is

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caused by cobalt. Dolomite occurs primarily in the chemical sedimentary rock called “dolomite rock” or “dolostone,” which is similar in color and fine-grained texture to limestone. Dolomite rock contains 90 percent or more dolomite and 10 percent or less calcite. Limestone formations can alter through dolomitization, a chemical process of diagenesis in which the chemical action of warm, magnesium-rich groundwater converts all or part of the calcite in limestone into dolomite, thus converting the original limestone into dolomite rock. Dolomite also occurs in contact-metamorphic skarns and hydrothermal veins, and in dolomitic marble (metamorphosed dolomite rock) in regional metamorphic rocks.

**COLLECTING LOCALITIES:** Although dolomite is abundant and widely distributed, relatively few localities provide fine specimens. Notable sources are found in China, Austria, France, Germany, Poland, Switzerland, Romania, Spain, Italy, Australia, Brazil, Bolivia, Peru, Democratic Republic of Congo, Morocco, Namibia, South Africa, and Mexico. In the United States, dolomite is collected in Oklahoma, Missouri, Illinois, Kentucky, Arkansas, Alabama, Georgia, New York, Pennsylvania, and Tennessee

**HISTORY, LORE, & GEMSTONE/TECHNOLOGICAL USES:** Dolomite was first described as a mineral species in 1791. Because it is soft, brittle, and lacks a distinctive color, dolomite has very limited use in jewelry. Crystals are sometimes wrapped in silver for wear as pendants, usually for metaphysical purposes. Dolomite rock is an important ore of magnesium metal and magnesium compounds, which have many uses in science, industry, metallurgy, and medicine. Dolomite rock is also quarried as a dimensional (building) stone, cement aggregate, and road-fill material. According to modern metaphysical practitioners, dolomite relieves sorrow and the symptoms of depression, aligns and balances mental and emotional energies, and encourages giving, charitable actions, and generosity.

**ABOUT OUR SPECIMENS:** Our dolomite specimens are from the Shangbao Pyrite Mine in Leiyang County, Hengyang Prefecture, Hunan Province, People’s Republic of China. The Shangbao Pyrite Mine is located 15 miles southeast of the city of Leiyang in a historic iron-mining region. In 1972, several small, iron-sulfur mines were consolidated into the Shangbao Pyrite Mine, which used a combination of open-pit and underground mining methods to extract pyrite ore as a source of both iron and sulfur. Shangbao exploits a skarn-type pyrite deposit that formed through the contact metamorphism of limestone and dolomitic limestone. Mineral specimens from the Shangbao Pyrite Mine first reached international markets in the 1980s. These included transparent, cubic fluorite crystals in green, pink, and violet hues; lustrous pyrite cubes; unusual crystals of green quartz; pearly, saddle-shaped crystals and snowball-like spheres of dolomite; bladed crystals of silvery-gray bismuthinite; and amber scalenohedrons of calcite. When Shangbao ceased commercial operations in 1995, it was one of the world’s few remaining mines that still exploited pyrite as a source of iron. Immediately after the mine closed, a group of former pyrite miners formed a syndicate and leased parts of the mine specifically to collect specimens. Our specimens were recovered from a skarn pocket that was opened in 2008. Although there is no ore production in the Shangbao Pyrite District today, an intensive mineral-exploration program that has been underway since 2006 has identified several economic concentrations of tin and tungsten mineralization. If tin and tungsten mining begins in the near future, as the Chinese government expects, the supply of fine mineral specimens from the Shangbao Pyrite District will likely increase.

**10 YEARS AGO IN OUR CLUB:** Inesite, Ezhou, Hubei Province, China. This was an amazing month, for our specimens featured not only the small pink needle-like inesite crystals, but small root beer-brown crystals of hubeite, a new mineral that was still in the process of being accepted--Members actually received specimens of a new mineral before it had even been recognized officially! We obtained 290 specimens from the Rocksmiths, mineral dealers who have since retired. Along with the inesite write-up, we sent Club members 14 additional pages with all the information submitted for approval of a new mineral, and in a special section explained what takes place in the acceptance process. A great month!

