

Mineral of the Month Club November 2016

PYRITE

This month's featured mineral is pyrite, or iron disulfide, from the world's leading source of pyrite specimens—Peru's Huanzala Mine. Our specimens are clusters of lustrous pyritohedral crystals; our write-up discusses pyrite's mineralogy and explains its crystal forms that include cubes, octahedrons, and pyritohedrons.

OVERVIEW

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 occurs as individual or clustered cubes and pyritohedrons, and less commonly as octahedrons; crystals are often striated and twinned; also granular, massive, and in globular, radiating, stalactitic, fibrous, mammillary, concretionary, and nodular forms.

Color: Pale, brassy-yellow or yellowish-gray to gray; tarnishes to yellow-brown; sometimes has a brown tarnish that produces iridescence.

Luster: Metallic

Transparency: Opaque

Streak: Greenish-black

Cleavage: None

Fracture and Tenacity: Conchoidal; brittle.

Hardness: 6.0-6.5

Specific Gravity: 4.9-5.2

Luminescence: None

Distinctive Features and Tests: Best field indicators are pale, brassy-yellow color; substantial hardness; striated crystal faces; and a tendency to spark on impact with iron and become weakly magnetic upon heating. Pyrite is similar in color to native gold [element, Au], but is brittle and much harder; it is easily confused with chalcopyrite [copper iron sulfide, CuFeS_2] and other metal sulfides.

Dana Mineral-Classification Number: 2.12.1.1

NAME: The word "pyrite," pronounced "PIE-rite," is derived from *pyr*, the Greek word for "fire," and literally means "fire mineral," alluding to its tendency to spark when struck with iron. The obsolete term "pyrites" refers both to similar-appearing metal sulfides and to 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," "ferropyrte," and "vitriolkies." Other names derive from

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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” are cross-shaped penetration twins of pyrite pyritohedrons; “pyrite suns” are flat, disk-like, radiating forms; and spherical or ovoidal forms are known as “concretions.” In European mineralogical literature, pyrite appears as *pyrit*, *pirita*, and *pyrita*.

COMPOSITION & STRUCTURE: The chemical formula FeS_2 shows that pyrite consists of iron (Fe) and sulfur (S). Its molecular weight is made up of 46.55 percent iron and 53.45 percent sulfur. Pyrite is one of approximately 350 members of the sulfide class of minerals, in which sulfur combines 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 other sulfide minerals and occurs in all mineralogical environments, including pegmatites, hydrothermal-vein deposits, carbonatites (carbonate-rich igneous rocks), regional metamorphic rocks, skarns (metamorphic calc-silicate rocks), and sedimentary rocks. As an idiochromatic or “self-colored” mineral, pyrite’s pale, brassy-yellow color is caused by its essential elemental components and the nature of its crystal structure.

COLLECTING LOCALITIES: Pyrite is collected in Peru, Brazil, Bolivia, Italy, England, Germany, Switzerland, Russia, Tanzania, Greece, Spain, Australia, Canada, China, and the United States (Utah, Colorado, Ohio, Pennsylvania, Missouri, Illinois, Kansas, and Wisconsin).

HISTORY, LORE & GEMSTONE/TECHNOLOGICAL USES: Collected since antiquity, pyrite has been used as a gemstone and decorative stone. It reached its greatest popularity as a gemstone during the Victorian era of the late 19th century, when hundreds of tiny, glittering, faceted pyrite gems were mounted in elaborate, sterling-silver settings. Because it sparks when struck sharply with iron, pyrite has been used as a “fire-starter” and as a sparking flint for early firearms. Pyrite once served as an ore of sulfur and a minor ore of iron; it now has only limited use as a coloring agent in the manufacture of amber-colored glass. Pyrite is a model in the study of mineral-crystal structure and pyrite-oxidation chemistry, the latter to better understand its role in mine-drainage pollution. 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 shields one from negativity and physical risk.

