

June 2010 Mineral of the Month: Pyrite Concretion

Nature is certainly full of surprises! When you first glimpsed this oddly shaped pyrite from a new find in China, you may have wondered, How could this occur? We invite you to read on and discover how!

OVERVIEW

PHYSICAL PROPERTIES

Chemistry: FeS₂ 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 individual or clustered cubes and pyritohedra (pentagondodecahedra or dodecahedra with pentagonal faces); less commonly as octahedra; often twinned and striated; also granular and in globular, radiating, stalactitic, fibrous, mammillary, concretionary and nodular forms.

Color: Pale brass-yellow or yellowish-gray to gray; may tarnish to yellow-brown; occasionally 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; and ability to spark on impact with metal and to become weakly magnetic upon heating.

Pyrite can have the general appearance of native gold, but is brittle and much harder; it can also be confused with chalcopyrite [copper iron sulfide, CuFeS₂] and other metal sulfides.

Dana Classification Number: 2.12.1.1.1

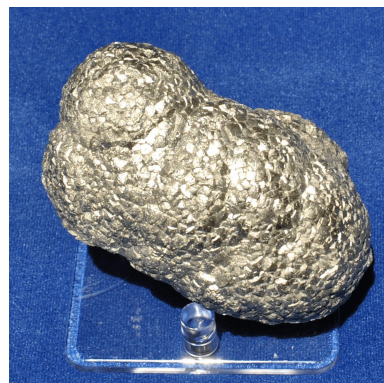


Figure 1. Pyrite concretion.

NAME The word “pyrite,” pronounced “PIE-rite,” is derived from the Greek *pyr*, “fire,” and means “fire mineral,” an allusion to its ability to spark when struck with metal. The obsolete term “pyrites” refers to similar-appearing metal sulfides and the sparking flints of early firearms. Pyrite’s many alternative names include “iron pyrite,” “yellow pyrite,” “fool’s gold,” “schwefelkies,” “kaltschedan,” “leber pyrites,” “lebereisener,” “leberschlag,” “marchasita,” “sideropyrite,” and “vitriolkies.” Other names stem from elemental impurities and unusual habits. The cobalt- and nickel-rich varieties are respectively known as “cobaltoan pyrite” and “nickelian pyrite.” “Iron crosses” and “iron-cross twins” are cross-shaped, penetration twins of pyrite pyritohedra; flat, disc-like, radiating forms are called “pyrite suns”; and spherical or ovoidal forms like ours this month are known as “concretions.” In European mineralogical literature, pyrite appears as *pyrit*, *pirita*, and *pyrita*.

COMPOSITION: When you learned we were featuring pyrite this month, did you yawn and say “Pyrite? Not again! I’ve seen it all!” Hopefully not, but if you did, examining your specimen and reading this write-up will no doubt change your thinking! Abundant minerals such as pyrite, quartz, and fluorite may seem common, but can grow in such a variety of forms and habits that they never cease to amaze and delight us! And when we consider how and why they form in these habits, our appreciation is greatly heightened.

June 2010 Mineral of the Month: Pyrite Concretion

The chemical formula FeS_2 shows that pyrite contains iron (Fe) and sulfur (S). The molecular weight of pyrite consists of 46.55 percent iron and 53.45 percent sulfur. Pyrite is one of some 350 members of the sulfide class of minerals, in which sulfur is combined with one or more metals. Most sulfides are dense, brittle, generally dark in color, and metallic in luster. As the most abundant sulfide, pyrite is associated with many other minerals and occurs in all mineralogical environments, from pegmatites and hydrothermal vein deposits to carbonatites (low-silica, carbonate-rich igneous rocks), regional metamorphic rocks, skarns (metamorphic deposits of calc-silicate rocks), and sedimentary rocks. As an idiochromatic or “self-colored” mineral, pyrite’s pale, brass-yellow color is caused by its essential elemental components and the nature of its crystal structure.

COLLECTING LOCALITIES: Pyrite is an abundant, widely distributed mineral with countless collecting localities. Spain and Peru produce superb pyrite crystals, as do Italy, Greece, Brazil, Germany, and China. In the United States, fine crystals are found in Missouri, Colorado, Utah, and Ohio. Pyrite concretions are found in several coal mines in China. In the United States, pyrite concretions occur in Kansas, Illinois, and Wisconsin.