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## **COMPREHENSIVE WRITE-UP**

### *COMPOSITION*

This is the third time we have featured dolomite. In January 2001, we sent Club members specimens from the prolific Vulcan Quarry, Lawrence County, Arkansas. The dolomite crystals were similar in color to this month, but most were significantly smaller, though we did send larger matrix pieces to Gold-level members, then known as our Deluxe Membership. (We didn't have a Platinum-level membership then; we started experimenting with the Platinum-level a few years later.) In 2002, we planned on featuring Cobaltocalcite, the hot-pink crystals from Zaire, until while doing our research we realized that our specimens were actually of dolomite rather than calcite! Accordingly, we labeled them correctly as Cobaltoan Dolomite, which we featured in August 2002. (You may also see it called "cobaltian dolomite.") The bright-pink color occurs when cobalt substitutes for magnesium in the crystal structure. As that write-up explained, many specimens from Zaire are assumed to be cobaltoan calcite when they are really cobaltoan dolomite, an understandable error, since these two minerals are closely related, as we will see.

Dolomite is a member of the carbonates, a class of nearly 100 minerals in which metallic elements combine with the carbonate radical  $(\text{CO}_3)^{2-}$ . Radicals are groups of atoms that act as entities in chemical reactions. The carbonate radical, the fundamental structural unit of all carbonates, consists of a central carbon ion  $\text{C}^{4+}$  covalently bound to three equidistant oxygen ions  $3\text{O}^{2-}$ . Carbonate anions are flat, triangular structures held together by shared electrons and strong, covalent bonding. As an anhydrous carbonate mineral, dolomite contains no water molecules ( $\text{H}_2\text{O}$ ) or hydroxyl ions  $(\text{OH})^{1-}$ . Of the roughly 70 anhydrous carbonates, dolomite is second in abundance only to calcite [calcium carbonate,  $\text{CaCO}_3$ ].

All molecules consist of cations (positively charged ions) and anions (negatively charged ions). In dolomite, a compound cation is bound to a double carbonate radical. This compound cation consists of a divalent calcium ion  $\text{Ca}^{2+}$  and a divalent magnesium ion  $\text{Mg}^{2+}$ . Each has a +2 charge that provides the dolomite molecule with a total +4 cationic charge. The dolomite anion consists of two carbonate radicals (radicals are bonded groups of ions of different atoms that behave as entities in chemical reactions). In each radical, the +4 charge of the carbon ion and the collective -6 charge of the three oxygen ions  $3\text{O}^{2-}$  provide a -2 anionic charge. This double carbonate ion  $2(\text{CO}_3)^{2-}$  therefore has a total anionic charge of -4 to balance the total +4 cationic charge and provide the dolomite molecule with electrical stability.

Carbonate minerals are the inorganic salts of carbonic acid ( $\text{H}_2\text{CO}_3$ ), a weak acid that consists of a hydrogen ion  $\text{H}^{1+}$  and a bicarbonate ion  $(\text{HCO}_3)^{1-}$ . Carbonic acid forms in near-surface conditions when carbon dioxide ( $\text{CO}_2$ ) from the atmosphere or from the chemical weathering of carbonate rocks dissolves in water 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, metal ions then bond ionically with the bicarbonate ions to form carbonate minerals and free hydrogen ions. In the case of dolomite, this formula is  $\text{Ca}^{2+} + \text{Mg}^{2+} + 2(\text{HCO}_3)^{1-} = \text{CaMg}(\text{CO}_3)_2 + 2\text{H}^{1+}$ . Many carbonate minerals, including dolomite, react with acids, notably hydrochloric acid (HCl). In hydrochloric acid, powdered dolomite will effervesce as the acid's reactive chlorine ions ( $\text{Cl}^{1-}$ ) replace the carbonate radicals in the dolomite. The formula  $\text{CaMg}(\text{CO}_3)_2 + 4\text{HCl} = \text{CaCl}_2 + \text{MgCl}_2 + 2\text{H}_2\text{O} + 2\text{CO}_2$  shows how dolomite and hydrochloric acid react to form calcium chloride, magnesium chloride, water, and carbon dioxide, the latter gas creating diagnostic bubbles of effervescence.

As an allochromatic (other-colored) mineral, dolomite's colors are created by color-causing metallic impurities called chromophores. Pure or nearly pure dolomite is colorless or white, but traces of impurities create a range of pale colors. In dolomite, bright-pink colors are due to cobalt; soft pink, purple, and lilac hues come from the presence of manganese; and yellows and browns from traces of iron. The ionizing

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effects of natural geophysical radiation can sometimes create purple colors by disrupting dolomite's normal lattice structure. When viewed with transmitted light, color varieties of transparent dolomite can appear nearly colorless, an indication that dolomite's perceived color is a function of the selective absorption of reflected light, rather than transmitted light.