ABOUT OUR SPECIMENS: Our specimens are from the Huanzala Mine, Huallanca District, Bolognesi Province, Ancash Department, Peru. (Under Peru’s new districting system, this locality is now referred to as “Huanzala Mine, Huallanca District, Dos de Mayo Province, Huánuco Region, Peru.” But because many maps and mineralogical publications do not yet reflect this change, we are continuing to base our Peruvian locality names on the old system.) The Huanzala Mine, elevation 12,000 feet, is located 155 miles north-northeast of the national capital of Lima and 7 miles west of the town of Huallanca. The lead-zinc-silver mineralization at Huanzala was emplaced following the Andean Orogeny when multiple phases of mineral-rich, hydrothermal solutions surged upward into fractures. Huanzala ores occur as lenticular and bedded replacement deposits in the Santa Formation limestone. Spanish prospectors discovered the deposit in 1721 and mined it briefly. Modern mining of lead-zinc-silver ores began in 1968

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when Compañía Minera Santa Luisa, S.A., a subsidiary of Tokyo, Japan-based Mitsui Mining & Smelting Corporation, opened an underground mine. Huanzala's daily production now amounts to 1,200 tons of ore grading 5.8 percent lead, 12.2 percent zinc, 2.8 troy ounces of silver, and 0.01 percent copper per ton. Ore reserves are sufficient for three more years of mining, but continuing exploration is expected to significantly extend the mine's life. Huanzala is the world's largest source of pyrite specimens and has yielded more mineral specimens on a tonnage basis than any other mine. In the early 1980s, management banned specimen-collecting in the mine and the sale of specimens in the tiny company town of Huanzala. Nevertheless, Huanzala remains a source of specimens as miners continue to smuggle specimens out of the mine, bribe shift bosses and supervisors to "look the other way," and sneak into the mine when it is not operating on Sundays or during frequent labor strikes. Recently, however, the supply of specimens from the Huanzala Mine has slowed because of increasing mechanization and tighter supervisory control.

COMPREHENSIVE WRITE-UP

COMPOSITION & STRUCTURE

This is the fifth time we have featured pyrite as our Mineral of the Month. In October 2003, we featured octahedral pyrite crystals from the Huanzala Mine; this month our pyrite specimens are also from Huanzala, but they are in the form of pyritohedrons. Cubic pyrite crystals from Navajún, La Rioja, Spain, were our Minerals of the Month for March 1996 and March 2006; in July 2007, we featured iridescent, "rainbow" pyrite from Russia.

The chemical formula FeS_2 shows that pyrite consists of iron (Fe) and sulfur (S). Pyrite's molecular weight is made up 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). Pyrite's simple cation is the single iron ion (ferrous, Fe^{2+}) with a +2 charge; pyrite's anion consists of two sulfur ions 2S^{2-} , each with a -2 charge. From its formula FeS_2 , the pyrite molecule might appear to be unstable because the +2 cationic charge of the single iron cation Fe^{2+} does not electrically balance the *apparent* -4 anionic charge of the two sulfur ions 2S^{2-} . But in pyrite and certain other metal disulfides, the two sulfur ions are covalently bonded and behave electrically as a single, polyatomic ion. This double-sulfur ion therefore has an effective anionic charge of -2 that balances the +2 cationic charge and provides the pyrite molecule with electrical stability.

Pyrite is the most abundant of the approximately 350 sulfide-class minerals, in which sulfur combines with one or more metals. Most sulfides are dense, brittle, generally dark in color, and metallic in luster. Pyrite is associated with many other minerals in virtually all mineralogical environments, including pegmatites, hydrothermal-vein deposits, carbonatites (carbonate-rich igneous rocks), regional metamorphic rocks, skarns (metamorphic calc-silicate rocks), and sedimentary rocks. Pyrite reaches its highest levels of crystal development in hydrothermal-vein and replacement deposits in association with quartz [silicon dioxide, SiO_2], chalcopyrite [copper

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iron sulfide, CuFeS_2], galena [lead sulfide, PbS], and sphalerite [zinc sulfide, ZnS]. Pyrite often exhibits cationic substitution when such metals as cobalt, nickel, manganese, silver, and gold replace iron and cause variations in hardness, density, and color. Because divalent cobalt Co^{2+} substitutes readily for the divalent iron ion Fe^{2+} and vice versa, pyrite forms a complete solid-solution series with cattierite [cobalt disulfide, CoS_2] with the intermediate grades known as cobaltous pyrite.

