

# Mineral of the Month June 2015

## ANHYDRITE var. "ANGELITE"

This month's mineral is the rare, blue angelite gem variety of anhydrite, or calcium sulfate. Our specimens were collected in Peru and our write-up explains anhydrite's mineralogy and relationship with gypsum, while providing an overview of the mines and minerals of Peru, one of the world's great sources of mineral specimens.

### OVERVIEW

### PHYSICAL PROPERTIES

Chemistry:  $\text{CaSO}_4$  Calcium Sulfate

Class: Sulfates

Subclass: Anhydrous Sulfates

Group: Anhydrite

Crystal System: Orthorhombic

Crystal Habits: The angelite variety of anhydrite is massive, granular, or compact.

Color: Angelite is always pale blue or grayish-blue.

Luster: Dull on natural fracture surfaces.

Transparency: Translucent

Streak: White

Refractive Index: 1.569-1.618

Cleavage: Perfect in one direction, good in two others; all cleavage planes at right angles to each other.

Fracture: Subconchoidal to uneven, brittle.

Hardness: 3.0-3.5

Specific Gravity: 2.97

Luminescence: Angelite sometimes fluoresces red under long-wave ultraviolet light.

Distinctive Features and Tests: Blue color; fine grain; and frequent association with gypsum [hydrous calcium sulfate,  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ].

Dana Classification Number: 28.3.2.1

**NAME:** The name "anhydrite," pronounced ann-HIGH-drite, stems from the Greek *anydros*, meaning "without water" and alluding to its anhydrous state (as opposed to the hydrous state of the chemically similar mineral gypsum). Anhydrite has been known as "anhydrous sulfate of lime," "anhydrous gypsum," "dry gypsum," "cube spar," "karstenite," and "muriacite." In European mineralogical literature, anhydrite appears as *anhidrita*, *anhidrit*, and *Anhydrit*. "Angelite" is the trade name for a blue, massive variety of anhydrite that occurs only in Peru. It is named for its bluish color that is linked to hues associated with angels and the heavens. Angelite is also known as "blue-heaven stone," "angel stone," and "sky stone." In European mineralogical literature, angelite appears as *Angelit* and *angelita*.

**COMPOSITION:** Anhydrite, chemical formula  $\text{CaSO}_4$ , consists of 29.44 percent calcium (Ca), 23.55 percent sulfur (S), and 47.01 percent oxygen (O). Anhydrite is a member of the sulfates, a

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class of nearly 200 minerals in which sulfur and oxygen combine as the sulfate radical  $(\text{SO}_4)^{2-}$ , which in turn bonds with one or more metals. Anhydrite crystallizes in the orthorhombic system with three mutually perpendicular axes of different lengths. Weak ionic bonding explains anhydrite's relative softness of Mohs 3.0-3.5 and its moderate solubility in water. Because of its solubility, anhydrite forms mainly as an evaporite mineral; it is an important rock-forming mineral in many chemical-sedimentary rocks. Anhydrite also occurs to a lesser extent in carbonatites, zeolite pockets within basalt formations, hydrothermal veins, altered limestone, and volcanic fumarole deposits. Anhydrite is chemically similar to gypsum. Both are calcium sulfates, but gypsum contains water of hydration while anhydrite does not. As an allochromatic or "other-colored" mineral, anhydrite's color is determined by traces of accessory elements, rather than by its essential elements or the nature of its crystal lattice. Pure anhydrite is colorless or white, but traces of nonessential elements produce a range of pale colors. Angelite's diagnostic blue color is caused by traces of ferrous iron ( $\text{Fe}^{2+}$ ).

**COLLECTING LOCALITIES:** Although anhydrite is a common mineral with many collecting localities worldwide, the blue angelite variety is rare and has only two sources. Our angelite specimens were collected near the Casapalca Mine at Casapalca, Huarochiri Province, Lima Department, Peru. Peruvian angelite also occurs in the adjacent Morococha district in Yauli Province, Junin Department. Blue anhydrite from these sources is the only material to which the variety name "angelite" should be applied. Forms of anhydrite with much paler bluish hues are found in Mexico, Germany, and the United States.