HISTORY, LORE, & USES: Collected since antiquity, pyrite has been used as amulets, in jewelry, and for display purposes. It achieved great popularity as a gemstone in the Victorian era of the late 1800s, when hundreds of tiny, glittering, faceted pyrite gems were mounted in elaborate, sterling-silver settings. Because it sparks when struck sharply with hard metal, pyrite has long been used as a “fire-starter.” Pyrite once served as an ore of sulfur and a minor ore of iron; it currently has only limited use as a coloring agent in the manufacture of amber glass. Pyrite is a model in the study of mineral-crystal structure and pyrite-oxidation chemistry, the latter to help understand its role in mine-drainage pollution. Metaphysical practitioners believe that pyrite supplements physical energy with the energy of the sun, increases stamina, stimulates the intellect, helps transform thought into intelligent action, and shields wearers from negativity and physical risk.

ABOUT OUR SPECIMENS: Our specimens were collected at the Hengyang Baifang coal mines near the city of Hengyang in Hengyang County, Hengyang Prefecture, Hunan Province, China. These concretions formed early in the coalification process during the Carboniferous Period of the mid-Paleozoic Era 360-290 million years ago, when heat and pressure expelled sulfur from peat and low-grade coal. This sulfur reacted with iron in adjacent layers of unconsolidated sediments to precipitate as tiny, single, pyrite crystals, which acted as seed crystals to promote additional pyrite precipitation. Because the surrounding sediments that would later lithify into shale were still unconsolidated, the growing pyrite concretions displaced the sediments as they developed radiating patterns of long, distorted, interlocked crystals and grew into spherical and ovoidal concretions. In 2009, coal miners discovered these pyrite concretions between laminated shale layers. These specimens were widely acclaimed by collectors when they made their market debut at the 2010 Tucson (Arizona) Gem & Mineral Show.

10 YEARS AGO IN OUR CLUB: Aragonite, Tazouta Mine, Sefrou, Sefrou Province, Morocco. June 2000 was the first of three times that we have featured this unique mineral over the years, from three different localities—first Morocco, probably the most prolific and best-known aragonite locality; next, in January 2004, when we sent Club members clusters of small, pointed, needle-like aragonite crystals from the Northern Lights Mine, Mineral County, Nevada; and finally, last July, when we sent aragonite in a crystal habit similar to the Moroccan specimens, but with an unusual purple tinge, from a collecting spot at the Retamal Ravine, near the village of Enguinados, Cuenca Province, Castilla-La Mancha, Spain. We still have nice specimens from these latter two localities if you’d like to add one to your collection! Let us know if you would like details.

June 2010 Mineral of the Month: Pyrite Concretion

COMPREHENSIVE WRITE-UP

COMPOSITION

The chemical formula FeS_2 shows that pyrite contains two elements: iron (Fe) and sulfur (S). Pyrite's molecular weight consists of 46.55 percent iron and 53.45 percent sulfur. Like all molecules, those of pyrite consist of cations (positively charged ions) and anions (negatively charged ions). The simple pyrite anion contains a single iron ion (ferrous, Fe^{2+}) with a +2 charge. Two sulfur atoms 2S^{2-} with a combined -2 charge make up the anion. Two covalently bonded, divalent sulfur atoms might appear to have a collective -4 charge, but in pyrite and certain other metal disulfides, these two sulfur ions behave electrically as a polyatomic ion with a covalent, elemental bond. This elemental bond gives the double sulfur ion a single charge of -2 to balance the +2 cationic charge of the ferrous ion, thus providing the pyrite molecule with electrical stability. Cationic substitution is common in pyrite when iron is replaced by such metals as cobalt, nickel, manganese, silver, and gold, which cause variations in hardness, density, and color. Because cobalt substitutes so readily for iron and vice versa, pyrite forms a solid-solution series with catterite (cobalt disulfide, CoS_2), the intermediate grades of which are called cobaltoan pyrite.

Pyrite is one of some 350 sulfide-class minerals, in which sulfur is combined with one or more metals. Most sulfides are dense, brittle, generally dark in color, and metallic in luster. As the most abundant sulfide, pyrite is associated with hundreds of other minerals 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 of calc-silicate rocks), and sedimentary rocks. The best-developed pyrite crystals occur in hydrothermal vein and replacement deposits in association with quartz [silicon dioxide, SiO_2], chalcopyrite [copper iron sulfide, CuFeS_2], galena [lead sulfide, PbS], and sphalerite [zinc sulfide, ZnS].

