

March 2006 Mineral of the Month: Pyrite

Highly reflective crystal faces, many interesting crystal habits, and overall visual appeal make pyrite one of the most collectible of all minerals. Because of their bright luster, sharp edges, high chemical purity, and near-perfect cubic form, many collectors consider pyrite crystals from Navajún, Spain—our Mineral of the Month for March—as the best in the world.

PHYSICAL PROPERTIES

Chemistry: FeS_2 Iron Disulfide, usually containing small amounts of nickel, cobalt, manganese, and sometimes silver and gold.

Class: Sulfides Group: Pyrite

Crystal System: Isometric (Cubic)

Crystal Habits: Usually as cubes and pyritohedra (pentagondodecahedra, or dodecahedra with pentagonal faces), less commonly as octahedra, or combinations thereof in both individual crystals and crystal clusters; often twinned and striated; also as granular, globular, radiating, drusy, fibrous, mammillary, and stalactitic masses, and as nodules and aggregations.

Color: Pale brass-yellow or yellowish-gray to gray; may tarnish to yellow-brown; sometimes iridescent.

Luster: Metallic

Transparency: Opaque

Streak: Greenish-black

Cleavage: None

Fracture: Conchoidal, brittle

Hardness: 6.0-6.5

Specific Gravity: 4.9-5.2

Luminescence: None

Distinctive Features and Tests: Best field indicators are pale brass-yellow color, hardness, striated crystal faces, ability to spark on sharp impact and to become weakly magnetic upon heating. Pyrite is sometimes mistaken for native gold, but is brittle and much harder.

Dana Classification Number: 2.12.1.1

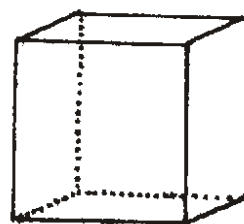


Figure 1. Pyrite Cube.

NAME

Correctly pronounced "PIE-rite," the name stems from the Greek *pyr*, meaning "fire," and translates as "fire mineral," a reference to its tendency to spark when struck with metal. The antiquated term "pyrites" (note plural usage) refers generally both to similar-appearing metal sulfides and to various types of sparking flints used in early firearms.

Thanks to its widespread distribution and familiarity to many cultures, pyrite has many alternative names. Among the most widely used—or misused—is "iron pyrite," which is actually a duplicative use of the word "iron," since pyrite by mineralogical definition *is* iron disulfide. Another common alternative name is "fool's gold," which recognizes the color similarity between pyrite and certain hues of native gold. Among the 19th-century names for pyrite are "schwefelkies," "kaltschedan," "leber pyrites," "lebereisener," "leberschlag," "marchasita," "sideropyrite," "vitriolkies," and "yellow pyrite."

Some additional names for pyrite stem from elemental impurities and unusual habits. The cobalt- and nickel-rich varieties are respectively known as "cobaltian pyrite" and "nickelian pyrite." "Iron crosses" and "iron-cross twins" refer to penetration twins of pyrite pyritohedra with shapes reminiscent of Maltese

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crosses, while the flat, disc-like, radiating forms of pyrite associated with coal shale are called “pyrite dollars” or “pyrite suns.”

COMPOSITION

Its chemical formula, FeS_2 , indicates that pyrite contains only two elements: iron (Fe) and sulfur (S). The atomic weight of pyrite consists of 46.55 percent iron and 53.45 percent sulfur. Within the pyrite molecule, the +2 charge of its single ferrous ion (Fe^{+2}) balances the -2 charge of its two covalently bonded sulfur ions. Single sulfur ions normally carry an ionic charge of -2, +4, or +6. But in pyrite and certain other metal sulfides, the two sulfur ions behave electrically as a polyatomic ion. The covalent electron sharing within the double sulfur ion results in a single charge of -2, which balances the +2 charge of the ferrous ion, thus providing electrical balance and molecular stability. Cationic substitution is common in pyrite, with several metals readily replacing iron. Most often, these metals are cobalt, nickel, manganese, silver, and gold, all of which, in sufficient quantity, can cause variations in hardness, density, and color. Cobalt substitutes so readily for iron and vice-versa that pyrite forms a solid-solution series with cattierite (cobalt disulfide, CoS_2), the intermediate grades of which are called cobaltian pyrite.