Pyrite is an idiochromatic or “self-colored” mineral; its pale, brassy-yellow color is due to both 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 high degree of metallic bonding. In metallic bonding, metal ions are held together by 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 at the surface of pyrite become energized; to return to their normal levels, they release their excess energy in wavelengths that we perceive as a metallic, brassy-yellow.

Within pyrite’s cubic-crystal lattice, iron ions occupy positions at the eight corners of a cube and at the middle of its six faces. Pairs of covalently bonded sulfur atoms are positioned midway along the edges of each lattice unit. This rigid cubic structure, together with strong, covalent, iron-sulfur bonding, explains pyrite’s considerable hardness (Mohs 6.0-6.5). Superficially, pyrite resembles several other sulfide minerals. Its brassy-yellow color and metallic luster are similar those of chalcopyrite [copper iron sulfide, CuFeS_2], cobaltite [cobalt iron arsenic sulfide, $(\text{Co,Fe})\text{AsS}$], and cattierite [cobalt disulfide CoS_2]. Pyrite also closely resembles marcasite [iron disulfide, FeS_2] in density, hardness, and metallic luster. Pyrite and marcasite are polymorphs of iron disulfide with identical chemistries but different crystal structures (pyrite crystallizes in the cubic system, marcasite in the orthorhombic system). Most pyrite crystal faces exhibit diagnostic striations formed by cubic and pyritohedral, twinned crystals that show subsequent convergence or juxtaposition of two or more faces. During crystal growth, these faces become truncated or “overgrown” by other faces to leave visible, repetitive pyritohedral edges on cubic faces and vice versa. Pyrite striations are parallel and perpendicular to those on adjacent faces, and are occasionally triangular or crossed. (For a detailed discussion of pyrite forms, see “Pyrite: From Cubes to Pyritohedrons”).

The Dana mineral-classification number 2.12.1.1 first identifies pyrite as a sulfide (2). It is subclassified (12) by the general formula AX_2 , in which “A” can be iron, zinc, mercury, gold, cobalt, copper, manganese, nickel, platinum, palladium, ruthenium, iridium, or osmium, while “X” can be sulfur, arsenic, antimony, bismuth, selenium, or tellurium. Pyrite is then assigned to the pyrite group (1) as the first (1) of 19 members, all having isometric crystal structures and similar chemistries, but varying in their physical properties. Pyrite is the group’s only abundant mineral. Other pyrite-group minerals include vaesite [nickel disulfide, NiS_2], cattierite [cobalt disulfide, CoS_2], villamaninite [copper disulfide, CuS_2], and hauerite [manganese disulfide, MnS_2].

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Although strong, covalent iron-sulfur bonding imparts considerable hardness to pyrite, its relatively weak, covalent, sulfur-sulfur bonding creates a chemical instability, causing it to oxidize slowly when exposed to water and atmospheric oxygen (O₂). This reaction produces iron ions (ferrous, Fe²⁺) and sulfuric acid (H₂SO₄) according to the formula $2\text{H}_2\text{O} + 3\text{O}_2 + \text{FeS}_2 = 2\text{H}_2\text{SO}_4 + \text{Fe}^{2+}$. Pyrite oxidation creates gossan deposits of limonite (a mix of iron oxides and hydroxides) that overlie lower bodies of 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,” a mix of iron oxides and hydroxides that stains creek beds a bright, yellow-orange color. Mining accelerates this natural oxidation process by quickly exposing large volumes of pyrite to atmospheric oxygen and water, thus creating the environmental problem of mine-drainage pollution.

COLLECTING LOCALITIES

Our specimens were collected at the Huanzala Mine, Huallanca District, Bolognesi Province, Ancash Department, Peru. Other Peruvian localities include the Cerro de Pasco district mines in Alcides Carrión Province, Pasco Department; the Julcani district mines in Angaraes Province and the Castrovirreyna district mines in Castrovirreyna Province, both in Huancavalica Department; the Pasto Bueno district mines, Pallasca Province, Ancash Department; and the Huaron mines in San José de Huayllay District, Cerro de Pasco Province.