**HISTORY, LORE & GEMSTONE/TECHNOLOGICAL USES:** German mineralogist Abraham Gottlieb Werner (1747-1817) described anhydrite as a new mineral species in 1794 after studying specimens collected at the Hall salt mine near Innsbruck, Styria, Austria. Mineralogists used newly developed X-ray diffraction methods to determine anhydrite's atomic structure in 1922. Anhydrite has occasionally served as a minor source of calcium for the industrial production of lime. Because of its rarity, the angelite variety of anhydrite has no technological uses. Unlike other forms of anhydrite which are usually white or gray, the blue, massive variety is fashioned into gems and decorative objects, including symmetrical and free-form beads, figurines, ashtrays, chandelier accents, pyramids, hearts, and spheres. Beads are strung into necklaces and bracelets; larger, free-form pieces are wrapped in silver wire for wear as pendants. Angelite's very fine grain enables it to take a superb polish that shows off its range of blue colors. Much of angelite's unusual metaphysical significance originated at the Harmonic Convergence gathering of 1987 in Peru, when the stone was first introduced to the public and recognized as a gem variety of anhydrite. Angelite is considered a stone that generates heightened awareness, with a special focus on peace and brotherhood. It promotes compassion and understanding, aids in speaking the truth when the truth is difficult, alleviates psychological pain, enhances astrological understanding, increases telepathic powers, clears energy pathways, and facilitates contact with angels. As a healing stone, angelite is believed to rejuvenate tissues and blood vessels, and to relieve throat inflammation.

**ABOUT OUR SPECIMENS:** Our specimens were collected in the Casapalca District, Huarochiri Province, Lima Department, Peru. Huarochiri Province is located east of the national capital city of Lima in west-central Peru. Covering 2,184 square miles, the province is about twice the size of the American state of Delaware. It has a rugged mountain topography, an

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average elevation of 7,800 feet, a sparse population of only 62,000 residents, and an economy based largely on mining. The Casapalca mining district is roughly 100 miles and four hours driving time east of Lima. The town of Casapalca, population 1,000, is at an elevation of 13,000 feet in the Cordillera Oriental sub-range of the Andes. The Casapalca mineral deposits are believed to have been first mined to a limited extent by the Spaniards in the 1600s; in modern times, they have been a significant source of silver, copper, lead, and zinc for more than a century. The occurrence of the angelite variety of anhydrite, however, is not related to metal mineralization. Instead, angelite formed when sulfate-rich solutions converted the calcite in limestone to massive anhydrite with a distinctive blue color that is caused by trace amounts of divalent (ferrous) iron. This anhydrite formed nodules within a layer of altered limestone. When the surface of these anhydrite nodules later contacted chemically neutral groundwater, it rehydrated into gypsum, which appears as a white coating on our specimens. Angelite is collected today by Casapalca metal miners and sold to dealers and gem cutters as a source of secondary income.

## COMPREHENSIVE WRITE-UP

### *COMPOSITION & STRUCTURE*

Angelite is the blue gem variety of massive anhydrite. Anhydrite, chemical formula  $\text{CaSO}_4$ , contains the elements calcium (Ca), sulfur (S), and oxygen (O). Anhydrite's molecular weight is made up of 29.44 percent calcium, 47.01 percent oxygen, and 23.55 percent sulfur. Like all molecules, those of anhydrite are composed of positively charged cations and negatively charged anions. Anhydrite's simple cation is the calcium ion  $\text{Ca}^{2+}$  with its +2 charge. Its anion is a radical, a group of ions of different atoms that behaves as an entity in chemical reactions. The anhydrite anion is the sulfate radical  $(\text{SO}_4)^{2-}$ , in which four oxygen atoms positioned at the corners of a tetrahedron surround a single sulfur ion. The sulfur ion  $\text{S}^{6+}$  has an oxidation state of +6. The four oxygen ions  $4\text{O}^{2-}$  each have an -2 oxidation state, and thus a collective -8 charge. This provides a cumulative -2 anionic charge to balance the +2 cationic charge and impart electrical stability to the anhydrite molecule.

