November 2010 Mineral of the Month: Hübnerite

This month's mineral is hübnerite, a manganese tungstate from the classic Pasto Bueno locality high in the Peruvian Andes. Our write-up explains the mineralogy of the uncommon mineral hübnerite, the history of the Pasto Bueno tungsten-mining district, and the many uses of the remarkable metal tungsten.

OVERVIEW

PHYSICAL PROPERTIES

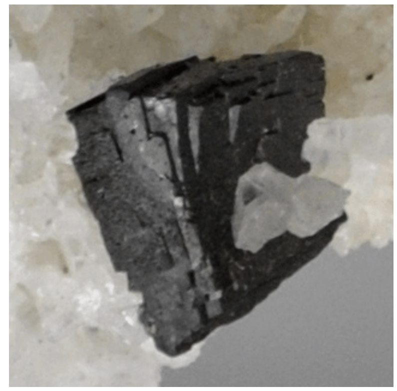

Figure 1. Hübnerite

Chemistry: $MnWO_4$ Manganese Tungstate. Almost always contains widely varying amounts of iron; sometimes contains small amounts of titanium, lead, chromium, and molybdenum.
Class: Molybdates and Tungstates
Subclass: Anhydrous Molybdates and Tungstates
Group: Wolframite
Crystal System: Monoclinic
Crystal Habits: Usually as long, striated, prismatic crystals and modified bladed, tabular, or flattened crystals; also granular and massive, and as columnar aggregates and lamellar masses. Twinning common.
Color: Reddish-brown, brown, brownish-black, and near-black; rarely red or brownish-yellow; internal reflections in thin, translucent crystals can be deep red.
Luster: Vitreous to submetallic
Transparency: Usually translucent to nearly opaque; sometimes transparent.
Streak: Brown, reddish-brown, or gray
Refractive Index: 2.170-2.320
Cleavage: Perfect in one direction
Fracture: Uneven, brittle
Hardness: 4.0-4.5
Specific Gravity: 7.1-7.5
Distinctive Features and Tests: Best field marks are crystal form and longitudinal striations; perfect, one-directional cleavage; reddish-brown to near-black color; and high specific gravity. Hübnerite resembles goethite [basic iron oxide, FeO(OH)] in color, but is softer and more dense.
Dana Classification Number: 48.1.1.1

NAME Hübnerite, pronounced HEWB-ner-ite, is named for the German mining engineer and metallurgist Friedrich Adolph Hübner (1802-1872). The two dots over the "u" in Hübner and Hübnerite are known as an "umlaut" and are a type of diacritic or diacritical mark. The purpose of the umlaut is to indicate a vowel sound different from that of the vowel without the umlaut. In this case, without the umlaut, we might pronounce the word HUB-ner-ite rather than HEWB-ner-ite. The umlaut is used particularly with words of German origin.

Hübnerite was formally known as "huebnerite," "manganese wolframite," "manganowolframite," "red wolframite," "wolfram," "red wolfram," and "blumit." In European mineralogical literature, hübnerite appears as *hübnerita*, *hübneriet*, and *hübnerit*.

COMPOSITION: Hübnerite is a manganese tungstate containing the elements manganese (Mn), tungsten (W), and oxygen (O) in the proportions of 18.14 percent manganese, 60.72 percent tungsten, and 21.14 percent oxygen. Hübnerite is one of 49 members of the Molybdates and Tungstates mineral class. It crystallizes in the monoclinic system, often as prisms that are oriented and elongated along one axis, a habit seen in the elongated, flattened prisms of hübnerite. As an idiochromatic (self-colored) mineral, hübnerite's color is caused by its essential elemental components and the nature of its crystal structure. When nearly pure, the essential element manganese colors hübnerite red or reddish-brown. But hübnerite almost always contains varying and sometimes substantial amounts of iron which imparts a blackish color and diminishes translucency. Hübnerite's unusual density (specific gravity 7.1-7.5) is due to the high atomic weight of its primary metal component tungsten. Hübnerite occurs most often in high-temperature, hydrothermal veins, and to a much lesser extent in granite pegmatites. Particles of hübnerite separated from weathered or eroded veins have sufficient density to concentrate in secondary, alluvial deposits, which are sometimes of economic importance.