Pyrite is also collected at the Galiléia pegmatite mines in Governador Valadares and the Conselhiero Pena mines in Minas Gerais, both in Brazil; the Atocha-Quechisla district mines in Sud Chichas Province in Potosí Department and the Ciudad Oruro mines in Cercado Province in Oruro Department, both in Bolivia; Rio Marina, Elba Island, Livorno Province, Tuscany, Italy; the Callington mines in Cornwall and the Nenthead mines in Cumbria, both in England; the Neustädtel mines in the Schneeberg District, Saxony, Germany; Lausanne, Lausanne District, Vaud, Switzerland; Ulyanovsk, Ulyanovsk Oblast', Russia; the Merilani Hills, Arushi, Tanzania; and the Cassandra Mine in Chalkadiki Prefecture, Macedonia Department, Greece. Spain's localities include Navajún, La Rioja; and the Río Tinto mines at Huelva and the Seville mines, both in Andalusia. Australian localities include Wood's Mine in Darling County in New South Wales and the Golden Mile Mine at Kalgoorlie in Western Australia. Among Canada's sources are the Alberni, Atlin, Liard, and Kamloops districts in British Columbia; the Algoma and Cochrane districts in Ontario; and Tea Cove on the Port au Pont Peninsula on the island of Newfoundland in the province of Newfoundland and Labrador. Chinese sources include the Hengyang Baifang coal mines near Hengyang, Hengyang County, Hengyang Prefecture, Hunan Province; the Maoniuping rare-earth deposit at Xuebaoding, Mianning County, Liangshan Prefecture, Sichuan Province; and the Dongchuan district coal mines at Guangxi, Kunming Prefecture, Yunnan Province.

Pyrite localities in the United States include the Bingham Canyon Mine in Salt Lake County and the Park City mines in Summit County, both in Utah; the mines of the Leadville, Gilman, Alma,

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Silverton, Ouray, Rico, and Telluride districts in Colorado; the Huff Quarry at Huntsville in Logan County and Frankfort in Ross County, both in Ohio; the French Creek Mine in Chester County, Pennsylvania; the Tri-State zinc-lead mining district in southwestern Missouri; the Gary Quarry near Hamilton in Hancock County and the Sparta coal mines in Randolph County, both in Illinois; the Smoky Hill Chalk member of the Niobrara Formation in Gove County, Kansas; and the Warren Peter Quarry near Burlington in Racine County, Wisconsin.

JEWELRY & DECORATIVE USES

Pyrite has served as a gemstone since antiquity and achieved its greatest popularity 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 style featured hundreds of small, glittering, faceted pyrite gems in elaborate, sterling-silver settings. This style regained popularity in the United States and Europe during the Art Deco period of the 1920s and 1930s. Pyrite continues to be worn in jewelry today, usually as polished beads in necklaces, bracelets, and earrings. Also popular are nodular coatings of tiny, iridescent crystals of “rainbow” pyrite that are cut into cabochons and mounted in pendants and brooches. Pyrite is sometimes cut into small “rosettes” for use as “edging” or “framing” stones in artistic creations. Clusters of pyrite crystals, both as individual and composite specimens, are popular as paperweights, bookends, and display pieces.

Because of its abundance, affordability, and variety of crystal habits, pyrite is widely collected. Pyrite specimens have a broad price range; small crystal clusters can cost only a few dollars, while fine cabinet specimens often sell for thousands of dollars. Some collectors have built extensive, specialized pyrite collections focused on localities, crystal habits, mineralogical associations, and even concretionary and nodular forms.