The dolomite crystal lattice is built of layers of calcium ions, magnesium ions, and carbonate ions. Because the substantial difference in the atomic radii of calcium and magnesium ions (calcium ions are one-third larger) would cause structural instability, calcium ions and magnesium ions cannot occupy the same layer. Dolomite thus consists of alternating layers of carbonate-calcium-carbonate-magnesium. Because these layers are bound to each other by weak, metal-carbonate, ionic bonding, dolomite is quite soft at Mohs 3.5-4.0. These alternating layers cause dolomite to crystallize in the trigonal system (which is sometimes included with the similar hexagonal system). The trigonal system is characterized by four axes, three of which are of equal length and lie in a plane perpendicular to the fourth axis. The trigonal system differs from the hexagonal system in its threefold symmetry, unlike the four- or sixfold symmetry of the hexagonal system. Dolomite's fold symmetry follows the planes of the weak, metal-carbonate ionic bonding and accounts for its perfect cleavage in three directions to form rhombohedrons. Rhombohedrons, dolomite's predominant crystal habit, are six-sided polygons in which crystal faces are parallelograms and opposite faces lie in parallel planes. Twinning within the crystal lattice causes dolomite crystals to gently curve into diagnostic "saddle" shapes. Dolomite also has a pronounced, pearly-to-vitreous luster that appears as sheens of light sweeping across the surfaces of the gently curved crystal faces.

Fluorescence often helps to distinguish dolomite from calcite: Calcite is frequently fluorescent, dolomite rarely so. Fluorescence occurs when ultraviolet (black) light energizes electrons, boosting them to higher orbits. As these energized electrons fall back to their regular orbits, they release excess energy as visible light. Although rarely fluorescent, dolomite is often triboluminescent (also called mechanoluminescent or fractoluminescent). Triboluminescence results from breaking, scratching, or cleaving certain minerals. The mechanical stresses generated by physically breaking atomic bonds excite electrons, which immediately release excess energy as tiny, bright flashes of white and yellow light.

The Dana mineral-classification number 14.2.1.1 identifies dolomite as an anhydrous carbonate (14) without hydroxyl ions or attached molecules of water. Dolomite is subclassified (2) by the general formula  $AB(CO_3)_2$ , in which "A" and "B" are ions of such divalent metals as calcium, magnesium, iron, manganese, or zinc. Dolomite is then assigned to the dolomite group (1) as the first (1) of four members. The other three members, all crystallizing in the trigonal system and sharing similar chemistries, include ankerite [calcium iron magnesium manganese carbonate,  $Ca(Fe,Mg,Mn)(CO_3)_2$ ], kutnohorite [calcium manganese magnesium iron carbonate,  $Ca(Mn,Mg,Fe)(CO_3)_2$ ], and minrecordite [calcium zinc carbonate,  $CaZn(CO_3)_2$ ]. Through complete cationic substitution, dolomite forms solid-solution series with ankerite and kutnohorite when iron, manganese, and zinc ions replace those of magnesium. Intermediate phases of these solid-solution series form varieties such as iron-rich "ferroan dolomite," manganese-rich "manganean dolomite," and zinc-rich "zincian dolomite." Lead also partially substitutes for magnesium in the lead-rich variety "plumbodolomite."

Dolomite occurs primarily in "dolomite rock" or "dolostone," a sedimentary rock that is similar to limestone in color and fine-grained texture. **Limestone** is a fine-grained sedimentary rock composed of more than 50 percent calcium carbonate (usually as calcite) and less than 5 percent dolomite. **Dolomite rock** or dolostone is a fine-grained sedimentary rock consisting of 90 percent or more dolomite and 10 percent or less calcite. **Dolomitic limestone** (also called **calcitic dolomite**) contains intermediate percentages of dolomite and calcite.

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Because the mineral dolomite, unlike calcite, is not known to form through sedimentary deposition, mineralogists were initially unable to explain the origin of large dolomite formations, and called it the “dolomite problem.” Only in the 1970s did mineralogists conclude that large formations of dolomite rock were originally deposited as limestone. These limestone formations later became altered through dolomitization, a chemical process of diagenesis in which the chemical action of warm, magnesium-rich groundwater converts all or part of the original calcite into dolomite, thus also converting the original limestone into dolomite rock or dolomitic limestone. A reverse process of dedolomitization can occur when groundwater devoid of magnesium circulates through dolomite formations, dissolving and removing the magnesium to convert dolomite back to calcite. Entire formations of dolomite rock can thus revert back to limestone. Because of this dolomitization-dedolomitization process, dolomite and calcite often form mutual pseudomorphs. Within dolomite rock, the mineral dolomite is often associated with calcite, barite [barium sulfate,  $\text{BaSO}_4$ ] and fluorite [calcium fluoride,  $\text{CaF}_2$ ]. Because dolomite is quite soluble, especially in groundwater that is saturated with carbon dioxide to form carbonic acid, it can, like calcite, dissolve to form caves and sinkholes and to redeposit as stalactites and stalagmites.