COLLECTING LOCALITIES: Notable hübnerite localities are found in La Libertad, Dos de Mayo, and Huarochiri provinces, Peru; Bustillos Province, Bolivia; the states of Durango and Chihuahua, Mexico; Maramures County, Romania; Cornwall, England; Elba Island, Italy; Salzburg, Austria; Saxony, Germany; and Auvergne, France. Other sources are in Australia, Russia, China, and Sweden. In the United States, hübnerite specimens are collected in California, Colorado, North Carolina, New Jersey, and South Dakota.

HISTORY, LORE, & GEMSTONE/TECHNOLOGICAL USES: In the 1500s, German tin miners noted a strange mineral known as *wolfram* that interfered with the smelting of tin ores. In 1785, chemists demonstrated that this mineral contained the newly discovered metallic element tungsten. In the 1860s, American researchers proved that *wolfram* was actually a solid-solution series consisting of manganese iron tungstate, of which hübnerite was the tungsten-rich end member and ferberite was the iron-rich end member. Hübnerite is a minor ore of tungsten, a metal that has an extraordinarily high melting point and many uses in science and industry.

ABOUT OUR SPECIMENS: Our specimens were collected at the Mundo Nuevo Mine, a part of the Huayllapon mine group in the Pasto Bueno district, near Huamachuco, Sanchez Carrion Province, La Libertad Department, Peru. The Pasto Bueno district is located in northwestern Peru in the northernmost extension of the Cordillera Blanca, a major sub-range of the Andes. Elevations within the 30-square-mile district range from 10,000 feet to nearly 16,000 feet above sea level. The Pasto Bueno district had been mined sporadically for zinc, lead, and small amounts of silver since the early 1800s. After tungsten was discovered in the district in 1910, the Huayllapon Mine and a mill were developed in the late 1930s. The Pasto Bueno deposit is a mineralogically complex, extensive, vein-type tungsten deposit emplaced within quartz-monzonite country rock. The Mundo Nuevo and other small underground mines were developed in the 1970s as part of an expansion program to supplement the production of the Huayllapon Mine. By the time an act of sabotage ended operations in the Pasto Bueno district in 1991, the Huayllapon mine group had produced more than six million tons of tungsten ore and the district had gained a worldwide reputation as a source of fine mineral specimens. In 2005, the Canadian-based mining company Malaga, Inc., acquired part of the Pasto Bueno district and has invested more than $20 million to reopen the tungsten mines. Geologists have already identified 85 tungsten-bearing veins with an average grade of 0.05 percent tungsten. Production is now approaching 500 tons of ore per day and reserves are sufficient for at least 12 years of mining, during which time about 800 tons of tungsten metal will be produced annually.

10 YEARS AGO IN OUR CLUB: Jarosite, Lavrion (Laurium) District, Attika Prefecture, Greece. We were pleased to obtain sufficient pieces to feature this Potassium Iron Sulfate Hydroxyl mineral in 2000, not because the specimens were particularly pretty (they weren't, just small brown crystals on brown matrix), but because we could research and discuss the history and importance of the Laurium District, which the *Mineralogical Record* calls "one of the most unique mineral localities in the world." Unfortunately, we lost our original write-up in a computer crash back around 2000, or we'd put it on our web site for you to see.

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COMPREHENSIVE WRITE-UP

COMPOSITION

The chemical formula $MnWO_4$ identifies hübnerite as a manganese tungstate containing the elements manganese (Mn), tungsten (W), and oxygen (O). Hübnerite's molecular weight is made up of 18.14 percent manganese, 60.72 percent tungsten, and 21.14 percent oxygen. The cation (positively charged ion) of the hübnerite molecule consists of a manganese ion Mn^{2+} with its +2 charge. The compound anion (negatively charged ion) is the tungstate radical $(WO_4)^{2-}$. Radicals are groups of atoms that act as entities in chemical reactions. The tungstate radical consists of a tungsten ion W^{6+} covalently bound to four oxygen ions $4O^{2-}$ The resulting collective -2 anionic charge balances the +2 cationic charge to provide the hübnerite molecule with electrical stability.