Anhydrite is a member of the sulfates, a class of nearly 200 minerals in which sulfur and oxygen, as the sulfate radical  $(\text{SO}_4)^{2-}$ , combine with one or more metals. Because its two excess negative charges are distributed evenly over the oxygen ions, the sulfate radical can easily accommodate one or more metal cations. Although anhydrite is a simple sulfate with a single metal cation, its lattice has two different types of atomic bonding. The sulfate radical  $(\text{SO}_4)^{2-}$  has strong covalent bonding with shared electrons between the four oxygen ions and the single sulfur ion. The negatively charged sulfate radical and the positively charged calcium ion are bonded ionically by the attraction of opposite charges.

Weak ionic bonding dominates within the crystal lattice and accounts for anhydrite's relative softness of Mohs 3.0-3.5 and its moderate solubility in water. In ionic bonding, the attractive forces are exerted more-or-less equally in all directions so that cations surround every anion and vice versa. This creates a three-dimensional, repeating arrangement within the lattice that is reflected in anhydrite's three cleavage planes that are perfect in one direction along the plane of

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predominant ionic bonding, and good in two other directions. Anhydrite crystallizes in the orthorhombic system, with three mutually perpendicular axes of different lengths. Its varying directional cleavage strength is due to the unequal axial lengths of the orthorhombic crystal.

Because of its moderate solubility in water, anhydrite forms primarily as an evaporite mineral. It is a major rock-forming mineral in evaporite deposits of chemical-sedimentary rocks, where it is associated with halite [sodium chloride, NaCl], calcite [calcium carbonate, CaCO<sub>3</sub>], and gypsum [hydrous calcium sulfate, CaSO<sub>4</sub>·2H<sub>2</sub>O]. Anhydrite makes up about three percent of the various salts in most salt domes and occurs nearly pure in massive formations in the upper caprock zones of salt domes after groundwater has leached away the halite. Nodular forms occur when anhydrite replaces gypsum in sedimentary deposits in dehydrating environments. Anhydrite also occurs to a lesser extent in carbonatites (carbonate-rich igneous rocks) with gypsum and barite [barium sulfate, BaSO<sub>4</sub>]; in zeolite pockets within basalt formations with calcite and zeolite minerals (a group of hydrated, complex aluminum silicates); in hydrothermal veins with calcite and quartz [silicon dioxide, SiO<sub>2</sub>]; and in volcanic fumarole deposits.

As an allochromatic or “other-colored” mineral, anhydrite’s color is determined by traces of accessory elements, rather than by its essential elements or the nature of its crystal lattice. Pure anhydrite is colorless or white, but traces of nonessential elements create a range of pale colors. Reddish and pale-pink colors are usually caused by the divalent manganese ion Mn<sup>2+</sup> substituting for calcium in the lattice; the blue colors seen in the angelite variety of anhydrite are due to ions of divalent iron (ferrous) Fe<sup>2+</sup> that substitute for calcium

Both anhydrite [calcium sulfate, CaSO<sub>4</sub>] and gypsum [hydrous calcium sulfate, CaSO<sub>4</sub>·2H<sub>2</sub>O] are calcium sulfates. But gypsum is a hydrous mineral that contains two attached molecules of water. In the water molecule, a large oxygen ion is covalently bonded to two small hydrogen ions that group together on one side of the oxygen ion. These two hydrogen ions retain a weak positive charge, while the opposite side of the molecule, dominated by the large oxygen ion, retains a weak negative charge. This causes water molecules to behave as tiny dipole magnets. Hydrogen bonding, also called polar bonding, takes place when the faintly positive poles of water molecules attract the negative charges of the electrons of other atoms. In gypsum, the positive poles of the water molecules are attracted to the slight negative charge of the oxygen ions in the sulfate radical. Because hydrogen bonding is strongest at cold temperatures, gypsum becomes unstable when heat separates its weak hydrogen bonds to drive off its water of hydration. Whether calcium ions and sulfate ions will crystallize from aqueous solutions as anhydrite or gypsum therefore depends upon temperature (and, to a lesser extent upon pressure and chemistry). With available water and low temperatures, anhydrite can hydrate (or rehydrate) and convert to gypsum. Conversely, in the absence of water and with high temperatures, gypsum can dehydrate into anhydrite.