Pyrite is one of more than 350 members of the sulfide class of minerals, all consisting of a combination of sulfur with one or more metals. All sulfides are dense, brittle, rather dark in color, and metallic in luster. Pyrite has a Dana classification number of 2.12.1.1, which first identifies it as a sulfide (2); subclassified (12) by the general formula AX_2 , in which the “A” cation can be iron, zinc, mercury, gold, cobalt, copper, manganese, nickel, platinum, palladium, ruthenium, iridium, or osmium, while the “X” anion can be sulfur, arsenic, antimony, bismuth, selenium, or tellurium; finally in the pyrite group (1) as the first member (1). The pyrite group, one of 17 groups in the sulfide class, includes 19 mineral species, all with an isometric crystal structure and related chemistry, but having widely varying physical properties. The pyrite group's only abundant and generally familiar mineral is pyrite itself. Other pyrite-group minerals include vaesite (nickel disulfide, NiS_2), cattierite (cobalt disulfide, CoS_2), villamaninite (copper disulfide, CuS_2 , a cubic polymorph of chalcocite), and hauerite (manganese disulfide, MnS_2).

Pyrite, the most abundant sulfide, is associated with hundreds of other minerals. It occurs in virtually all mineralogical environments, from pegmatites and hydrothermal vein deposits to carbonatites (low-silica, carbonate-rich igneous rocks), regional metamorphic rocks, skarns (metamorphic deposits characterized by calc-silicate rocks), and sedimentary rocks. Pyrite crystals usually achieve their greatest levels of crystal development in hydrothermal vein and replacement deposits, where they are commonly associated with quartz and other sulfides such as chalcopyrite (copper iron sulfide, CuFeS_2), galena (lead sulfide, PbS), and sphalerite (zinc sulfide, ZnS). But this month's specimens, which originated in sedimentary formations, are an exception to this rule, as explained in “About Our Specimens.”

Superficially, pyrite resembles a number of other sulfides. Its brassy color and metallic luster are similar to that of chalcopyrite (copper iron disulfide, CuFeS_2); cobaltite (cobalt sulfarsenide, $[(\text{Co},\text{Fe})\text{AsS}]$); and cattierite (cobalt disulfide, CoS_2). In general appearance, pyrite closely resembles marcasite (iron disulfide, FeS_2) in density, hardness, and metallic luster. Marcasite is actually a pyrite polymorph—a mineral with an identical chemistry, but which crystallizes in a different system (orthorhombic).

The pyrite molecule consists of iron ions at each of the eight corners of a cube and at the middle of its six faces. A pair of covalently bonded sulfur atoms is positioned midway along each edge. But because the iron ions are poorly shielded from each other, some degree of metallic bonding also exists within the pyrite lattice. The inherent rigidity of the cubic structure accounts for pyrite's considerable hardness (Mohs 6.0-6.5). While the predominant covalent bonding explains pyrite's brittleness, the lesser degree of metallic

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bonding provides its metallic luster. The relatively weak, covalent sulfur-sulfur bonding also explains pyrite's chemical instability and tendency to oxidize in water and atmospheric oxygen into iron ions and sulfuric acid (H_2SO_4). Pyrite oxidation creates gossan, or deposits of limonite (a variable mixture of iron oxides and hydroxides) that overlie lower bodies of unoxidized pyrite. In highly mineralized areas, the effects of pyrite oxidation are readily apparent, because the sulfuric acid acidifies surface water and dissolves large quantities of iron and other metals. As dilution eventually decreases this acidity, the iron precipitates out of solution as "yellow boy," an iron hydroxide that stains creek banks a characteristic, bright yellow-orange color. Mining often accelerates pyrite oxidation by exposing large volumes of unoxidized pyrite to atmospheric oxygen and water, creating the environmental problem known as mine-drainage pollution.

Long-term storage in warm, humid climates can sometimes accelerate oxidation in pyrite specimens. Large pyrite crystals have the greatest stability. Because it consists of millions of tiny crystals with a greatly expanded surface area, massive pyrite oxidizes much more rapidly, often developing a gray-white efflorescent (flower-like) coating of iron sulfates and sulfuric acid that can damage labels, storage boxes, and occasionally minerals stored nearby. Because of this, some collectors keep their pyrite specimens away from other minerals in their collections. However, this month's specimens are an exception, because their unusually high chemical purity maximizes their chemical stability (see "About Our Specimens").

Pyrite crystallizes in the isometric (cubic) system, which is fundamentally defined by three axes of equal length that intersect at the crystal center and are perpendicular to their opposing faces. Variations of this cubic shape are the 4-faced tetrahedron, 8-faced octahedron, 12-faced dodecahedron, and 24-faced cubic trapezohedron. Because crystals can assume any of these forms or any combination thereof, pyrite exhibits an unusually broad variety of crystal habits. The dodecahedral habit alone has four basic forms that are categorized by face shape—symmetrical and asymmetrical pentagonal faces (five-sided polygons), delta-shaped faces (four-sided polygons), and rhombic faces (four-sided, diamond-shaped polygons). Pentagonal dodecahedrons are termed "pyritohedrons" because they are most commonly found on pyrite.