Dolomite also occurs with calcite in dolomitic marble (metamorphosed dolomite rock) of regional metamorphic rocks; in contact-metamorphic skarns (see “About Our Specimens”) with calcite, fluorite, and quartz [silicon dioxide,  $\text{SiO}_2$ ]; in high-, medium-, and low-temperature hydrothermal veins with galena [lead sulfide,  $\text{PbS}$ ], calcite, siderite [iron carbonate,  $\text{FeCO}_3$ ], and rhodochrosite [manganese carbonate,  $\text{MnCO}_3$ ]; and in disseminated, hydrothermal replacement deposits with calcite and gypsum [hydrous calcium sulfate,  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ].

### ***COLLECTING LOCALITIES***

Although dolomite is abundant and widely distributed, few localities provide fine specimens. Our dolomite specimens were collected at the Shangbao Pyrite Mine in Leiyang County, Hengyang Prefecture, Hunan Province, China. European dolomite specimens come from the Rahm Quarry at Kammern, Lising-Palten Valley, Styria, Austria; the Rocher du Boeuf Quarry, L'Argentolle, Saône-et-Loire, Burgundy, and the Trimouns talc mine at Luzenac, Ariège, Midi-Pyrénées, both in France; the Schmitt dolomite quarry at Altenmittlau in the Spessart Mountains, Bavaria, Germany; the Rędziny dolomite quarry at Czarnów, Lower Silesia, Poland; the dolomite outcrops at Giesen, Freichi, and Binn in the Binn Valley, Valais, Switzerland; the Cavnic Mine at Cavnic, Baia Sprie, Maramures County, Romania; and the Azcárate Quarry at Euqui, Esteribar, Navarre, Spain. Localities in Italy include the Transversella Mine at Transversella, Canavese district, Torino Province, Piemonte; the Carrara marble quarries in the Apuan Alps, Massa-Carrara Province, Tuscany; and the Alpi Dolomitische marble quarries in Bolzano Province, Trentino, Trentino-Alto Adige.

Other localities are the Riverview dolomite quarry at Torrens Gorge, Mount Lofty Range, South Australia, Australia; the Itos Mine at Oruro, Cercado Province, Oruro Department, Bolivia; the Pedra Preta Pit at Brumado, Bahia, Brazil; the Casapalca Mine at Casapalca, Huarachiri Province, Lima Department, Peru; the Kolwezi Mine at Kolwezi in Katanga's Copper Crescent, Democratic Republic of Congo; the Bou Azer dolomite outcrops at Tazenakht, Ouarzazate Province, Souss-Massa-Draâ Region, Morocco; the Jan Coetzee copper mine in the Okiep district, Namaqualand, Northern Cape Province, South Africa; the Tsumeb Mine at Tsumeb in the Otokojo Region and the Kombat Mine at Kombat, Grootfontein District, Otjozondjupa Region, both in Namibia; and the Santa Rosalía Mine, Boleo district, Mulegé, Baja California Sur, and the San Antonio Mine in the Santa Eulalia district, Aquiles Serdán, Chihuahua, both in Mexico. In the United States, dolomite localities include the Tri-State zinc-mining district, notably the Cardin mines in the Picher Field, Ottawa County, Oklahoma, and the Joplin Field mines in Jasper County, Missouri. Specimens are also collected in the Viburnum Trend lead mines in Sweetwater, Reynolds, and Ellington counties in eastern Missouri. Fine dolomite crystals come from the Illinois-Kentucky Fluorspar District,

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especially the Mahoning Group mines in the Cave-in-Rock subdistrict, Hardin County, Illinois, and the Hutson zinc mines at Salem, Livingston County, Kentucky. Arkansas specimens come from Magnet Cove in Hot Spring County; the dolomite quarries in the Rush Creek and Warner Creek-Hall Mountain districts in Marion County; and the Black Ridge dolomite quarry in the Lawrence County Zinc district, Lawrence County. Other localities include the dolomite quarries of Lee and Jefferson counties, Alabama; the Hale Quarry at Graysville, Catoosa County, Georgia; the Hickory Hill and Diamond Acres quarries at Fonda, Montgomery County, New York; the Binkley-Ober Quarry at East Petersburg, Manheim Township, Lancaster County, Pennsylvania; and zinc mines of the Middle Tennessee district in Putnam, Polk, and Smith counties, Tennessee.