Hübnerite is one of 49 members of the Molybdates and Tungstates mineral class, which has two subclasses: the 23-member Anhydrous Molybdates and Tungstates, and the 26-member Basic and Hydrous Molybdates and Tungstates. As an anhydrous tungstate, hübnerite contains neither hydroxyl ions $(OH)^{1-}$ nor attached water molecules (H_2O). The core of the hübnerite molecule is the tungstate radical $(WO_4)^{2-}$, which forms a distorted tetrahedral structure with four oxygen ions occupying the four tetrahedral corners surrounding a tungsten ion. Each oxygen ion shares electrons with, and is covalently bound to, the tungsten ion. Because the four oxygen ions collectively share the resulting -2 charge, the tungstate radical can bond ionically (opposite charges attract) with various metal cations. In hübnerite, the tungstate radical bonds with the divalent manganese ion Mn^{2+}. Repetitive bonding forms a three-dimensional, layered lattice structure held together by ionic bonds. Because these ionic bonds are weak, hübnerite is relatively soft at Mohs 4.0-4.5. Hübnerite exhibits its perfect, single-direction cleavage along the single plane in which ionic distance is greatest and the ionic bonding is therefore the weakest.

Hübnerite crystallizes in the monoclinic system, which is characterized by three axes of different lengths, two of which are perpendicular. The third axis is not perpendicular to either of the other two, but makes an angle that imparts a deformed (flattened) orthorhombic shape to the resulting crystals. Common monoclinic forms are prisms that are oriented and elongated in the direction of one axis, a habit that is seen in the elongated, often-flattened prisms of hübnerite. Minerals with complex chemistries or bonding arrangements commonly crystallize in the monoclinic system.

As an idiochromatic (self-colored) mineral, hübnerite's color is caused by its elemental components and the nature of its crystal structure. When nearly pure, the essential element manganese imparts a red or reddish-brown color and also causes the characteristic, deep-red, internal reflections seen in transparent or translucent hübnerite. When nearly pure, hübnerite can often be transparent. But hübnerite almost always contains varying and sometimes substantial amounts of iron that create a blackish color and diminish the degree of translucency. Many hübnerite specimens contain sufficient amounts of iron to impart a nearly opaque property to crystals. Small amounts of accessory elements such as lead, chromium, molybdenum, and titanium impart their own chromophoric effects that provide hübnerite with colors ranging from red, reddish-brown, and brownish-yellow to brownish-black and near-black.

Hübnerite is among the densest of all translucent minerals. Its high specific gravity (7.1-7.5) is due to the very high atomic weight of its primary metal component tungsten (183.85). The variation in the specific gravity of hübnerite is due to the presence of varying amounts of iron and other accessory elements. Hübnerite's great density imparts a very high index of refraction of 2.170-2.320. Index of refraction is a measure of a crystal's ability to refract or bend light. The index of refraction of any transparent or translucent object is the ratio of the speed of light in air to the speed of light in the crystal. Hübnerite's index of refraction of 2.170-2.320 means that light travels that many times faster in air than it does while passing through a hübnerite crystal. Hübnerite's index of refraction is considerably higher than that of most other minerals and approaches that of diamond (2.417–2.419).