As an idiochromatic or "self-colored" mineral, pyrite's pale, brass-yellow color is due to its essential elemental components and the nature of its crystal structure. Except in thin section, pyrite is opaque and reflects, but does not transmit, light. Because sulfur ions do not completely shield the iron ions within the crystal lattice, pyrite has a prominent metallic luster. It also exhibits substantial metallic bonding, in which iron ions share a pool of free-moving electrons. The manner in which these free electrons interact with light accounts for pyrite's opacity, color, and metallic luster. When exposed to incident light, the free electrons on the surface of pyrite become energized. To return to their normal levels, they release excess energy in wavelengths that we perceive as brassy yellow.

Within the pyrite lattice, iron ions occupy the eight corners of a cube and the middle of its six faces, a configuration that causes pyrite to crystallize in the cubic system (for details on pyrite crystallography, see "The Many Forms of Pyrite"). A pair of covalently bonded sulfur atoms is positioned midway along each edge. This inherently rigid cubic structure together with strong, covalent, iron-sulfur bonding explains pyrite's considerable hardness (Mohs 6.0-6.5). Superficially, pyrite resembles a number of other sulfides. Its brassy color and metallic luster are similar that of chalcopyrite, CuFeS_2 , cobaltite [cobalt sulfarsenide, $(\text{Co,Fe})\text{AsS}$], and catterite [cobalt disulfide CoS_2]. Pyrite closely resembles marcasite [iron disulfide, FeS_2] in density, hardness, and metallic luster. Marcasite is a pyrite polymorph—a mineral with an identical chemistry, but a different crystal structure (orthorhombic). Most pyrite crystals exhibit diagnostic striations formed by the twinning of cubic and pyritohedral crystals with the subsequent convergence or juxtaposition of two or more faces. During crystal growth, these faces can become truncated or "overgrown" by other faces to leave visible edges or stria that represent repetitively juxtaposing internal pyritohedron edges on cube faces. Pyrite striations are usually parallel and perpendicular to those on adjacent faces, and occasionally triangular or crossed.

June 2010 Mineral of the Month: Pyrite Concretion

Although strong, covalent, iron-sulfur bonding imparts considerable hardness to pyrite, relatively weak, covalent, sulfur-sulfur bonding creates a chemical instability, causing it to oxidize slowly in water and atmospheric oxygen to produce iron ions and sulfuric acid. Pyrite oxidation creates gossan (a deposit of limonite, a variable mixture of iron oxides and hydroxides) that overlies lower bodies of unoxidized pyrite. In highly mineralized areas, the sulfuric acid resulting from pyrite oxidation impacts the environment by acidifying surface water and dissolving iron and other metals. As natural dilution decreases this acidity, the iron precipitates out of solution as “yellow boy,” an iron hydroxide that stains creek banks and beds a characteristic, bright yellow-orange color. Metal mining and coal mining accelerate this oxidation by exposing large volumes of pyrite to atmospheric oxygen and water, thus creating the environmental problem of mine-drainage pollution.

The Dana classification number 2.12.1.1 identifies pyrite as a sulfide (2). Pyrite is 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. Pyrite is assigned to the pyrite group (1) as the first (1) of 19 members, all of which share the same isometric crystal structure and similar chemistries, but vary widely in physical properties. Pyrite is the group’s only abundant and familiar mineral. Other pyrite-group minerals include vaesite [nickel disulfide, NiS_2], catterite [cobalt disulfide, CoS_2], villamaninite [copper disulfide, CuS_2], and hauerite [manganese disulfide, MnS_2].

COLLECTING LOCALITIES

First, let’s list worldwide localities where fascinating concretions of pyrite like ours occur. Our pyrite-concretion specimens were collected at the Hengyang Baifang coal mines near the city of Hengyang in Hengyang County, Hengyang Prefecture, Hunan Province, China. Other Chinese sources of pyrite concretions include the Maoniuping rare-earth-element deposit at Xuebaoding, Mianning County, Liangshan Prefecture, Sichuan Province; and the Dongchuan district coal mines at Guangxi, Kunming Prefecture, Yunnan Province. Pyrite concretions are also found at Lausanne in the Lausanne District, Vaud, Switzerland. Septarian nodules coated with iridescent pyrite crystals occur at Ulyanovsk, Ulyanovsk Oblast, Russia. Canadian specimens occur at Tea Cove on the Port au Pont Peninsula near Stephenville on the island of Newfoundland in the province of Newfoundland and Labrador. In the United States, Illinois has two notable sources of pyrite concretions: the Gary Quarry near Hamilton, Hancock County, and the Sparta coal mines in Randolph County. In Kansas, pyrite concretions are collected at outcrops of the Smoky Hill Chalk member of the Niobrara Formation in Gove County; in Wisconsin, specimens are found at the Warren Peter Quarry near Burlington in Racine County.