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

Because of its softness (Mohs 3.5-4.0), brittleness, and lack of a distinctive color, dolomite has very limited use in jewelry. Crystals are sometimes wrapped in silver for wear as pendants, usually for metaphysical purposes. Transparent crystals have been cut into collectors' gems up to 50 carats in weight. Collectors acquire dolomite specimens because of the rarity of well-developed crystals, interesting mineralogical associations, and unusual, curved crystal faces.

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

French geologist Déodat de Dolomieu (Dieudonné Sylvain Guy Tancrede de Dolomieu, 1750-1801) first described dolomite as a mineral species in 1791. While on a collecting trip to northeast Italy's Tyrolean Alps, de Dolomieu discovered a calcareous, sedimentary rock similar to limestone, but which did not effervesce as readily in hydrochloric acid. Analyzing samples, he detected magnesium, a metallic element that had already been identified, but not yet isolated, and realized that he had discovered a new mineral. The following year, Swiss chemist Nicolas-Théodore de Saussure (1767-1845) named the new mineral in de Dolomieu's honor—*dolomie* ("dolomite" in English). Italy's Tyrolean Alps, which consist largely of dolomite rock, later became known as the Alpi Dolomitische (Dolomite Alps or Dolomites).

Dolomite was featured on Yugoslavia's 3.40-dinar postage stamp of 1980 and on Spain's 30-céntimo stamp of 1995. According to modern metaphysical practitioners, dolomite crystals relieve sorrow and the symptoms of depression, align and balance mental and emotional energies, and encourage giving, charitable actions, and generosity.

### ***TECHNOLOGICAL USES***

Dolomite rock is an important ore of both magnesium metal and magnesium compounds, which have many uses in science, industry, metallurgy, and medicine (see "About Magnesium"). Dolomite rock is also quarried as a dimensional (building) stone, cement aggregate, and road-fill material. Because of its divergent end products, production statistics for dolomite rock are difficult to compile accurately. Nevertheless, annual, worldwide quarry production of dolomite rock amounts to many millions of tons.

As a source of magnesium, dolomite rock is mined from open quarries, crushed and ground to a powder, then calcined or heated to drive off carbon dioxide and convert the calcium magnesium carbonate to calcium oxide, magnesium oxide, and carbon dioxide according to the formula  $\text{CaMg}(\text{CO}_3)_2 + \text{heat} \rightarrow \text{CaO} + \text{MgO} + 2\text{CO}_2$ . Magnesium oxide (MgO) is the basic feedstock for conversion to other magnesium compounds. It is used to produce metallic magnesium by the Pidgeon Process, a chemical-reduction process invented in 1941 by Canadian chemist Lloyd Montgomery Pidgeon (1903-1999). In the Pidgeon Process, finely ground dolomite rock is calcined, then mixed with ferrosilicon (an iron-silicon alloy used in

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steelmaking) and fired at high temperatures. The silicon chemically reduces the magnesium oxide component of the calcined dolomite rock to elemental magnesium as seen in the formula  $\text{Si} + 2\text{MgO} = \text{SiO}_2 + 2\text{Mg}$ . The products of the Pidgeon Process are silica ( $\text{SiO}_2$ ), calcium silicate ( $\text{CaSiO}_3$ ), and magnesium vapors, which are condensed into metallic magnesium of high purity.

As a dimensional stone, dolomite rock is quarried in blocks, shaped, sized, and smoothed for us as architectural and structural block. Dolomite dimensional stone has several advantages over limestone, including somewhat greater density and, most importantly, greater inertness and subsequently less susceptibility to attack by acids in groundwater and acid rain. Dolomite rock of less-than-dimension-stone grade is crushed as cement aggregate, road-fill material, and ballast.