Pyrite crystals often exhibit diagnostic striations that are formed by the twinning of cubic and pyritohedral crystals and the subsequent convergence or juxtaposition of two or more faces. During crystal growth, faces can become truncated or "overgrown" by other faces that leave visible edges, or stria. These edges are usually formed by repetitively juxtaposing internal pyritohedron edges on cube faces. Pyrite striations are always perpendicular to those on adjacent faces and are usually parallel, but sometimes triangular or crossed.

COLLECTING LOCALITIES

Thanks to its abundance and occurrence in all mineralogical environments, pyrite has countless collecting localities, including virtually every metal-mining district in the world. Collectors of fine pyrite specimens generally agree that Spain and Peru have the two most notable deposits. The Peruvian source, the Huanzalá Mine in Dos de Mayo Province in Huanuco Department, which provided our Mineral of the Month specimens for October 2003, is noted for its superb clusters of octahedral crystals, while the Spanish site, recognized for its brilliant, near-perfect cubic crystals, is the village of Navajún in the province of La Rioja.

Other noted Spanish pyrite sources are the Rio Tinto mines at Huelva and the mines in the "pyrite belt" of metal-sulfide deposits west of Seville in Andalusia. Sharp cubic pyrite occurs at Rio Marina, Elba, Italy. In England, pyrite has been collected in mines at Callington in Cornwall and at Nenthead in Cumbria.

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German sources include the mines at Neustädtel in the Schneeberg District of Saxony. Pyrite cubes as large as 15 inches and weighing 150 pounds are found at the Cassandra Mine in Chalkadiki Prefecture, Macedonia Department, Greece.

Along with its Huanzala Mine, Peru has another great pyrite source—the Cerro de Pasco District in Alcides Carrión Province in Pasco Department. Brazil provides fine pyrite specimens from numerous pegmatite mines at Galiléia in Governador Valadares, and from mines at Conselheiro Pena in Minas Gerais. Bolivian sources of excellent pyrite specimens include the Atocha-Quechisla District, Sud Chichas Province, Potosí Department, and the mines at Ciudad Oruro, Cercado Province, Oruro Department.

In Australia, excellent pyrite specimens are found in the mines of the New England District in New South Wales and at the Golden Mile gold mine at Kalgoorlie in Western Australia. Canada's list of sources of fine pyrite specimens is headed by the Alborn, Atlin, Cariboo, Liard, and Kamloops districts in British Columbia, and the Algoma and Cochrane districts in Ontario.

Many fine pyrite localities exist in the United States, mostly in sulfide-ore, metal-mining districts. Especially notable are the cubes and pyritohedrons from the American Mine at Bingham Canyon and from mines at Park City, both in Utah. Superb Colorado specimens have come from the Leadville district and the nearby Climax Mine, as well as from the Gilman, Alma, Silverton, Ouray, Rico, and Telluride districts. The Tri-state zinc-lead mining district of southwestern Missouri and adjacent sections of Kansas and Oklahoma has yielded many large, well-developed pyrite cubes. Bright "pyrite dollars" occur in shales associated with coal seams at Sparta, Illinois. Fine cubes and dodecahedra have come from the Huff Quarry at Huntsville, Ohio, and unusual, distorted octahedra from Pennsylvania's French Creek Mine.

JEWELRY & DECORATIVE USES

Archaeologists have recovered pyrite crystals in jewelry from 4,000-year-old Egyptian tombs. Although pyrite has been used in jewelry and certain decorative objects for millennia, its greatest popularity as a gemstone came during the Victorian era of the late 1800s. Pyrite, which was then marketed as "marcasite," was faceted and polished for mounting in pendants, brooches, necklaces, and bracelets. One particularly popular Victorian jewelry style featured hundreds of tiny, glittering, faceted pyrite gems mounted in large, elaborate sterling-silver settings. This jewelry style regained popularity in the United States and Europe during the Art Deco period of the 1920s and 1930s. We still see it offered at shows.

Today, pyrite has a niche share of the jewelry market and is usually seen as polished beads strung for use in necklaces, bracelets, and dangling earrings. Also popular is drusy "rainbow" pyrite—natural coatings of thousands of tiny, iridescent pyrite crystals on base rock—that is fashioned into cabochons for mounting in pendants and brooches. In addition, pyrite is sometimes cut into small "rosettes" for use as edging or "framing" stones in decorative objects.