HISTORY & LORE

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

Physicians in medieval Europe treated throat and circulatory ailments with elixirs containing finely ground pyrite. Intrigued by its golden color, European alchemists attempted to transmute pyrite into gold. Although their experiments failed, they developed a number of practical uses

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for pyrite. By 1400 A.D., alchemists were roasting ground pyrite over charcoal fires to drive off sulfur as sulfur-dioxide (SO_2) gas, which they dissolved in water to produce sulfuric acid (H_2SO_4). Sulfuric acid was an important reagent during the period of alchemistic experimentation that led to the emergence of modern chemistry. Pyrite's tendency to spark when struck with iron made it valuable as a "fire-starter." Early European firearms employed pyrite as a sparking "flint." 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, causing the instantaneous release of thermal and light energy in the form of sparks. In the early 1700s, pyrite was among the first mineral compounds that European chemists qualitatively identified by its elemental components. A century later, pyrite became the chemical model that helped determine the elemental compositions of many other metal sulfides. Until that time, all metal sulfides had been collectively known as "pyrites"; pyrite was later called "iron pyrite," "ferropyrnite," or "yellow pyrite" to distinguish it from "copper pyrite" or chalcopyrite [copper iron sulfide, CuFeS_2]. The term "iron pyrite" is still used today.

Pyrite occasionally served as an ore of iron in regions lacking more abundant iron-oxide deposits. Pyrite's greatest commercial value, however, was as a source of sulfur. In the 1800s, pyrite was mined for its sulfur content in many regions without access to 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 declared pyrite a strategic mineral. The United States then had two dozen primary pyrite mines and was also recovering pyrite as a by-product of base-metal and precious-metal mining.

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; the 29-peseta stamp of Spain in 1994; and the 15-cent stamp of Cyprus in 1998. 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: FROM CUBES TO PYRITOHEDRONS

Because pyrite crystallizes in the cubic or isometric system, yet occurs in such divergent habits as cubic, octahedral, and dodecahedral (pyritohedral), it is a classic model for crystallographic study. The cubic system is defined by three axes of equal length that intersect at the crystal center and are perpendicular to their opposing faces. Because of varying degrees of symmetry, some isometric minerals crystallize exclusively in the cubic habit, while others, such as pyrite, also occur in other habits.

"Symmetry" is defined as correspondence of size, shape, and position of parts on opposite parts of a median plane. Comparing galena [lead sulfide, PbS] and pyrite illustrates the varying degrees of crystallographic symmetry. Both minerals crystallize in the cubic system and have the same basic, cubic structures. However, galena has a simpler chemical composition and a

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simpler crystalline structure, and thus a greater crystallographic symmetry than does pyrite. Galena crystals almost always occur as cubes, and only rarely as octahedrons. This is because the galena molecule, with its single sulfur anion, has a simple, four-fold symmetry. But because pyrite's double-sulfur anion disrupts this symmetry, pyrite develops different crystal habits that include cubic, tetrahedral, octahedral, and dodecahedral. These habits are defined as follows:

Cubic: a solid bounded by six equal, square sides with 12 straight edges and eight vertex corners (in crystallography, a vertex corner is the intersection of two or more edges) ;

Tetrahedral: a solid bounded by four triangular faces with six straight edges and four corners;

Octahedral: a solid bounded by eight triangular faces with eight edges and six vertex corners (octahedrons appear as two four-sided triangles joined base-to-base);

Dodecahedral: a solid bounded by 12 pentagonal faces with 30 edges and 20 vertex corners. The pentagonal-dodecahedral modification, which occurs often in pyrite, is known as "pyritohedral."

Because pyrite can assume any of these forms individually or in combination, it exhibits an unusually large number of crystal habits. The common pyrite habits in order of abundance are cubic, pentagonal-dodecahedral, octahedral, and tetrahedral. Because of modifications and combinations of these basic habits, pyrite crystallography is quite complex. As an example, a combined octahedral-pyritohedral habit is known as "icosahedral." Many other such combinations exist. Our Mineral of the Month specimens consist of clusters of pentagonal-dodecahedrons or pyritohedrons, each crystal being a modified dodecahedron with 12 identical, but irregular, pentagonal faces.

The development of pyrite crystals requires free space for unrestricted growth. Accordingly, pyrite crystals (and those of most other minerals) achieve their highest levels of development in hydrothermal-vein and in replacement-type deposits. Vein deposits form when mineral-rich, hydrothermal fluids partially fill fissures; replacement deposits form when fluids dissolve carbonate rocks to create voids.