Non-concretionary pyrite comes from many outstanding localities as well. Fine, nearly-symmetrical cubic pyrite crystals come from Navajún, in La Rioja, Spain. Other noted Spanish sources are the Río Tinto mines at Huelva and the metal-sulfide mines west of Seville, both in Andalusia. Pyrite pyritohedrons are collected in Peru at the Huanzalá Mine, Dos de Mayo Province, Huanuco Department; and in the Cerro de Pasco district, Alcides Carrión Province, Pasco Department. Sharp, cubic pyrite crystals are found at Rio Marina, Elba, Italy. In England, pyrite occurs in the Callington mines in Cornwall and at Nenthead, Cumbria. German sources include the Neustädte mines in the Schneeberg District of Saxony. Large pyrite cubes are found at the Cassandra Mine in Chalkadiki Prefecture, Macedonia Department, Greece. Fine Brazilian pyrite comes from the Galiléia pegmatite mines in Governador Valadares, and from the Conselheiro Pena mines in Minas Gerais. Among Bolivia’s sources are the Atocha-Quechisla district mines in Sud Chichas Province, Potosí Department; and the Ciudad Oruro mines in Cercado Province, Oruro Department. Australian localities include the New England district mines in New South Wales and the Golden Mile gold mine at Kalgoorlie, Western Australia. Among Canada’s sources are the Alberni, Atlin, Liard, and Kamloops districts in British Columbia; and the Algoma and Cochrane districts in Ontario.

June 2010 Mineral of the Month: Pyrite Concretion

Notable sources in the United States include the American Mine at Bingham Canyon and the silver-lead mines at Park City, both in Utah. Colorado specimens come from the Leadville, Gilman, Alma, Silverton, Ouray, Rico, and Telluride districts. Fine cubes and dodecahedra are found at the Huff Quarry at Huntsville, Ohio, while distorted octahedra come from Pennsylvania's French Creek Mine. The Tri-State zinc-lead mining district in southwestern Missouri yields large, well-developed pyrite cubes.

JEWELRY & DECORATIVE USES

Pyrite has been used in jewelry since antiquity—the ancient Greeks in particular produced pyrite jewelry. Its greatest popularity as a gemstone during the Victorian era of the late 19th century, when faceted, polished pyrite gems were set into pendants, brooches, necklaces, and bracelets. An especially popular Victorian jewelry style featured hundreds of small, glittering, pyrite gems in 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. This style is still sold today, and is called “Marcasite Jewelry,” although the actual crystals used are of the more stable pyrite, rather than its less-stable polymorph marcasite.

Pyrite is still worn in jewelry today, usually as polished beads in necklaces, bracelets, and dangling earrings. Also popular is drusy “Rainbow Pyrite” (Our Mineral of the Month for July 2007). These are natural coatings of tiny, highly iridescent pyrite crystals on nodules that are fashioned into cabochons and mounted in pendants and brooches to striking effect. Pyrite is sometimes cut into small “rosettes” for use as edging or “framing” stones in decorative objects. Pyrite crystals, both as individual and composite specimens, continue to be popular as paperweights and display pieces.

Because of its abundance, affordability, and variety of crystal habits, pyrite is one of the most widely collected of all minerals. Pyrite specimens have an unusually broad price range; small crystal clusters can cost only a few dollars, while fine cabinet specimens sell for thousands of dollars. Collectors have amassed extensive, specialized pyrite collections variously based on localities, crystal habits, mineralogical associations, and even unusual varieties such as concretions and nodules.

HISTORY & LORE

The ancient Chinese symbol for Earth, a golden cube, was patterned after cubic pyrite crystals. Archaeologists have recovered crystals and amulets of pyrite from 4,000-year-old Egyptian tombs and classical Greek and Roman ruins. The first-known, written reference to pyrite is in the treatise *Peri Lithon* (*On Stones*), in which Greek philosopher and naturalist Theophrastus (ca. 372-ca. 287 B.C.) describes tiny grains of pyrite glittering in the blue gemstone lapis lazuli. The ancestors of the Incas on South America's western coast polished the smooth faces of large pyrite cubes into mirrors that they believed offered a glimpse of one's soul. The healers and shamans of several North American native cultures carried pyrite crystals as “medicine” and may have used their reflective faces in their attempts to conjure shamanistic visions.