Pyrite specimens continue to enjoy great popularity among mineral collectors. Along with quartz crystals, pyrite is one of the most widely collected of all minerals. Like quartz, pyrite has a broad price range; while some small clusters of pyrite crystals can cost only a few dollars, rare or unusually fine cabinet specimens regularly sell for thousands of dollars.

HISTORY & LORE

Anthropologists believe that the ancient Chinese symbol for Earth—a golden cube—was patterned after natural cubic pyrite crystals. Pyrite has been recovered as both natural crystals and worked amulets from

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archaeological sites in ancient Egypt and from sites dating to classical Greece and Rome. Possibly the first written reference to pyrite appears in the treatise *Peri Lithon* (*On Stones*), in which the Greek philosopher and naturalist Theophrastus (ca. 372-287 B.C.) describes tiny, glittering grains of pyrite embedded in lapis lazuli. At about the same time that Theophrastus was describing pyrite in Greece, the ancestors of the Incas in South America were polishing the smooth faces of large pyrite cubes for use as mirrors, believing that the reflected self-images provided a look into one's soul. Meanwhile, in North America, the healers and seers of various tribes carried pyrite cubes as "medicine" materials and possibly used their reflective crystal faces to help conjure shamanistic visions.

Medieval physicians administered elixirs containing finely ground pyrite to treat disorders of the throat and circulatory system. By 1400, European metalworkers had come up with perhaps the first practical use for pyrite. They roasted finely ground pyrite over charcoal fires to drive off sulfur dioxide (SO_2), a gas that they then dissolved in water to make sulfuric acid, a powerful acid with many uses. Sulfuric acid was also a vital reagent during the following centuries of experimentation that led to the emergence of modern chemistry.

Pyrite has long been valued as a "fire-starter" because of its tendency to emit sparks when struck sharply with an iron implement or a hard rock such as flint. By the late 1400s, pyrite was the standard sparking material in early European wheel-lock firearms. Sparking occurs when a sharp impact produces extreme mechanical pressure within a miniscule area of the pyrite surface, thus parting its covalent sulfur-sulfur bonds with an instantaneous release of heat and light energy in the form of a spark.

In the early 1700s, pyrite was among the first minerals that European chemists qualitatively identified by its elemental components, iron and sulfur. A century later, researchers used pyrite as a chemical model to help determine the previously unknown elemental compositions of other, similar metal sulfides. True pyrite then became known as "iron pyrite" or "yellow pyrite," and chalcopyrite as "copper pyrite," differentiating terms which still have limited usage today.

Pyrite has occasionally served as an ore of iron in places without deposits of primary iron ores such as magnetite (ferrous and ferric iron oxide, FeFe_2O_4) and hematite (ferric iron oxide, Fe_2O_3). Pyrite's greatest value as an ore, however, was as a source of sulfur. By the mid-1800s, pyrite had become an important sulfur ore in regions without minable deposits of native sulfur. During World War I, soaring industrial and military demand for sulfur made pyrite a strategic mineral in the United States, Great Britain, and Germany, where it was an important source of sulfur for the manufacture of vulcanized rubber, fertilizers, medicines, and explosives. Among the more than two dozen pyrite mines in the United States, one of the largest was the Cabin Branch Mine near Batesville, Virginia. Between 1889 and 1920, the Cabin Branch Mine produced more than a quarter-million tons of pyrite. When sulfur demand peaked in 1917, a ton of pyrite was worth \$16—as much as a ton of ore containing one troy ounce of gold. Today, only small amounts of pyrite are recovered from metal-mine mill tailings for use as a coloring agent in the manufacture of amber-colored glass.

According to modern metaphysical beliefs, pyrite, along with its polymorph marcasite, supplements one's physical energy with the energy of the sun, increases stamina, stimulates the intellect, and helps to transform thought into intelligent action. Some practitioners also consider pyrite to be a shield stone that protects its wearer from negativity and physical risk.

Pyrite specimens have appeared on the 60-centavo and 2,600-sucre postage stamps of Ecuador in 1960 and 1997, respectively; the 3-cent stamp of New Zealand in 1982; the 170-dram stamp of Armenia in 1998; and the 15-cent stamp of Cyprus in 1998. A superb cluster of intergrown, sharp-edged, brilliant pyrite crystals from Navajún, Spain, was featured on that nation's 29-peseta stamp in 1994.