The absence or restriction of growth space can create radically different forms of pyrite. In the absence of growth space in many igneous and most metamorphic environments, pyrite forms tiny, individual grains or granular bodies. These grains have pyrite's internal cubic structure, but no recognizable external, cubic shape. Other forms develop when iron and sulfur ions are transported by acidic, aqueous solutions and are precipitated in globular, mammillary, fibrous, and stalactitic shapes. Unusual forms of pyrite also develop in sedimentary environments with restricted growth space.

Iron is often present in sedimentary environments as a common component of inorganic sediments, while sulfur is present in organic remains, especially in coal deposits that form from buried vegetal matter. As a result, pyrite often occurs within coal-shale deposits as spherical and flattened concretions and nodules. Concretions are volumes of sedimentary rock in which mineral precipitates displace surrounding sediments or fill the pores between sediment grains.

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Concretions can be spherical, elongated, or irregular in shape, and range in size from microscopic to several feet in diameter. Modified concretionary forms of pyrite include disk-like “suns” that are thin, flat, and round in shape and form by precipitation in lithified, coal-shale strata. 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.

TECHNOLOGICAL USES

Pyrite was formerly a major ore of sulfur and a minor ore of iron, but is now used only in limited quantities as a coloring agent to manufacture amber-colored glass. Pyrite also serves as a model in the study of mineral-crystal structure to determine the weathering qualities of pyrite-containing structural (building) stone such as granite and marble, and in the study of pyrite-oxidation chemistry to better understand the oxidation process that causes mine-drainage pollution.

ABOUT OUR SPECIMENS

Our specimens of pyrite pyritohedrons are from the Huanzala Mine, Huallanca District, Bolognesi Province, Ancash Department, Peru. The names of Peruvian mineral localities have been somewhat confusing since 2002, when Peru’s federal government redistricted many departmental and provincial boundaries. Prior to 2002, Peru had 24 departments (political divisions comparable to American states); these have now been reorganized into 25 regions. Under the new system, the locality name for our specimens would be “Huanzala Mine, Huallanca District, Dos de Mayo Province, Huánuco Region, Peru.” But because many maps and mineralogical publications do not yet reflect this change, we are continuing to base our Peruvian locality names on the old system.

The Huallanca District is 155 miles north-northeast of the Peruvian national capital of Lima. The town of Huallanca, the district capital, has a population of 1,500 and is located in an 8,000-foot-high valley surrounded by 14,000-foot-high mountains. The district population is mostly of Quechua Indian descent and speaks both Spanish and the Quechua language. The Huanzala Mine and the tiny, company town of Huanzala are located seven miles west of the town of Huallanca at an elevation of 12,000 feet.

Peru’s complex geology, dramatic topography, and abundant mineralization originated with the Andean Orogeny (mountain-building episode) that uplifted the Andes Mountains some 60 million years ago. Peru is a tectonically active region that lies directly on the contact of the Nazca and South American tectonic plates, the interface of which follows the Peruvian coast. At a rate of about two inches per year, the Nazca Plate is grinding over the South American Plate. For millions of years, this collision has stressed the regional crust, triggering an ongoing succession of major earthquakes and enabling magmatic intrusions and associated, mineral-rich fluids to emplace rich mineral deposits.

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The lead-zinc-silver mineralization at Huanzala was emplaced following the Andean Orogeny when multiple phases of mineral-rich, hydrothermal solutions surged upward into the fractured, early-Cretaceous limestone of the Santa Formation. The first phase of mineralization emplaced pyrite; this was followed by an emplacement of zinc and lead mineralization. The third and final surge emplaced copper mineralization along with small amounts of tungsten, silver, and tin. These ores, which occur as lenticular and bedded replacement deposits in limestone, were originally emplaced at depth and were later exposed by erosion.