Physicians in medieval Europe treated throat and circulatory ailments with elixirs containing finely ground pyrite. Intrigued by its gold-like color, European alchemists also attempted to transmute pyrite into gold. Although their experiments failed, they developed a number of practical uses for pyrite. By 1400 A.D., alchemists had learned to roast ground pyrite over charcoal fires, driving off the sulfur as sulfur dioxide (SO₂) and dissolving this gas in water to produce sulfuric acid (H₂SO₄). Sulfuric acid was an important reagent during the centuries of alchemistic experimentation that eventually led to the emergence of modern chemistry. Pyrite's ability to spark when struck with iron made it valuable as a “fire-starter.” The earliest European wheel-lock firearms employed fragments of pyrite crystals as a sparking material.

June 2010 Mineral of the Month: Pyrite Concretion

Sparking occurs when a sharp impact upon a tiny surface area of a pyrite crystal creates sufficient mechanical pressure to break its covalent, sulfur-sulfur bonds, resulting in the instantaneous release of thermal and light energy in the form of sparks. In the early 1700s, pyrite was among the first minerals that European chemists qualitatively identified by its elemental components. A century later, pyrite became a chemical model that helped to determine the elemental compositions of other metal sulfides. Until that time, all metal sulfides had been collectively known as “pyrites”; after that, pyrite was called “iron pyrite” or “yellow pyrite” to distinguish it from “copper pyrite” or chalcopyrite [copper iron sulfide, CuFeS_2]. The terms “iron pyrite” and “yellow pyrite” are still in limited use today.

Pyrite occasionally served as an ore of iron in regions lacking the more abundant iron-oxide ores like hematite. Pyrite’s greatest commercial value, however, was as a source of sulfur. By the mid-1800s, pyrite was being mined for its sulfur content in regions without native-sulfur deposits. During World War I, when sulfur was in high demand for the manufacture of vulcanized rubber, fertilizers, medicines, and explosives, the United States, Great Britain, and Germany all declared pyrite a strategic mineral. The United States then had more than two dozen primary pyrite mines and also recovered pyrite as a by-product of base- and precious-metal mining.

Modern metaphysical practitioners believe that pyrite supplements physical energy with the energy of the sun, increases stamina, stimulates the intellect, helps transform thought into intelligent action, and protects its wearers from negativity and physical risks.

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 cluster of sharp-edged, brilliant pyrite crystals from Navajún, Spain, was featured on that nation’s 29-peseta stamp in 1994.

TECHNOLOGICAL USES

Formerly an ore of sulfur and a minor ore of iron, pyrite is now used only in limited quantities as a coloring agent in the manufacture of amber-colored glass. Pyrite also serves as a model in the study of mineral-crystal structure and pyrite-oxidation chemistry, the latter to help predict the weathering qualities of pyrite-containing structural (building) stone such as granite and marble and understand the role of oxidation in mine-drainage pollution.

THE MANY FORMS OF PYRITE

Pyrite is a beautiful, abundant mineral with many interesting forms. In the past, we have featured several different pyrite forms, including clusters of octahedral crystals from the Huanzalá Mine in Dos de Mayo Province in Huanuco Department, Peru (October 2003); near-perfect cubes of pyrite from Navajún, La Rioja, Spain (March, 1996; March 2006); and “Rainbow Pyrite”—septarian nodules coated with iridescent pyrite crystals—from Ulyanovsk Oblast’ in Russia (July 2007). Pyrite is most familiar as well-developed, sharp-edged, cubic crystals. But as seen in this month’s specimens, pyrite also occurs in forms far different from its classic cubic crystals.

Pyrite crystallizes in the isometric (cubic) system, which is defined by three axes of equal length that intersect at the crystal center and are perpendicular to their opposing faces. This pyrite structure is analogous to that of galena [lead sulfide, PbS]. Both crystallize in the cubic system, but galena has much greater symmetry. “Symmetry” is defined as correspondence of size, shape, and position of parts on

June 2010 Mineral of the Month: Pyrite Concretion

opposite parts of a median plane. The predominant habit of galena is the simple cube; it occurs only occasionally as octahedrons. On the other hand, pyrite occurs not just in cubes, but a large number of modified cubic habits including 4-faced tetrahedrons, 8-faced octahedrons, 12-faced dodecahedrons, and 24-faced cubic trapezohedrons. Because crystals can assume any of these forms alone or in combination, pyrite exhibits an unusually large number of habits. The dodecahedral habit alone has four variations 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, a form common to pyrite, are termed “pyritohedrons.” The difference between galena and pyrite is in structure. Galena has a single sulfur atom, which results in simple, four-fold symmetry. But the double-sulfur atom in pyrite disrupts this simple symmetry, enabling pyrite to assume many different crystal habits. Development of pyrite crystals demands free space for unrestricted crystal growth. Accordingly, pyrite (and most other minerals) achieves its highest development in hydrothermal-vein and replacement-type deposits. Vein deposits form when mineral-rich, hydrothermal fluids flow through fissures or voids; replacement deposits are created when mineral-rich, hydrothermal solutions dissolve carbonate rocks to create their own voids.