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TECHNOLOGICAL USES

Pyrite's greatest technological impact today is as a model in the study of mineral-crystal structure and pyrite-oxidation chemistry, the latter a key to understanding pyrite's mineralogical origin and the causes for its eventual conversion into other minerals and chemical compounds. Knowledge of pyrite-oxidation chemistry has been applied practically to predicting the weathering qualities of pyrite-containing structural (building) stone such as granite and marble, and to understanding the role of oxidation in mine-drainage pollution and devising prevention and remediation methods.

ABOUT OUR SPECIMENS

Despite its abundance, pyrite has only a few world-class collecting localities, one of which is the Victoria Mine at Navajún, La Rioja, Spain. Navajún is rarely shown even on the most detailed maps of Spain. It is a tiny village in northeastern Spain in the province of La Rioja. One of Spain's smallest provinces, La Rioja is only slightly larger than the state of Rhode Island. Despite its diminutive size, it is internationally famed for its blended red wines made primarily from Tempranillo grapes. La Rioja is a sparsely populated and predominantly rural province; 90 of its 174 municipalities have populations of less than 200. The population of the entire province is only 280,000, with half residing in the capital city of Logroño.

Navajún is nestled in the southwestern corner of La Rioja some 50 road miles from Logroño. The village is located at an elevation of 3,000 feet near the headwaters of the Barranca de la Nava River in the sparsely vegetated foothills of the Sierra de Alcarama. Aguilar del Río Alhama, population 700 and the nearest town of any size, is located four miles to the east. The local trading center is the highway-junction and agricultural town of Cervera del Río Alhama, population 4,000 and eight miles to the east. Currently, Navajún has only 20 permanent residents. The town was once considerably larger, but during the 1950s, following the general trend in much of Spain, many Navajún residents migrated to the cities to seek jobs. In much



Figure 2. Navajún.

mineralogical literature, locality information for Navajún pyrite often includes the name "Logroño." This is somewhat misleading, but its use persists for two reasons. Prior to the 1930s, what is now the province of La Rioja was known generally as "Logroño." Also, because Logroño is the only major city in La Rioja, many locality citations continue to use its name as a familiar, albeit general, geographic reference.

The existence of pyrite crystals at Navajún and at several other geologically related occurrences in the region has been known since antiquity. Archaeologists have recovered Navajún pyrite, in the form of individual cubes and as mosaics containing hundreds of inlaid crystals, from regional cultural sites dating back more than 1,000 years. In more recent times, local shepherds had another use for Navajún pyrite crystals—as sling projectiles to drive away the wolves that threatened their flocks. Considering the relatively high density (specific gravity about 5.0) and the sharp edges and corner points of these pyrite cubes, the larger crystals certainly would have made formidable projectiles.

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Although Navajún pyrite first appeared in mineralogical literature in 1910, its source would remain only a mineralogical curiosity for another 50 years. The relatively few collectors who visited the site did little more than gather loose crystals from the surface. Then in 1960, a team of expert mineral collectors from France arrived at Navajún to conduct several weeks of extensive digging that resulted in the recovery of the largest and best collection of Navajún pyrite yet assembled. The work of these French collectors came to the attention of don Pedro Ansorena Garret, superintendent of the Las Manfores zinc mine at Aliva in Cantabria near Spain's northern coast, who was visiting the Navajún area to investigate a reported galena occurrence. Having marketed many well-developed, transparent, red sphalerite crystals collected in the Las Manfores Mine, Ansorena was well aware of the collector value of fine mineral specimens.

After the French collectors departed, Ansorena visited Navajún to investigate their diggings. He found the site about a mile northwest of Navajún and noted with interest that the pyrite originated in several distinct sedimentary strata. Unlike the weathered pyrite Ansorena found lying on the surface, the crystals that he was able to extract from the protective matrix rock were lustrous and brilliant. Not only were they the most perfectly formed pyrite crystals he had ever seen, they were abundant within the matrix rock. As a mining man, Ansorena knew that the pyrite had no value as ore—but he also realized that these particular crystals had considerable commercial potential on the specimen market. Accordingly, Ansorena acquired the mining rights to the site, which he named Amplicación de Victoria ("Extension of Victory").

Ansorena invited several geologists to the site, now known as the Victoria Mine, who explained the likely origin of the pyrite deposit. Near the end of the Jurassic Period some 140 million years ago, what is now the province of La Rioja was a warm, coastal flood plain that supported a profusion of vegetation and animal life, the latter including many dinosaurs. Over millions of years, sediments accumulated into thick formations consisting of alternating strata of sandstone, limestone, and marlstone (a general term for calcareous clay), which form the bedrock in most of La Rioja today.