At Mohs 3.0-3.5, anhydrite is considerably harder than gypsum (Mohs 1.5-2.0) because gypsum’s water molecules separate its calcium ions and sulfate ions and thus weaken its ionic bonding. Because increased inter-ionic distance also decreases density, gypsum’s specific gravity is only 2.32. The specific gravity of anhydrite, with its closer atomic packing, is a substantially higher at 2.97. Water of hydration also affects crystallization. Anhydrite crystallizes in the orthorhombic system, while gypsum crystallizes in the monoclinic system

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because its water of hydration distorts the crystal lattice. And because anhydrite can hydrate and convert into gypsum, and gypsum can dehydrate into anhydrite, these two minerals often form mutual pseudomorphs, with gypsum assuming the orthorhombic external shapes of anhydrite, and anhydrite assuming the monoclinic external shapes of gypsum.

The Dana mineral-classification number 28.3.2.1 first identifies anhydrite as an anhydrous sulfate or normal sulfate (28). Acid sulfates contain free hydrogen ions; because anhydrite has no hydrogen ions, it is classified as a normal sulfate. Anhydrite is then subclassified (3) by the chemical formula  $A^{2+}XO_4$ , in which “A” can be divalent ions of calcium, barium, strontium, or lead, and “X” is the sulfur ion  $S^{6+}$ . Anhydrite is then assigned to the anhydrite group (2) as the first and only member (1). The perceived color of transparent or translucent anhydrite is a function of reflected light only. When a specimen is backlighted and viewed with transmitted light, it appears nearly colorless. This is because the wavelengths of white light are selectively absorbed only through reflection, while transmitted white light passes through the crystal lattice with virtually no wavelength absorption. The blue color of our angelite specimens is created only by reflected light.

## *COLLECTING LOCALITIES*

As a common sulfate mineral, anhydrite has many collecting localities worldwide. The blue angelite variety of anhydrite, however, is rare and has only two sources. Our angelite specimens were collected near the Casapalca Mine at Casapalca, Huarochiri Province, Lima Department, Peru. The other nearby Peruvian source is the Morococha mining district in Yauli Province, Junin Department. The variety name “angelite” should be applied only to blue anhydrite from these two sources.

Anhydrite with much paler blue colors occurs at several other localities. One is the Naica Mine at Naica, Municipio de Saucillo, Chihuahua, Mexico. Others localities are in Germany and include the Hänigsen and Wathlingen potash works in Lower Saxony, the Gröna Mine at the Stassfurt potash deposit in Saxony-Anhalt, and the Kohnstein Quarry at Niederschwerfen near Harz in Thuringia. In the United States, pale-blue anhydrite occurs in the Carlsbad potash district in Eddy and Lea counties in New Mexico. Decorative objects fashioned from pale-blue anhydrite have been recovered from ancient Egyptian tombs, but it is not known if this anhydrite was found in Egypt or obtained through foreign trade.

## *JEWELRY & DECORATIVE USES*

Most forms of anhydrite are usually white or grayish in color and have little use in jewelry. However, angelite, the fine-grained, massive, blue variety, is an exception. Because of its fine grain, it takes a superb polish that enhances its range of blue colors. In top-quality angelite, translucency imparts a softness and depth, usually described as a “glow,” to the basic blue color. “Angelite” is a trade name that refers specifically to blue and grayish-blue anhydrite from two localities in Peru: the Casapalca District, Huarochiri Province, Lima Department, the source of our specimens; and the adjacent Morococha District, Yauli Province, Junin Department.