But the absence or restriction of growth space can create radically different forms of pyrite. In the absence of growth space in metamorphic and most igneous environments, pyrite forms tiny, individual grains or granular bodies consisting of aggregates of grains. Although these grains have pyrite’s characteristic, internal cubic structure, they have little or no recognizable external, cubic shape. Other forms of pyrite develop because iron and sulfur ions are readily soluble even in weakly acidic, aqueous solutions. This enables circulating groundwater to precipitate pyrite in globular, mammillary, fibrous, and even stalactitic external forms, all of which seem to belie pyrite’s basic cubic nature.

“Pyrite Concretions” and “Pyrite Suns” are two very unusual forms of pyrite that develop in sedimentary environments where growth space is restricted, and here is how. Both iron and sulfur are present in many sedimentary environments, iron as a common component of inorganic sediments, and sulfur as a significant component of organic remains. Sulfur is therefore especially common in and near coal-shale deposits that form from massive amounts of vegetal matter. As a result, pyrite sometimes occurs within coal-shale deposits as spherical and flattened concretions and nodules.

Concretions, a word derived from the Latin con, “together,” and cresco, “to grow,” are volumes of sedimentary rock in which mineral precipitates displace surrounding sediments or fill the pores between sediment grains. Concretions can be spherical, ovoidal (egg-like), elongated, or irregular in shape and can range in size from microscopic to five feet in diameter. They form within sediment layers soon after deposition and usually, but not always, before the sediments have lithified. Concretions, which are most common in such sedimentary rocks as shale, siltstone, and sandstone, form from mineral precipitation around a nucleus. Nodules (from the Latin nodus or “knot”) are a specific type of concretion and are generally similar in appearance to precipitate concretions. However, nodules form not by precipitation, but by the replacement of another mineral or a mass of organic material.

Pyrite concretions, as represented by our specimens, form when pyrite precipitates from solution around a carbon granule to form a tiny “seed” crystal (for details of this formation process, see “About Our Specimens”). The seed crystal promotes further precipitation that eventually creates a pyrite concretion. Because this process takes place in unconsolidated or loose sediments, the concretion assumes a generally spherical or ovoidal shape. The energy of the crystal-growth process is actually sufficient to displace the surrounding, loose sediments to create room for continued growth. However, restriction of the

June 2010 Mineral of the Month: Pyrite Concretion

growth environment prevents the development of pyrite's external cubic form. Instead, the pyrite crystals become elongated and interlocked, and grow with a radiating, internal structure to form the spherical or ovoidal shapes seen in our specimens.

A modified form of pyrite concretions are disklike, pyrite "suns," which are thin, flat, and round in shape. Like our specimens, these also form by precipitation in coal-shale environments, but only in strata that has already lithified (turned to rock). Because this hard rock prevents spherical growth, the pyrite concretions develop laterally along the direction of least resistance—the horizontal laminations within the coal-shale seams. The radically different shapes of spherical pyrite concretions and flat, pyrite "suns" are interesting variations to the many forms of pyrite.

ABOUT OUR SPECIMENS

As noted, our pyrite concretions were collected at the Hengyang Baifang coal mines near the city of Hengyang, Hengyang County, Hengyang Prefecture, Hunan Province, China. Located in south-central China, Hunan Province has a population of 70 million, yet is only the size of the state of Kansas. Hengyang City is located on the Xiang River 350 miles north-northwest of the coastal city of Hong Kong. Hengyang, population eight million, is not only a rapidly developing industrial city, but a major transportation hub for waterways, railroads, and highways and a manufacturing center for chemicals, mining and agricultural equipment, textiles, paper, and processed foods. Hengyang has a moist, subtropical climate and is located at an elevation of 700 feet amid low hills and broad valleys.

Nearby underground coal mines supply the dozens of small, coal-fired, power plants that satisfy Hengyang's enormous appetite for electricity. These mines exploit coal beds within the Ceshui Formation, a coal-shale formation that scientists believe was deposited during the Carboniferous Period of the mid-Paleozoic Era some 360-290 million years ago. Most major coal deposits are thought to have formed during the Carboniferous Period (the name comes from the Latin *carbo*, "coal," and *ferre*, "to bear"), when the warm, humid climates of developing continents promoted the growth of lush forests and tropical swamps, the remains of which would eventually form coal. During the Carboniferous Period, a warm, shallow sea covered the region that is now Hunan Province, and fluctuating sea levels periodically covered and uncovered a broad, densely vegetated, swampy shoreline. Over millions of years, the organic-rich sediments that were deposited along this shoreline eventually formed three coal-rich formations: the Wanshoushan, Simen, and Ceshui, and it is in these environments that pyrite concretions may form.