When originally deposited, certain of these sedimentary strata contained large amounts of sulfur-rich organic material. After eventual burial to a depth of nearly 2,500 feet, these strata were subjected to increased pressures and temperatures of about 400 degrees F. The resulting, low-grade metamorphism created two things. The first was a marlstone consisting of roughly 50 percent clay, 15 percent calcite (calcium carbonate, CaCO_3), and varying amounts of other sediments. The second was an ideal set of conditions within the metamorphosing marlstone for the formation of remarkably well-developed pyrite crystals. With an abundant supply of both iron and sulfur—iron from the inorganic sediments and sulfur from the organic remains—these pyrite crystals grew in profusion. Their exceptional development and uniform dissemination throughout the marlstone matrix indicates that low-grade metamorphism had produced a somewhat homogenous mix of the marlstone components, and that the metamorphism was followed by a long, slow period of cooling that optimized crystal development.

Millions of years later, tectonic uplifting raised much of this region to its current elevation and created the low mountain ranges seen in La Rioja today. The uplifting exposed the Jurassic sedimentary formations to surface erosion, which eventually exposed the pyrite-rich marlstone strata, outcrops of which were discovered in prehistoric times. The Navajún deposit consists of three steeply inclined marlstone strata between six and ten feet thick, varying somewhat in pyrite crystal morphology and degree of oxidation. Navajún pyrite occurs both as isolated, single crystals and as groups of intergrown crystals, both of which are characterized by near-perfect development. During the low-grade metamorphism of the marlstone strata, tiny, evenly disseminated pyrite particles apparently acted as seeds for the slow growth of larger crystals. Even in crystal clusters, many individual crystals appear to have grown from common seed particles. The crystals range in size from a microscopic 0.05 microns (a micron is equal to a micrometer or one-millionth of a meter) to 7.5 inches, although those exceeding 2 inches in size are rare. The pyrite habit is almost exclusively cubic, with small octahedron faces appearing only rarely on the corners of the cubes.

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The extraordinary crystal development typical of Navajún pyrite is due in part to an unusually high degree of chemical purity. Navajún pyrite consists of more than 99 percent iron and sulfur; the minimal amount of impurities present, mostly nickel and cobalt with traces of silver and gold, is too little to modify the basic cubic structure. Among the few notable impurities in Navajún pyrite are small, dark, crystalline inclusions of chloritoid [basic iron magnesium manganese aluminum silicate, $(\text{Fe,Mg,Mn})_2\text{Al}_2\text{Si}_2\text{O}_{10}(\text{OH})_4$], which have been studied extensively to better understand the development of the pyrite crystals. Most Navajún pyrite also has smooth, mirror-like crystal faces devoid or nearly devoid of striations (the faint, parallel edge lines common to most forms of pyrite). This general absence of striations reflects optimum growth conditions that produced almost perfect crystal lattices. Because this combination of high chemical purity and near-perfect lattice structure provides a significantly higher degree of chemical stability, Navajún pyrite resists atmospheric oxidation to a considerably greater extent than does pyrite from other localities.

Pedro Ansorena finally began mining pyrite specimens in commercial quantities in the early 1970s. His miners manually removed large masses of pyrite-bearing marlstone from surface diggings, broke them into smaller pieces to find the pyrite crystals, then prepared marketable specimens by removing certain portions of the matrix rock to expose the crystals in relief. Collectors snapped up the first crystals as quickly as they reached Spanish and other European specimen markets. In 1976, a mention of Navajún pyrite in *The Mineralogical Record* attracted worldwide attention. More acclaim came in 1984, when the National Museum of Natural History (Smithsonian Institution) in Washington D.C. added a stunning, eight-inch-tall cluster of ten individual, near-perfect, cubic pyrite crystals to its mineral collection. By then, researchers in the United States and Europe had begun buying Navajún pyrite which, because of its high chemical purity, near-perfect crystallography, and smooth, mirror-like surfaces, was the best material available for studying pyrite oxidation.

In 1990, with the surface diggings about exhausted, Ansorena began underground mining. Although the underground workings were limited in extent, the rock proved very unstable; Ansorena was caught in a rockfall, partially buried, and suffered two broken legs. From that point on, timbers were installed for ground support and safety. Underground mining increased production to make possible spectacular displays of Navajún pyrite that garnered much attention at Spain's two biggest gem-and-mineral shows at Bilbao and Barcelona. In the United States in 1996, Navajún pyrite and descriptions of its source received so much interest at the Tucson show that Ansorena's son, Pedro Ansorena Conde, soon afterwards opened the mine to fee-collecting. Coincidentally, we featured their pyrite as our first featured mineral in March 1996!