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Massive anhydrite with much paler bluish hues occurs in Mexico, several localities in Germany, and the United States and is occasionally marketed as “angelite.” However, the name “angelite” correctly refers only to the more intensely colored material coming from Peru.

Angelite is fashioned into gems and decorative objects, including symmetrical and free-form beads, figurines, ashtrays, chandelier accents, hearts, pyramids, and spheres. Beads are fashioned into necklaces and bracelets; free-form, tumbled pieces of angelite are wrapped in silver wire and worn as pendants.

Because of its only moderate hardness of Mohs 3.0-3.5, about the same as that of calcite [calcium carbonate,  $\text{CaCO}_3$ ], angelite is poorly suited for use in high-wear jewelry items such as rings. Care must also be taken to avoid excessive immersion of angelite gems and decorative objects. Constant immersion of polished angelite objects in water will eventually cause the surfaces to hydrate and convert into gypsum (see “Composition & Structure”). At Mohs 1.5-2.0, gypsum is much softer than anhydrite and very susceptible to abrasion. This conversion to gypsum will also compromise the bright luster of polished angelite surfaces.

As the popularity of angelite gems has increased in recent years, so, too, have efforts to imitate them. Because of anhydrite’s natural porosity, white and grayish forms of massive anhydrite are easily dyed to imitate the delicate, blue hues of angelite. Also, true angelite gems are sometimes waxed or oiled to intensify their bluish color.

Natural specimens of the angelite variety of anhydrite are valued by collectors for their rarity, range of pleasing blue colors, extremely fine grain, and frequent association with gypsum, which often occurs as a white rind on the exterior of blue angelite nodules.

## *HISTORY & LORE*

German mineralogist Abraham Gottlieb Werner (1747-1817) described anhydrite as a new mineral species in 1794 after studying specimens from the Hall salt mine near Innsbruck, Styria, Austria. Werner determined that the mineral’s chemical composition was otherwise identical to that of gypsum, although it did not include water. In 1804, he named the new mineral “anhydrite” to reflect its anhydrous state and to differentiate it from the hydrous mineral gypsum. Mineralogists used newly developed X-ray diffraction methods to determine the atomic structure of anhydrite in 1922.

The angelite variety of anhydrite, although probably long known to Peruvian miners in Casapalca, did not receive public attention until the Harmonic Convergence of 1987, a major, international New Age event. The Harmonic Convergence celebrated an extraordinary planetary alignment that occurred on August 24<sup>th</sup> of that year. Believing that this planetary alignment signaled a great shift in metaphysical energies, thousands of people converged on the world’s “power centers” where the energy shifts were believed to be the greatest. These included Japan’s Mount Fuji, California’s Mount Shasta, Egypt’s pyramids, and the Peruvian sites of Nazca and Machu Picchu. Angelite was introduced commercially as a gemstone at Harmonic Convergence gatherings in Peru. Angelite also received its trade name at that time, as its bluish colors began

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to be linked to hues often associated with angels and the heavens. At the same time, mineralogists recognized angelite as a distinct variety of anhydrite. Angelite has since retained its popularity as a gemstone and a decorative stone.

Much of angelite's metaphysical significance emerged at the 1987 Harmonic Convergence gathering in Peru. Angelite is considered to be a stone that generates heightened awareness with an emphasis on peace and brotherhood. It promotes compassion and understanding, aids in speaking the truth when the truth is difficult, alleviates psychological pain, enhances astrological understanding, increases telepathic powers, clears energy pathways, and facilitates contact with angels. As a healing stone, angelite is thought to rejuvenate tissues and blood vessels, and to soothe throat inflammations.

## *TECHNOLOGICAL USES*

Anhydrite has occasionally served as a minor source of calcium for the industrial production of lime (calcium oxide, CaO). Because of its rarity, the angelite variety of anhydrite has no technological uses.