The Dana mineral-classification number 48.1.1.1 identifies hübnerite as an anhydrous molybdate or tungstate (48). Its subclassification (1) defines it by the general formula AXO_4, in which "A" can be manganese, iron, or zinc, while "X" is tungsten. Hübnerite is then assigned to the wolframite group (1) as the first (1) of three members. The other two members are ferberite [iron tungstate, $FeWO_4$] and sanmartinite [zinc iron tungstate, $(Zn,Fe)WO_4$]. Ferberite forms a graded, solid-solution series with hübnerite through cationic substitution in which the divalent (ferrous) iron ion Fe^{2+} replaces the divalent manganese ion Mn^{2+}. In hübnerite, manganese makes up at least 80 percent of the cation; in ferberite, iron makes up 80 percent of the cation. The manganese-rich, hübnerite end-member of this series tends to have reddish, reddish-brown, or near-black colors, while the iron-rich, ferberite end-member is distinctly black. Darker colors in hübnerite specimens indicate the increasing substitution of iron ions. The intermediate stages of the hübnerite-ferberite solid-solution series are known as "wolframite" and are the most abundant. Wolframite, a term that is not a formal mineralogical name, is represented by the variable chemical formula $(Fe,Mn)WO_4$. Hübnerite is much more common than ferberite, but not nearly as abundant as wolframite. Ferberite and the intermediate wolframite grades are weakly magnetic, a property that is useful in concentrating wolframite ores as the first step in the recovery of tungsten.

Hübnerite occurs mainly in high-temperature, hydrothermal vein deposits and is associated with quartz [silicon dioxide, SiO_2]; cassiterite [tin oxide, SnO_2]; arsenopyrite [iron arsenic sulfide, FeAsS]; hematite [iron oxide, Fe_2O_3]; tourmaline (a complex group of sodium aluminum borosilicates); topaz [basic aluminum fluorosilicate, $Al_2SiO_4(F,OH)_2$]; and fluorite [calcium fluoride, CaF_2]. Particles of hübnerite separated from weathered or eroded veins have sufficient density to concentrate in secondary, alluvial, placer-type deposits, which are sometimes of economic importance. Hübnerite also forms in granite pegmatites.

COLLECTING LOCALITIES

Hübnerite is an uncommon mineral with relatively few important collecting localities. Our specimens are from a classic hübnerite locality—the Mundo Nuevo Mine, which is part of the Huayllapon mine group in the Pasto Bueno district, near Huamachuco, Sanchez Carrion Province, La Libertad Department, Peru. Other Peruvian sources include the Huanzala Mine in the Huallanca district, Dos de Mayo Province, Huánuco Department; and the Casapalca Mine at Casapalca, Huarochiri Province, Lima Department. In neighboring Bolivia, hübnerite is collected at the Siglo Veinte Mine at Llallagua, Bustillos Province, Potosí Department. Mexican specimens come from the Flaca Mine at Rodeo, Durango, and El Potosí Mine in the Santa Eulalia district, Aquiles Serdán, Chihuahua.

In Europe, hübnerite specimens are collected at the Cavnic Boldut Mine at Baia Sprie, Maramures County, Romania; the Hingston Down Quarry in the Gunnislake area of the Callington district, Cornwall, England; the Rosina Vein at Campo Nell'Elba on Elba Island, Livorno Province, Tuscany, Italy; the Western Ore scheelite deposit in the Felben Valley of the Hohe Tauern Mountains, Salzburg, Austria; the Lengenfeld wolframite mine in the Johanngeorgenstadt district at Erzegebirge, Saxony, Germany; the Man and Lil mines in the Nyborg ore field at Lindesberg, Västmanland, Sweden; and the Le Mazet Vein at Allier, Auvergne, France.

Other hübnerite sources include the Elliots Wolfram Mine in Clyde County, New South Wales, Australia; the Yaogangxian Mine in Yizhang County, Chenzou Prefecture, Hunan Province, and the Duoluoshan Mine in Hauiji County, Zhaoqing Prefecture, Guangdong Province, both in China; the Tanakayiyama Mine at Otsu, Shiga Prefecture, Kinki Region, Honshu Island, Japan; and the Alyaskitovoye tin-tungsten deposit at Ust-Nera', Saha Republic, Eastern-Siberian region, and the Kalgutinskoye tungsten-molybdenum deposit at Kalgutinskoye, Altai Republic, Western-Siberian region, both in Russia.