Spanish prospectors discovered outcrops of these deposits on the south slope of Cerro Huanzalan (Huanzalan Mountain) in 1721. They mined the deposits only briefly because of the area's remoteness and because the ore yielded primarily zinc and lead, rather than silver. Mining was limited and sporadic for the next 250 years. A major development effort began in 1964 when the Tokyo, Japan-based Mitsui Mining & Smelting Corporation founded a Peruvian subsidiary, Compañía Minera Santa Luisa, S.A., and began core-drilling to delineate several lead-zinc-silver ore zones. Underground mining began in 1968. Today, Huanzala, which mines 1,200 tons of ore per day, has one million tons of reserves that grade 5.8 percent lead, 12.2 percent zinc, 2.8 troy ounces of silver, and 0.01 percent copper per ton—enough for about three more years of mining at the current rate of production. However, an ongoing exploration program is expected to significantly extend the mine's operating life.

Huanzala's ore minerals include chalcopyrite [copper iron sulfide, CuFeS_2], enargite [copper arsenic sulfide, Cu_3AsS_4], galena [lead sulfide, PbS], sphalerite [zinc sulfide, ZnS], and tennantite [copper iron zinc arsenic sulfide, $\text{Cu}_{10}(\text{Fe,Zn})_2\text{As}_4\text{S}_{13}$]. Silver is present in both galena and as acanthite [silver sulfide, Ag_2S]. The gangue minerals are pyrite, quartz [silicon dioxide, SiO_2], fluorite [calcium fluoride, CaF_2], calcite [calcium carbonate CaCO_3], and dolomite [calcium magnesium carbonate, $\text{CaMg}(\text{CO}_3)_2$].

Huanzala is well-known for its mineral specimens, especially pyrite. The huge supply of Huanzala pyrite specimens was instrumental in developing Peru's mineral-specimen industry. Huanzala pyrite remains the staple species of most Peruvian mineral dealers. For many years, Huanzala yielded pyrite by the ton (literally) and is generally recognized as the world's largest source of pyrite specimens. According to American specimen importer and collector Rock H. Currier (1940-2015), Huanzala has yielded more mineral specimens on a tonnage basis than any other mine in the world. Three of the four major habits of pyrite—cubic, octahedral, and dodecahedral (pentagonal-pyritohedral)—occur at Huanzala, where crystals typically vary from mirror-bright to satiny in luster. In the cubic crystals, prominent striations give a wavy appearance to the crystal faces. The mirror-bright pyritohedrons are only lightly striated. Some Huanzala pyrite crystals measured nearly 12 inches in size. The most famous Huanzala pyrite specimen, recovered in 1990, is a cluster of 10-inch, octahedral crystals weighing 150 pounds that is now displayed at the National Museum of Natural History (Smithsonian) in Washington, D.C. Huanzala is also known for its octahedral crystals of pink and multicolored fluorite [calcium fluoride, CaF_2].

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The abundance of valuable mineral specimens at Huanzala had created managerial and ore-production problems from the mine's opening in 1968. Seeking a source of secondary income, miners spent much of their work time collecting specimens rather than mining ore; *pyriteros*—specimen buyers from Lima—visited the mine almost daily to buy these “high-graded” specimens. In the early 1980s, management banned both specimen-collecting in the mine and the selling of specimens in the mine's tiny company town. Nevertheless, miners continue to smuggle specimens out of the mine, bribe shift bosses and supervisors to “look the other way,” and sneak into the mine when it is not operating on Sundays or during frequent labor strikes. Recently, however, increasing mechanization and tighter supervisory control has limited the supply of Huanzala specimens.

As you examine your Huanzala pyrite specimen, note first the pentagonal-pyritohedral structure of the crystals with their irregular, pentagonal faces; pale, brassy-gold color; and bright, metallic luster. Most faces are finely striated, although a few may appear perfectly smooth. These crystals rest atop a matrix of granular pyrite and dark masses of minor sphalerite [zinc sulfide, ZnS]. Notice also that your specimen has considerable heft in the hand, reflecting its specific gravity of 4.9-5.2, a density twice that of quartz. Your specimen is a fine example of pyritohedral pyrite from Peru's Huanzala Mine—the world's greatest source of pyrite specimens.

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Mineral of the Month Club November 2016