### **MAGNESIUM**

*In the form of dolomite rock, dolomite is a major source of magnesium. Many of us were introduced to this metal in high-school chemistry classes, when instructors ignited a small piece of magnesium ribbon. The burning magnesium produced an intense, dazzling white light as rapid chemical oxidation transformed it into white, powdery magnesium oxide. Years ago, a friend threw an old Volkswagen magnesium-alloyed engine case on a bonfire, and it burned with an extremely intense bright light—thirty years later, we now understand why.*

*Magnesium, an alkaline earth element, is a silvery-white metal with considerable rigidity and structural strength. It ranks sixth among the elements in crustal abundance, but does not occur free in nature. Magnesium's most remarkable property is its light weight. With an atomic weight of 24.31 and a specific gravity of only 1.74, magnesium is one-third lighter than aluminum (specific gravity 2.70). Because of its high chemical activity, magnesium oxidizes quickly in contact with air. However, this oxidation forms a thin coating of inert magnesium oxide that prevents further atmospheric oxidation of the underlying metal.*

*Oxide and hydroxide compounds of magnesium have been known since antiquity. In 1618, at Epsom, England, a farmer noticed that his astringent well water had certain beneficial, cathartic properties. The salt in the well water, later named "epsomite" [hydrous magnesium sulfate,  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ ], became known as "Epsom salt" and was widely used for medicinal purposes. In 1755, Scottish chemist Joseph Black (1728-1799) studied the salt obtained from the Epsom well and concluded that it contained a previously unknown element. Black informally named this mysterious new element "magnesia," after a district in the Thessaly area of Greece where similar salts existed. In 1808, British chemist Sir Humphry Davy (1778-1829) confirmed Black's theory by isolating from Epsom salt a new metallic element in powder form. Davy proposed naming the new element "magnium," but Europe's scientific community instead adopted the name "magnesium." In 1831, French chemist Antoine Alexandre Brutus Bussy (1794-1882) isolated magnesium in coherent metallic form.*

*Although magnesium compounds quickly found many uses in medicine and industry, the metal itself seemed initially suited only for photographic flash powder, flares, and incendiary devices.*

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*German engineers used the metal and its first alloys in military aircraft in World War I and much more extensively in World War II. Following the war, metallurgists devised new copper-magnesium, zinc-magnesium and, most importantly, aluminum-magnesium alloys. The latter, with the structural strength of aluminum and considerably less weight, found great use in aviation and aerospace applications.*

*Today, readily available and inexpensive magnesium is the third most commonly used structural metal after iron and aluminum. Strong, lightweight, aluminum-magnesium and magnesium-aluminum alloys are used in virtually all aircraft and spacecraft and in many high-performance automotive parts, including engines. Because of light weight and excellent structural and electrical properties, magnesium-aluminum alloys are employed extensively in today's digital cameras, laptop computers, cell phones, and similar electronic devices. Metallic magnesium is also used in pyrotechnics ranging from aerial and ground fireworks to handheld "sparklers"; in steelmaking to remove sulfur and oxygen; and in the manufacture of vacuum tubes as a "getter" to remove residual traces of oxygen.*

*Magnesium compounds have a wide array of everyday and specialized applications. The hydroxide is the active ingredient in milk of magnesia and similar laxatives and antacids; the hydrous sulfate (Epsom salt), borate, bromide, chloride, gluconate, stearate, and citrate have many medicinal, veterinary and agricultural uses; the oxide is a component of refractory firebrick and oven liners, a flux to remove impurities from molten steel, and a feedstock to formulate other magnesium compounds. The sulfite is used in the "sulfite process" of papermaking; the phosphate is a fire-retardant for wood; the hexafluorosilicate is a moth repellent for textiles; and the carbonate is the "dust" that improves the grips of weightlifters and gymnasts.*

*Until the 1970s, evaporation and electrolysis of magnesium chloride-rich brines was the primary source of magnesium metal. Today, the Pidgeon Process, which produces magnesium by the silicon-reduction of dolomite rock (see "Technological Uses"), now accounts for more than half of the world's magnesium output. China employs the Pidgeon Process exclusively to provide 60 percent of world production. Lesser amounts of magnesium and magnesium compounds are also obtained by mining deposits of brucite [magnesium hydroxide,  $Mg(OH)_2$ ], magnesite [magnesium carbonate,  $MgCO_3$ ], and forsterite [the magnesium-rich end-member of the olivine solid-solution series, magnesium silicate,  $Mg_2SiO_4$ ]. Some 600,000 metric tons of magnesium metal are produced worldwide each year. Refined magnesium metal sells for \$2.40 per pound. Annual world production of magnesium compounds stands at 18 million metric tons. A metric ton of magnesium oxide currently costs about \$280.*