In the United States, hübnerite is collected in Arizona at the Primos mine group at Dragoon in the Cochise district in the Little Dragoon Mountains of Cochise County; and at the Williams and Jewel tungsten mines in the Williams Camp area of the Aquarius Mountains in Mohave County. Fine specimens come from the Advance Mine in the Monitor-Mogul district, Alpine County, California. Colorado localities include the mines of the Boulder tungsten district, Boulder County; the Camp Bird Mine at Ouray in the Sneffels district in Ouray County; and the Sunnyside Mine at Howardsville in the Silverton District of San Juan County. Other notable sources are the Blue Wing district mines in Lemhi County, Idaho; the River and Apex No. 2 shafts in the Fredericktown district of Madison County, Missouri; the hübnerite type locality at the Erie and Enterprise veins in the Ellsworth Mine, Ellsworth district, Nye County, Nevada; the Franklin Mine at Franklin, Franklin district, Sussex County, New Jersey; the Questa molybdenum mine at Questa, Taos County, New Mexico; the Tungsten Queen Mine at Townsville, Vance County, North Carolina; the Comstock and Two Bit mines in the Two Bit district, Lawrence County, South Dakota; the Cave Creek deposit at Sierra Diablo, Culberson County, Texas; and the Blue Grouse tungsten mine at Deer Lake, Stevens County, Washington.

JEWELRY & DECORATIVE USES

Although hübnerite is too soft and brittle for general jewelry use, well-formed, bladed crystals are occasionally wrapped in silver wire for wear as pendants. Hübnerite specimens, most often composites in association with clear quartz, are valued by collectors for their rarity, distinctive crystal forms, and unusual colors. Hübnerite from Peru's Pasto Bueno district, the source of our specimens, is especially in demand; composite hübnerite-quartz specimens from the Pasto Bueno district measuring just two inches square can cost as much as $100 each!

HISTORY & LORE

In the 1500s, German tin miners noted that a strange mineral associated with tin ores formed a surface scum that reduced tin recovery. German scholar and mining author Agricola (Georg Bauer, 1494-1555), named this mineral "*volfram*," from v*olf*, or "wolf," and *rahm*, meaning "cream" or "froth," an allusion to the troublesome smelting froth that "devoured tin like a wolf." This name was later anglicized to "wolfram." In 1785, the Spanish chemists Juan José d'Elhuyar (1754-1796) and Fausto d'Elhuyar (1755-1833) demonstrated that the newly discovered element tungsten (see "About Tungsten") was present in wolfram. For the next six decades, mineralogists assumed that wolfram—manganese iron tungstate—was a single mineral.

In 1860, amateur German mineralogist Moritz Rudolph Ferber (1805-1875) studied wolfram specimens collected in Spain and Chile by his son, mining engineer Johann Hermann Ferber (1836-1861). His analyses showed that these specimens consisted almost entirely of iron tungstate, and thus represented a new mineral. In 1863, German mineralogist August Breithaupt (1791-1873) confirmed Ferber's findings and named the new mineral in his honor—ferberite. In 1865, San Francisco-based American mining engineer Eugene N. Riotte studied wolfram specimens collected from the Erie and Enterprise veins in the Ellsworth Mine in the Ellsworth district in Nye County, Nevada, and found that they consisted almost entirely of manganese tungstate and thus represented a new mineral, which he named hübnerite in honor of German mining engineer and metallurgist Friedrich Adolph Hübner (1802-1872). Mineralogists then accepted hübnerite and ferberite as the end members of a solid-solution series. The intermediate grades of this solid-solution series were informally named wolframite, after the old German *wolfram*. The similar atomic structures of hübnerite and ferberite were defined by X-ray diffraction methods in 1922.

Wolframite was featured on the 20-yuan postage stamp of China in 1982. According to modern metaphysical belief, hübnerite enhances creative thinking and promotes the insight necessary for rapid and confident decision-making.

TECHNOLOGICAL USES

Although hübnerite has no technological uses on its own, it is a minor ore of tungsten. With its great hardness and extraordinarily high melting point, tungsten has many important industrial and consumer uses (see “About Tungsten”).