Figure 3 Underground workings at Victoria Mine.

Today, the Victoria Mine is owned by Piritas de Navajún, S. L. (*Sociedad Limitada*, "Limited Corporation"), which is headed by Pedro Ansorena Conde, José Chaver Atanasia, and Néstor López Ogalde. Mechanized equipment is used to move barren ground to access the pyrite-containing strata, two of which

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are currently being mined and the third held in reserve. Because explosives could shatter the brittle pyrite crystals, the pyrite-rich marlstone itself is mined manually in large blocks with the use of picks. Miners now extract about 30-35 tons of pyrite-rich marlstone each year. The large blocks of newly mined marlstone are inspected for partially exposed pyrite crystals and broken down accordingly with drills, chisels, and hammers. Matrix rock is then removed physically or chemically, the latter with the use of acid baths, either to expose the pyrite crystals in high relief or to extract them completely from the matrix. Prepared specimens of Navajún pyrite include both crystals-in-matrix and "free" crystals. Navajún pyrite has also recently appeared in jewelry, usually as pendants with sharp, bright, single crystals wrapped in silver wire.

The Victoria Mine welcomes visitors who wish to see the site or collect their own crystals. Visitors have included earth-science professionals, student groups, gem-and-mineral club members, individual mineral collectors, and even tourists who come across the crystals in area shops. Nearby, late-Jurassic dinosaur-track sites are an added attraction. Comfortable accommodations, good restaurants, and fine wines are available in the nearby town of Cervera del Río Alhama. Feel free to ask us for contact information if you would like to plan a trip to this extraordinary location.

The success in making the Victoria Mine in Navajún a commercial source of fine pyrite specimens and a visitor attraction has recently encouraged activity at other area pyrite outcrops both in La Rioja and in the adjacent province of Soria. Although these other outcrops are geologically related to the Navajún deposit, their pyrite generally lacks the chemical purity and degree of crystal perfection of Navajún crystals.

A few years after we started our Mineral of the Month Club, we realized that we had made a tactical error by featuring several exceptional minerals in our first year when we had so few members: no doubt the few members we had then really appreciated the Navajún pyrite, Indian cavanite, Tasmanian crocoite, etc., that we featured that year, but did this mean that we could never again feature these exceptional minerals? We decided it would be appropriate to feature common minerals such as pyrite, fluorite, apatite, and quartz more than once, since they are available from different localities in different colors and crystal habits, and have done so. Still, we wanted to feature these classic minerals from our early years, and finally hit on what seemed to us the perfect solution: we would feature them ten years after we did the first time, as a sort of tribute both to the desirability of the mineral and to the continuation of our Club. With this in mind, we plan to repeat some of the other mineral classics from our early years.

We began our Club in March 1996 for a couple of reasons. We had started selling at gem and mineral shows in 1995, after we sold our share of a business in a completely different field. Though suffering from major burnout, we wanted to remain self-employed, but without having to deal with employees, payroll taxes, the EPA, Workmen's Compensation insurance, and the like, and did not want to be tied down to a store front. (Those of you who have run small businesses perhaps can relate.)

At the same time, we had been developing a fascination with crystals and minerals by visiting mall stores like Natural Wonders and the Nature Store, and attended our first gem show in 1994. Completely enthralled, we leapt into the business, signing up for shows for 1995, opening a small display at our previous home in Quartz Hill, California, and visiting Tucson for the first time in 1995. We still remember the excitement of seeing all those amazing rocks, minerals, and gems and discussing the possibilities!

During 1995, we were most fortunate to get in as last minute replacements to some of the best shows in California, and even traveled to Denver for the big show there. In spring 1995, we also realized that, if we didn't mind driving longer distances to shows, we could live almost anywhere, (and since we had fallen in love with Cambria on a business trip here in 1991,) we were blessed to be able to move here in August 1995. But a lot of the shows were disappointing as far as sales were concerned: at times, the

March 2006 Mineral of the Month: Pyrite

high costs of the show plus related travel expenses were greater than what we sold; besides, traveling almost every week took its toll, and of course we had a 13-year-old son who was in school. We needed to cut down on our travel and come up with a way to offer these fascinating minerals from home, and it was from such needs that we came up with the idea in late 1995 for a Mineral of the Month Club.

First we sought feedback from others in the industry, learning of the Filer's version of the Club, which ran from 1972 to 1982, the year we were married. We called them and asked for suggestions and advice, and they pointed us to several good sources of material, also warning us that it would be a lot of work! We placed an advertisement for our Club in the February 1996 Lapidary Journal (see Figure 4), and waited for the calls and letters to come rushing in, though of course they didn't. We were selling at the Inn Suites Hotel in 1996 when our first member called and joined, while a few others joined at the Inn Suites and at our March shows, so we featured our first mineral back in March 1996, and sent specimens to 11 Club members!