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

Our dolomite specimens were collected at the Shangbao Pyrite Mine in Leiyang County, Hengyang Prefecture, Hunan Province, People's Republic of China. Located in south-central China, Hunan Province is the size of the state of Kansas and has a population of more than 70 million. The capital of Hengyang



## ***August 2011 Mineral of the Month: Dolomite***

Prefecture, a political subdivision of Hunan Province, is the city of Leiyang, population 1.3 million, where the regional topography is dominated by low hills and broad valleys. At an elevation of only 250 feet, the climate is moist and subtropical. Leiyang's economy is based on agriculture, forestry, marble-cutting, kaolin-clay processing and, most importantly, papermaking. Leiyang is the birthplace of Cai Lun (ca. A.D. 50-121), a royal servant who is traditionally recognized as the inventor of modern paper and the papermaking process. By the time of Cai Lun's death, his inexpensive paper had already replaced silk cloth and bamboo tablets to greatly advance Chinese literacy and promote literature.

The Shangbao Pyrite Mine is located 15 miles southeast of Leiyang in an area where iron mining has flourished since ancient times. By 500 B.C., the Chinese were mining iron from shallow pyrite deposits using both open-pit and underground workings. Miners hand-sorted the pyrite, crushed and ground it a powder, added oxygen-rich reducing agents such as lime (calcium oxide, CaO) and fired the mixture in charcoal ovens. The oxygen in the lime combined with the sulfur in the pyrite to form sulfur dioxide gas and leave behind elemental iron. Regional pyrite mining and iron production continued for many centuries. In recent times, pyrite was also mined for its sulfur content. By the 1970s, pyrite was no longer an ore of iron in most of the world. Nevertheless, pyrite continued to serve as an ore of iron in China, where a major economic-development program demanded use of all natural resources. In 1972, several small pyrite mines were consolidated into the Shangbao Pyrite Mine, which continued to mine pyrite ore from open-pit and shallow, underground workings as a source of both iron and sulfur.

The Shangbao Pyrite District ore occurs in skarn deposits, relatively small, complex mineral assemblages that originated when igneous magma of granitic or syenitic composition intruded formations of limestone or dolomite rock. The resulting combination of contact metamorphism, impurities in the limestone and dolomite rock, and the introduction of mineral-rich, hydrothermal fluids associated with the intrusions, formed a variety of unusual and often valuable minerals. These include such ore minerals as pyrite; sphalerite [zinc sulfide, ZnS]; galena [lead sulfide, PbS]; chalcocopyrite [copper iron sulfide, CuFeS<sub>2</sub>]; bismuthinite [bismuth trisulfide, Bi<sub>2</sub>S<sub>3</sub>]; wolframite [intermediate phases of the hübnerite-ferberite solid-solution series, iron manganese tungstate, general formula (Fe,Mn)WO<sub>4</sub>]; and stannite [copper iron tin sulfide, Cu<sub>2</sub>FeSnS<sub>4</sub>].

In the Leiyang region, the country rock consists of massive formations of Hutian and Qiqia limestone and dolomitic limestone that were laid down by shallow seas during the Permian Period of the late Paleozoic Era some 260 million years ago. About 100 million years later during the Jurassic Period of the Mesozoic Era, granitic magma enriched with such unusual elements as fluorine, tin, tungsten, and bismuth intruded these formations. This intrusion altered the adjacent limestone and dolomitic limestone into low-grade marble. Its associated hydrothermal fluids then introduced new elements into the geochemistry and eventually dissolved parts of the limestone and dolomitic limestone to provide space for the growth of well-developed mineral crystals. The Shangbao Pyrite District skarn deposits consist of small, but richly mineralized pockets of calcite, dolomite, pyrite, quartz, fluorite, bismuthinite, wolframite, stannite, phlogopite [mica group, basic potassium magnesium aluminum silicate, KMg<sub>3</sub>AlSi<sub>3</sub>O<sub>10</sub>(OH)<sub>2</sub>], bournatite [lead copper antimony trisulfide, PbCuSb<sub>3</sub>S<sub>3</sub>], and jamesonite [lead iron antimony sulfide, Pb<sub>4</sub>FeSb<sub>6</sub>S<sub>14</sub>]. In the crystallization sequence within these skarn pockets, quartz and dolomite generally crystallized first as wall linings atop which other minerals later crystallized. These skarn deposits formed underground, but were much later exposed by erosion