Is it possible that in the more than thirteen years our Club has been in operation that we have not discussed the origin of coal? It would seem so, and that now is high time! Coal is a sedimentary rock derived from vegetal remains that settle to swamp bottoms and lose oxygen and hydrogen to become a material consisting mainly of carbon. Layers of mud and sand accumulate over this decomposed plant matter, compressing and hardening the carbon-rich, organic material. Over millions of years, increasing heat and pressure transform these organic remains into peat, a dark-brown, compact, carbonaceous material with a high moisture content. Additional heat and pressure then transform peat into lignite, the lowest rank of coal. By losing its volatile components and additional moisture, and thus increasing its fixed-carbon content, lignite metamorphoses into the successively higher-ranked grades of coals: subbituminous, bituminous, and anthracite.

The Ceshui Formation of southern Hunan Province, the body of coal from which our specimens originated, consists of alternating layers of bituminous coal and shale. Shale is a dense, fine-grained, laminated sedimentary rock of marine origin. The Ceshui Formation was once buried at a depth of several thousand feet, but during the Tertiary Period some 40 million years ago, the Himalayan Orogeny

June 2010 Mineral of the Month: Pyrite Concretion

(mountain-building episode) uplifted south-central China by several thousand feet, accelerating the surface erosion that later exposed parts of the coal strata within the Ceshui Formation.

Coal has been mined from the Ceshui Formation near Hengyang for hundreds of years from open pits or small underground mines. As Hengyang grew into a major industrial city after World War II, coal production increased sharply to provide fuel for railroads, riverboats, power plants, and industrial and residential heating. A dozen state-controlled, underground coal mines were developed near Hengyang in the 1950s. The Hengyang mines make up only a small part China's booming coal-mining industry. China now mines 1.7 billion tons of coal annually, about 38 percent of world production. Several million workers are employed in some 10,000 Chinese coal mines.

Because many of these mines operate on shoestring budgets, are forced to meet unrealistic production quotas, and have no safety inspections, they are exceedingly dangerous. During the past two decades, about 5,000 miners have died *each year* in cave-ins, floods, and methane explosions in China's coal mines. The Hengyang mines are no exception; since 2000, more than 200 Hengyang miners have died in floods and methane explosions. The Chinese government is currently working to modernize its coal-mining industry by closing smaller, obsolescent underground mines and developing larger and safer surface mines. Obviously, this matter of safety deserves top priority, not only in China, but everywhere coal and other mining takes place. As a society, we need the raw materials the earth provides, but extracting them should only be done in a manner that is as safe as humanly possible and that takes into account the environmental effects of the mining operations. The current emphasis on bottom-line profitability often trumps these other, more important considerations, a situation that current governments do not seem to be able to correct.

While removing shale to access coal seams in 2009, Hengyang miners discovered numerous well-developed pyrite concretions between the laminated shale layers. How did they occur? These concretions had formed relatively early in the coalification process, when increasing heat and pressure was expelling sulfur from low-grade lignite coal. As this sulfur permeated through the adjacent, unconsolidated sediments, it contacted iron ions. Iron and sulfur have a mutual chemical affinity, and under the proper conditions of chemistry and temperature, their ions react to form pyrite. Initially, this reaction produced only tiny, single, pyrite crystals. These, however, acted as seed crystals that caused additional pyrite to precipitate out of solution and directly onto existing pyrite crystal faces. As new crystals grew outward from the original seed crystals, they formed concretions that displaced the loose sediments to make room for further growth. In this restricted growth environment, the pyrite could not develop its characteristic, external cubic shapes, and instead grew in radiating patterns of long, distorted, interlocked crystals into spherical or ovoidal concretions. Later, the surrounding, loose sediments lithified into shale. (For a detailed discussion of the unrestricted and restricted growth of pyrite crystals, see "The Many Forms of Pyrite.")