## *THE MINES AND MINERALS OF PERU*

Although only about the size of France, Peru is one of the world's greatest sources of minerals and mineral specimens. Peru currently ranks third worldwide in the production of copper, silver, tin, and zinc; fourth in molybdenum; and fifth in gold and lead. It is also an important source of borate minerals, chalk, clay, gypsum, phosphate, and travertine. Mining accounts for two-thirds of the value of all Peruvian exports. An estimated 83,000 Peruvians are currently employed directly in the nation's mining industry.

Mining in Peru began more than 3,000 years ago with pre-Incan cultures working rich gold placers. When the Spanish arrived in 1533 A.D., the then-dominant Incan culture was systematically mining gold, silver, copper, tin, and even small amounts of platinum. Incan metalworkers, along with those of related, nearby cultures, fashioned exquisite decorative, ceremonial, and jewelry items from gold, copper, and gold-copper alloys.

Initially, the Spanish only looted golden objects from Incan cities. But decades later, after they had begun prospecting and mining, the most economically important metals turned out to be silver and mercury—silver for use in coinage and bullion bars and mercury for the amalgamation recovery of silver and gold from crushed ores. At the time, Spain's viceroyalty of Peru was a vast expanse of territory that included what is now modern-day Peru, Bolivia, and parts of Chile. Spanish prospectors discovered the enormous silver deposit at Potosí (now in Bolivia) in 1545. By 1590, Potosí was producing two million troy ounces of silver per year. In 1559 at Huancavelica, the Spanish found large deposits of mercury. Other major silver discoveries in what is now Peru followed at Hualgoyoc, Huallanca, Castrovirreyna, Huancapeti, and Cerro de Pasco. By 1630, Spain's Peruvian mines were producing more than five million troy ounces of silver annually. Metal mining declined after Peru attained independence in 1821, when

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government instability and wars compounded the difficulties of mining in the high Andes. Mineral exploration and mine production, not only for silver, but also for lead, zinc, and copper, picked up again in the 1880s after Peru legalized foreign mine ownership to attract outside development capital and technical expertise.

The Andean Orogeny (mountain-building episode) that began uplifting the Andes Mountains some 60 million years ago was the key event that accounts for Peru's contorted geology, dramatic topography, and abundant mineralization. Peru occupies one of the Earth's most tectonically active regions directly on the boundary of two tectonic plates: the Nazca Plate and the South American Plate, the common interface of which follows the Peruvian coast. At a rate of more than two inches per year, the Nazca Plate is moving west toward the Pacific Ocean and grinding over the South American Plate. For millions of years, this tectonic interaction has greatly strained the regional crust and triggered major earthquakes. Because of continued fracturing of the unstable crust, magmatic intrusions and associated, mineral-rich fluids have surged upwards and emplaced numerous, rich mineral deposits.

Despite its highly-mineralized mining districts, many different types of metal ores, hundreds of mines, and long mining history, Peru has only recently become a leading source of mineral specimens. For centuries, all Peruvian mineral specimens, despite their unusual aesthetic qualities, had routinely been sent to the crushers. This started to change only in the 1970s, when rising prices for base and precious metals began stimulating Peru's mining industry.