ABOUT TUNGSTEN

Wolframite, the intermediate stage of the hübnerite-ferberite solid-solution series, is the primary ore of tungsten; hübnerite is a minor ore of tungsten. Tungsten, a remarkable metal with many extraordinary properties, does not occur free in nature. It is uncommon, ranking 59th in crustal abundance among the 92 natural elements, making it only a bit more common than silver. In its elemental form, tungsten is a heavy, silvery-white metal with a metallic luster. Among the densest of all metals, its specific gravity of 19.3 is comparable to that of gold. Tungsten’s melting point of 6,170˚ F. (3,410˚ C.) is the highest of all metals and more than twice that of iron; its boiling point of 10,031˚ F. (5,555˚ C.) approaches the temperature of the surface of the sun. Despite its extreme hardness, tungsten is so brittle that it can be cut with a hacksaw. Of the relatively few tungsten-containing minerals, wolframite, hübnerite, and scheelite [calcium tungstate, $CaWO_4$] are the only ores.

In 1758, Swedish chemist Axel Fredrik Cronstedt (1722-1765) described a heavy, calcium-containing mineral which he named *tung-sten*, Swedish for “heavy stone,” and suspected that it contained a new metallic element. In 1781, another Swedish chemist, Carl Wilhelm Scheele (1742-1786), confirmed Cronstedt’s suspicion by isolating the new metal’s oxide from a compound that he called tungstic acid. In Scheele’s honor, the original mineral, a calcium tungstate with the chemical formula $CaWO_4$, was named “scheelite.” Two years later, Spanish chemist Fausto d’Elhuyar (1755-1833) prepared tungstic acid from the old German *volfram* (See “History & Lore”). D’Elhuyar then isolated the new metal and named it tungsten, after the Swedish *tung-sten*. The word “tungsten” has become standard in most nations, but Germany and several other nations still use the traditional “wolfram,” which is the origin of tungsten’s chemical symbol, W.

Initially, tungsten was prohibitively expensive and could be obtained only as a by-product of tin smelting. In the 1860s, British researchers improved recovery methods and prepared iron-tungsten alloys that were hard enough to cut steel. Despite tungsten’s obvious industrial potential, it remained a laboratory curiosity until the early 1900s, when metallurgists sought a suitable filament material for incandescent lightbulbs. Tungsten proved ideal because of its extremely high melting point; high output of incandescent light per watt of electricity; and its ability to maintain excellent electrical conductivity at elevated temperatures. But tungsten was nearly impossible to melt and too hard and brittle to draw into the hairlike filaments needed for incandescent lightbulbs. Finally in 1907, William D. Coolidge (1873-1975), an electrical engineer with the General Electric Company in Schenectady, New York, prepared a ductile tungsten wire by chemically treating powdered tungsten oxide, then reducing it to metallic tungsten and forging it into thin rods with heat and pressure. He then drew these rods in stages through progressively smaller diamond dies to produce uniform, hair-thin tungsten filaments. By 1910, the General Electric Company had begun to mass-produce incandescent lightbulbs by the millions, employing cheap, reliable tungsten filaments that glowed brightly and lasted for hundreds of hours.

At about the same time, tungsten's potential as an alloying metal was also fulfilled. In 1900, the Bethlehem Steel Company introduced the first "high-speed," tungsten-steel alloys that retained sharpness and rigidity even at the elevated temperatures encountered in high-speed machining. In the 1920s, German metallurgists developed tungsten carbide, a synthetic tungsten-carbon compound many times harder than high-speed tungsten steels. Metallurgists then learned to sinter powdered tungsten-carbide particles with heat and pressure to produce an extraordinarily hard, tough solid called cemented carbide, or "hardmetal." Hardmetal revolutionized the metalworking industries while upgrading the quality and reducing the cost of countless consumer and industrial products. Metallic tungsten was subsequently applied to everything from automotive distributors to arc-welding electrodes. During World War II, tungsten, tungsten steels, and hardmetal were assigned a strategic priority second only to uranium, which was needed for the development of the atomic bomb. After World War II, tiny hardmetal roller balls—the only material that did not deform or abrade even with extended use—made possible the development of the ballpoint pen.