Initially, Hengyang miners collected these pyrite concretions only as oddities. Fortunately, the specimens soon came to the attention of mineral dealers in Changsha, the provincial capital 100 miles to the north. Familiar with the pyrite concretions from coal mines in neighboring provinces, these dealers immediately recognized the unusual size, brightness, attractive surface texture, and overall quality of the Hengyang concretions. Changsha dealers then visited Hengyang to "recruit" miners to collect the concretions in commercial quantities, and made them available to American wholesale buyers seeking out new finds in China. We first saw these last year—a huge pile of them sitting in a wholesaler's warehouse in Colorado, awaiting final cleaning and sorting. They were much larger, heavier, and more interestingly formed than other Chinese pyrite concretions we have seen the last few years in our travels. As you can imagine, we were immediately interested and made arrangements to pick up a lot this year in Tucson. We noticed other dealers were offering them this year in Tucson, where they were widely acclaimed by collectors.

June 2010 Mineral of the Month: Pyrite Concretion

When putting together our write-ups, we make every effort to provide precise locality information. This can sometimes be difficult, however, with Chinese specimens because of confusion in the transliteration of Chinese place names. Since 1892, Chinese words have been transliterated into English according to the Wade-Giles Romanization phonetic-spelling system. While this system sufficed for certain purposes, it was also confusing because of China's numerous language dialects and the varying interpretations of individual translators. This confusion becomes readily apparent in older world atlases that variously spell the Chinese capital of Beijing as "Beiping," "Pei-ching," "Pei-p'ing," "Peking," and "Jing." But since 1958, the Chinese government has encouraged the use of a standardized Romanization system called Pinyin (literally, "arrange sound"). Pinyin is now used by Chinese schools, the New China News Agency, the United States government, modern atlases, scholarly journals, and leading newspapers. This is the system we use whenever possible in our write-ups about Chinese mineral specimens. Unfortunately, many Chinese mineral dealers (and Chinese citizens in general) continue to use older spellings of place names, which do not correspond to Pinyin and are therefore not compatible with modern atlases. As an example, Hengyang, the source of our pyrite concretions, still appears on many maps in its older spellings of "Hengchou" and "Hengzhou." We will continue to rely on Pinyin for the transliteration of locality place names, both to provide the most precise locality information possible and for the convenience of our members who wish to pinpoint specimen localities on modern maps of China.

In examining your specimen, note first its unusual "heft" in the hand. Your specimen consists entirely of pyrite which, with its high specific gravity of 4.9-5.2, has almost twice the weight of an equal volume of quartz. The surface of your specimen resembles a mosaic made of thousands of tiny "tiles." Each "tile" is, in fact, the face of a radically modified, cubic pyrite crystal. The opposite end of each of these elongated pyrite crystals terminate near the original seed crystal at the center of the concretion. Notice also the parallel striations, a diagnostic feature of pyrite, that are visible on many crystal faces. The interior of your specimen consists of a radiating structure that formed as a result of the outward growth of the concretion. This is easily evident to Silver-level members, who received pieces that have been broken in half, revealing the radiating crystal form—amazing! (We have additional halves available if Gold- or Platinum-level members would like one.)

We also had fun examining the overall shapes of the larger specimens we offered to Platinum-level members! Our Email to them mentioned the unusual shapes we were seeing, along with the more common spheroidal and ovoidal concretions—muffin tops, acorns, snowmen, and even brains, among others! Some of the larger specimens seemed to have a second layering of pyrite sitting somewhat askew from the initial growth. Others were not completely formed, leaving strange looking gaps in the outer shell. A few showed two or more spheroidal growths that had grown into one another. Quite a variety to marvel at! Each one is fascinating in its own way. Your specimen is a fine example of an unusual form of pyrite—and a rare souvenir from a Chinese coal mine.

References: *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," Bob Jones, *Rock & Gem*, October 1994; "Pretty, Problematic Pyrite," Steve Voynick, *Rock & Gem*, May 1998; "The Crystal Forms of Pyrite," R. I. Gait, *The Mineralogical Record*, July-August 1978; "What's New in Minerals: Sixteenth Annual Rochester Academy of Science Mineralogical Symposium," George W. Robinson and Vandall T. King, *The Mineralogical Record*, September-October 1989; "Rock Chips: Are 'Free' Concretions and Geodes Cobblestones?" R. V. Dietrich, *Rocks & Minerals*, December 1996; "Paradoxical Pyrite," Steve Voynick, *Rock & Gem* October 2004; "Costa Mesa Show 1996," Jeffrey A. Scovil, *The Mineralogical Record*, November-December 1996; "Macrominerals," William A. Henderson, Jr., *The Mineralogical Record*, May-June 1988; "The Frugal Collector: Pyrite Packs a Punch," Bob Jones, *Rock & Gem*, August 2003.