Pyrite [iron disulfide,  $\text{FeS}_2$ ] had long been one of Peru's most abundant gangue minerals and as production increased, mine dumps quickly filled with large quantities of lustrous, well-developed pyrite crystals. Traditionally, this pyrite had been considered nothing more than a worthless gangue mineral. But Peruvian entrepreneurs now learned that they could sell the beautiful pyrite specimens to foreign visitors and middle-class Peruvian citizens in the marketplaces and plazas of the capital city of Lima. By the mid-1970s, dozen of pyrite marketers, called *piriteros*, were collecting or buying pyrite specimens from the mines and selling them for a profit in Lima. Some even began exporting pyrite to foreign specimen dealers for sale on the international market. By 1978, hundreds of Peruvian *piriteros* were earning a living by buying and selling pyrite specimens. That same year, world-class rhodochrosite [manganese carbonate,  $\text{MnCO}_3$ ,] specimens were found at mines in Pasto Bueno. After these spectacular specimens appeared on the world markets, collectors and dealers from around the world descended on Peru. Peruvian miners then realized that collecting fine mineral specimens could become a substantial source of secondary income. By the 1980s, Peru had become a huge source of superb specimens of pyrite, rhodochrosite, quartz [silicon dioxide,  $\text{SiO}_2$ ], barite [barium sulfate,  $\text{BaSO}_4$ ], galena [lead sulfide,  $\text{PbS}$ ], sphalerite [zinc sulfide,  $\text{ZnS}$ ], and other collectible minerals. Today, with Peruvian metal mining thriving thanks to increasingly liberal mining-privatization laws, the supply of fine Peruvian mineral specimens has never been better.

Gold makes for a particularly interesting aspect of Peru's mining industry. Peru ranks fifth in world gold production, yielding 160 metric tons (nearly five million troy ounces) per year. Fourteen percent of this output is attributed to the "informal" sector, meaning unregulated, independent miners, approximately 10,000 of whom mine small placer deposits, some of which were first mined by pre-Incan cultures thousands of years ago. The resulting gold production is



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neither documented nor taxed. With gold currently selling for more than \$1,200 per troy ounce, even the daily recovery of just a few grams of gold provides a substantial income for many poor residents of Peru's high mountains. The Peruvian government is now acting to "formalize" independent gold mining by registering the miners and taxing their production.

With large reserves of silver, lead, zinc, copper, and tin ores, Peru is continuing to attract foreign investment to fund mineral exploration and mine development. The result is that mineral dealers are confident that Peru will remain a major source of fine mineral specimens in the years to come.

## *ABOUT OUR SPECIMENS*

Our specimens of the angelite variety of anhydrite were collected in the Casapalca District, Huarochiri Province, Lima Department, Peru. Because of a recent administrative political and geographic revision instituted by the Peruvian government, Lima Department is now part of La Costa Department. But since few maps and mineralogical publications have been updated to reflect these new revisions, we will continue, at least for the time being, to refer to the old system when discussing Peru in our write-ups.

Huarochiri Province is located east of the national capital city of Lima in west-central Peru. Covering 2,184 square miles, the province is roughly twice the size of the American state of Delaware. Huarochiri Province has a rugged mountain topography, an average elevation of 7,800 feet, a sparse population of only 62,000, and an economy based largely on mining. The Casapalca mining district is 100 miles and four hours driving time east of Lima. The town of Casapalca, population 1,000, is located at an elevation of 13,000 feet in the Cordillera Oriental sub-range of the Andes. The barren, rocky, steep terrain is well above timberline, where vegetation is limited to hardy grasses and scrub growth. Mining in the Casapalca district is concentrated on the west side of Cerro Carlos Francisco (formerly Cerro Casapalca), which has a summit elevation of just over 17,000 feet. The district's active mines are at elevations of about 14,600 feet. The adjacent Morococha mining district is located on the east side of Cerro Carlos Francisco. Both mining districts share a common geology and exploit the same system of mineralized veins.

The complex geology of the Casapalca region involves sedimentary deposition, dramatic uplifting and fracturing, and intense mineralization. The origin of our specimens of the angelite variety of anhydrite began some 200 million years ago during the Jurassic Period with the deposition of marine sediments that later lithified into the massive Potosí Limestone formation. After tectonic stresses generated by colliding continental plates began uplifting the Andes some 60 million years ago (see "The Mines and Minerals of Peru"), these limestone formations became fractured and chemically altered. Limestone consists primarily of calcite [calcium carbonate,  $\text{CaCO}_3$ ]. When sulfate-rich solutions (weak sulfuric acid) percolated downward into this limestone, certain thin, fractured strata of calcite converted into massive anhydrite according to the formula  $\text{H}_2\text{SO}_4$  (sulfuric acid) +  $\text{CaCO}_3$  (calcite) =  $\text{CaSO}_4$  (anhydrite) +  $\text{H}_2\text{CO}_3$  (carbonic acid). Because of traces of ferrous iron ( $\text{Fe}^{2+}$ ), this anhydrite exhibits an unusually intense blue color. Portions of this blue anhydrite (which occurs as nodules within strata of altered limestone) later contacted chemically neutral groundwater and partially converted or hydrated into gypsum