Mineral specimens from the Shangbao Pyrite Mine first reached international markets in the 1980s. These included transparent, cubic fluorite crystals in green, pink, and violet hues, many with dodecahedral-beveled faces and inclusions of sharp, bright pyrite cubes and tiny prisms of milky quartz. Other specimens included lustrous pyrite cubes; prisms of unusual, green quartz; pearly, saddle-shaped rhombohedrons and snowball-like spheres of dolomite; bladed crystals of silvery-gray bismuthinite; and

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beautifully developed, amber scalenohedrons of calcite. Many specimens exhibited complex and unusual mineralogical associations. Although Shangbao developed a reputation for fine mineral specimens, the supply remained limited because pyrite production always took priority over specimen collecting.

But by 1990, China's domestic supply of iron had shifted from small mines like Shangbao to modern, large, open-pit, oxide mines. Many small, older mines were ordered to close, including the Shangbao Pyrite Mine. When Shangbao ceased production in 1995, it was one of the world's few mines with pyrite as its primary ore. When Shangbao closed, a group of miners founded a syndicate and leased parts of the mine specifically to collect specimens. Since then, the Shangbao Pyrite Mine has been recognized as a classic locality for superb specimens of dolomite, fluorite, and pyrite.

The 10 miners that still work at Shangbao are completely dependent upon the recovery and sale of specimens for their income. That income can be erratic, because collectible specimens occur in scattered pockets that can be exposed only by removing large volumes of rock. On average, only one sizeable pocket is exposed each year, but the recovered specimens can be worth many thousands of dollars. Chinese dealers from Changsha, Hunan's bustling provincial capital 150 miles to the north, submit bids to the Shangbao miners for rights of first selection of newly recovered material. From Changsha, these specimens are exported to international markets. Our specimens were recovered from a relatively small pocket that the Shangbao miners opened in 2010. Imagine, straight from the pocket through the hands of a wholesale importer into our hands to be shipped to you, all within about a year!

There is currently no active ore production in the Shangbao Pyrite District, but an intensive, mineral-exploration program has been underway since 2006. Core drilling has identified several economic concentrations of tin and tungsten sulfide mineralization within the Shangbao skarn zones. Should mining of tin and tungsten ores begin in the Shangbao Pyrite District, as the Chinese government expects, the supply of fine mineral specimens from this classic locality will likely increase.

As you examine your specimen, note first the bright, pearly-to-vitreous luster that is typical of dolomite. The pale-pink color of these dolomite crystals is due to the trace presence of manganese, which has replaced some of the magnesium in the crystal lattice. Now closely study the individual rhombohedral dolomite crystals to see that the crystal faces are not perfectly flat, but either slightly convex or concave. This curvature, which is caused by twinning within the crystal lattice, forms "saddle-shaped" crystals that are a diagnostic feature of dolomite. Often, the dolomite crystals rest atop, or are intimately associated with, a matrix of needle-shaped prisms of clear or milky quartz. This association and the fact that dolomite and quartz form the wall lining of the skarn pockets, indicate that quartz and dolomite crystallized simultaneously in the first phase of pocket crystallization. A few specimens may also show small, cubic crystals of brassy-yellow pyrite or small cubic crystals of green, pink, or violet fluorite. The pretty, light pink color, the curved crystals, the intimate association with quartz—there is a lot to love about this month's featured mineral!

References: *Dana's New Mineralogy*, Eighth Edition; *Encyclopedia of Minerals*, Second Edition, Roberts, et al, Van Nostrand Reinhold Company; *2008 Glossary of Mineralogical Species*, J. A. Mandarino and Malcolm Back; *Mineralogy*, John Sinkankas, Van Nostrand Reinhold Company; *An Introduction to Crystal Chemistry*, R. C. Evans, Cambridge University Press, 1966; *Dictionary of Rocks*, Richard S. Mitchell, Van Nostrand Reinhold Company, 1985; *The Complete Guide to Rocks & Minerals*, John Farndon, Hermes House, 2007; "Magnesium" and "Magnesium Compounds," Deborah A. Kramer, *2009 Minerals Yearbook*, United States Geological Survey; *Fine Minerals of China*, Guangua Liu, AAA Minerals AG, 2006; *Geochemistry of Sedimentary Carbonates*, J. W. Moore and F. T. Mackenzie, Elsevier, 1990; "What's New in Minerals," Thomas P. Moore, *The Mineralogical Record*, November-December 2007; "China" (Special Issue), *The Mineralogical Record*, January-February 2005.