JOIN THE MINERAL OF THE MONTH CLUB!

Would you like to receive a different and fascinating Mineral Specimen each month from U.S. and foreign localities delivered right to your door?

Join the Mineral of the Month Club now and you'll receive:

- One excellent quality Mineral, Crystal or Fossil each month, 1/2" to 3" in size.
- A full page write-up detailing its composition and formation, collecting localities, technological uses and other interesting facts. Learn mineralogy as your collection grows each month!
- The 160 page paperback book *Rocks and Minerals* with 100's of illustrations to each new member.

<p>For more information, or to become a member by Visa/Mastercard, call 1-805-927-2223 or write to:</p> <p style="text-align: center;">Mineral of the Month Club P.O. Box 1224 Dept LJ Cambria, CA 93428</p>	<p>Club Membership Prices:</p> <table border="0"> <tr> <td>3 month trial</td> <td>\$19.00</td> </tr> <tr> <td>6 month trial</td> <td>\$38.00</td> </tr> <tr> <td>1 full year</td> <td>\$69.00</td> </tr> </table>	3 month trial	\$19.00	6 month trial	\$38.00	1 full year	\$69.00	<p>Satisfaction Guaranteed! Return any specimen for refund or exchange if not happy or cancel at any time for pro-rated refund.</p> <p><small>Club administered by WonderWorks Richard & Cheryl Sittinger, proprietors</small></p>
3 month trial	\$19.00							
6 month trial	\$38.00							
1 full year	\$69.00							

Figure 4 Our first ad in the February 1996 Lapidary Journal. The price listed was for our "Basic Membership," which later became our "Junior Membership."

Our Club grew steadily as the years passed, and we gained a large influx of new members when we advertised in the now-defunct *Earth* magazine in 1997, at the suggestion of one of our suppliers. Many of those who joined from that advertisement are still with us! For more details on the growth of our Club and its history, check out the article from the August 2003 *Rock & Gem* that is reprinted on our web site at <http://mineralofthemonthclub.org/R&Gpage1.htm>. We plan to continue our Mineral of the Month Club for as long as our health and our circumstances allow, for many more decades if possible! One of the greatest benefits of the Club to us, apart from helping us make a living doing something we love, has been getting to know members over the course of the months and years, so that we have become friends with many of you—a much appreciated and totally unanticipated outcome!

Two major benefits for Club members have to do with our need for large quantities of nice specimens. First, we regularly feature new finds that may be abundant for a time, and then hard to obtain, such as in October 1997 when we featured Sweet Home rhodochrosite. Since then, the mine has been closed and the remaining material is costly. Also, we often obtain specimens that normally cost much more than the \$22.50 we charge for our Deluxe membership. Looking back over the last ten years, we are very happy we carried our original idea to fruition, and sincerely thanks every one of you who made it a success! And most of all, we look back on ten years of marvelous minerals, with, we hope, many more to come!

References: *Manual of Mineralogy*, Klein and Hurlbut, John Wiley & Sons; *Dana's New Mineralogy*, Eighth Edition; *Encyclopedia of Minerals*, Second Edition, Roberts, et al, Van Nostrand Reinhold Company; *2004 Glossary of Mineralogical Species*, J. A. Mandarino and Malcolm E. Back, The Mineralogical Record, Inc.; *Mineralogy*, John Sinkankas, Van Nostrand Reinhold Company; *Rocks and Minerals*, Joel Arem, Geoscience Press; *Gemstone and Mineral Data Book*, John Sinkankas, Geoscience Press; *Gemstones of the World*, Walter Schumann, Sterling Publishing Company; "Pyrite Crystals from Soria and La Rioja Provinces, Spain," Miguel Calvo and Emelia Sevillano, *The Mineralogical Record*, November-December 1989; "Pyrite," Bob Jones, *Rock & Gem*, October 1994; "Pretty, Problematic Pyrite," Steve Voynick, *Rock & Gem*, May 1998; "What's New in Minerals," Wendell Wilson, *The Mineralogical Record*, March-April 1976; "The Crystal Forms of Pyrite," R. I. Gait, *The Mineralogical Record*, July-August 1978; "Chloritoid Inclusions in Pyrite from Navajún, Spain," K. Lodders, G. Klingelhöfer, and D. T. Kremser, *The Canadian Mineralogist*, Vol. 36, 1998.