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[hydrated calcium sulfate,  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ], leaving blue anhydrite nodules coated with white gypsum.

About 30 million years ago, intrusions of magma enabled mineral-rich, hydrothermal solutions to surge through the fractured country rock to precipitate various metallic and semimetallic minerals in large, erratic vein systems. Fractures filled with such minerals as pyrite [iron disulfide,  $\text{FeS}_2$ ], chalcopyrite [copper iron sulfide,  $\text{CuFeS}_2$ ], bornite [copper iron sulfide,  $\text{Cu}_5\text{FeS}_4$ ], argentiferous (silver-bearing) galena [lead sulfide,  $\text{PbS}$ ], sphalerite [zinc sulfide,  $\text{ZnS}$ ], tetrahedrite [copper iron zinc antimony sulfide,  $\text{Cu}_{10}(\text{Fe,Zn})_2(\text{Sb,As})\text{S}_{13}$ ], and chalcocite [copper sulfide,  $\text{Cu}_2\text{S}$ ].

Surface erosion eventually exposed outcrops of these veins, which the Spanish may have mined to a limited extent for silver in the 1600s. Modern exploration and development in the Casapalca district began in the 1880s. By World War I, the Casapalca district and the adjacent Morococha district had become important sources of silver, copper, lead, and zinc. On average, ores from these districts contain 40 troy ounces of silver, 2 percent copper, 5 percent lead, and 13 percent zinc; tetrahedrite is the most abundant ore mineral. The Casapalca district continues to produce today.

When Casapalca miners began collecting and selling pyrite specimens in the 1970s, the blue anhydrite that they had also found had no value. But in 1987, mineral dealers displayed specimens of the blue anhydrite at Peru's Harmonic Convergence gatherings (see "History & Lore"). A market quickly developed for the blue anhydrite which was named "angelite." Today, miners in both the Casapalca and Morococha districts continue to collect and sell angelite nodules to dealers and gem cutters.

Until the Tibet railroad was built in China in 2005, the Peruvian railroad that connects Morococha and Casapalca with Lima was the world's highest rail line, reaching an elevation of 15,800 feet. Today, large deposits of low-grade copper mineralization in the Morococha district has attracted the Chinese mining corporation Chinalco, which is developing a huge, modern open-pit mine there. To make room for the mine, Chinalco has moved Morococha's 3,000 residents to a newly constructed town six miles distant. The new mine is expected to produce 250,000 tons of copper annually for the next 30 years. Casapalca, which has similar, low-grade copper mineralization, may also see development in the future.

As you study your specimen of angelite, first note its blue color that is caused by traces of divalent iron (ferrous,  $\text{Fe}^{2+}$ ). Because of its fine grain, angelite takes a nice polish that intensifies its blue color and enhances its soft translucency. This translucency is especially apparent when the specimen is viewed with strong backlighting. Your specimen is part of an angelite nodule. Its white "rind" or outer covering consists of gypsum, the hydrated form of calcium sulfate. It formed when the outer surface of the anhydrite nodule contacted groundwater and hydrated into gypsum. Using the point of a needle, make a tiny scratch in both the white gypsum and the blue angelite. Notice that the gypsum (Mohs 1.5-2.0) is much softer than the angelite (anhydrite, Mohs 3.0-3.5). Your specimen is a fine example of the angelite gem variety of anhydrite from one of only two sources in the world—the Casapalca district of Peru.

# Mineral of the Month June 2015

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