Today, 75 percent of all tungsten goes into hardmetal and tungsten-steel alloys, including super alloys for turbine and rocket applications. Another 12 percent is used to manufacture tungsten filaments for tungsten-halogen lightbulbs, automotive headlamps, movie and audio-visual projectors, video-camera lights, fiber-optical systems, airport runway lights, photocopiers, stage lights, outdoor security lights, cathode-ray emitters for televisions, electron guns for scientific instruments, and X-ray generators for medical and industrial use. The remainder is used in welding electrodes and electrical components for high-temperature ovens, and in chemicals for catalysts, dyes and pigments, corrosion-resistant coatings, and special lubricants.

About 37,000 tons of metallic tungsten are mined each year, a very small amount when compared to the production of other base metals. Nevertheless, tungsten mining, milling, and processing is a billion-dollar-per-year industry that employs some 7,000 workers. China now mines 75 percent of the world's tungsten, followed by Austria, Bolivia, Portugal, and Russia. Refined tungsten metal, such as that used in lightbulb filaments, currently costs about $55 per pound. The United States, the world's largest consumer of tungsten, has only one small, tungsten-producing mine in California. Interestingly, tungsten—in the form of tungsten carbide or hardmetal—has recently become a jewelry "metal" for rings. Because of its great hardness, hardmetal polishes to a gleaming silver–gray color and has a spectacular luster and is virtually scratch-proof, even in the roughest, everyday wear.

ABOUT OUR SPECIMENS

As noted, our specimens were collected at the Mundo Nuevo Mine, a part of the Huayllapon mine group in the Pasto Bueno district, near Huamachuco, Sanchez Carrion Province, La Libertad Department, Peru. Older publications list this locality as being in Pallasca Province, Ancash Department–Huamachuco is near the border of these two provinces, and so we are going with the locality information given us by our supplier, who best know the area. La Libertad, meaning "freedom" is Spanish, is the only Peruvian department that reaches Peru's three natural regions–coast, mountains, and rain forest. This department covers an area of about 25,000 square kilometers. The Pasto Bueno district is in the northernmost extension of the Cordillera Blanca, a sub-range of the Andes just west of the Continental Divide. The 30-square-mile district, located at 8.80 degrees south latitude and 77.42 degrees west longitude, is 50 miles from the Pacific Coast. Elevations within the district range from 10,000 to 16,000 feet above sea level.

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The Pasto Bueno district had been mined sporadically for zinc, lead, and small amounts of silver since the 1800s. In the early 1900s, high demand for tungsten for use in newly developed incandescent lightbulbs and high-speed, machine-tool alloys (see "About Tungsten") spurred a worldwide search for tungsten deposits. Exploration geologists reevaluated many old mining districts and, in 1910, discovered an extensive system of high-grade vein deposits of wolframite at Pasto Bueno that had been emplaced within quartz-monzonite country rock. Mineralization had occurred during the crustal fracturing associated with the uplift of the Andes some 60 million years ago when mineral-rich hydrothermal solutions surged upward into fractures in four separate events, each precipitating an array of minerals. The first surge emplaced molybdenite [molybdenum disulfide, MoS_2] and pyrite [iron disulfide, FeS_2]. The second deposited wolframite (including hübnerite); tetrahedrite [copper iron zinc antimony arsenic sulfide, $Cu_{10}(Fe,Zn)_2(Sb,As)_4S_{13}$]; chalcopyrite [copper iron sulfide, $CuFeS_2$]; and pyrite. The third hydrothermal surge emplaced galena [lead sulfide, PbS]; sphalerite [zinc sulfide, ZnS]; and tennantite [copper iron zinc arsenic antimony sulfide, $Cu_{10}(Fe,Zn)_2(As,Sb,)_4S_{13}$]. The final surge deposited fluorite [calcium fluoride, CaF_2] and various carbonates, including rhodochrosite [$MnCO_3$]. The late deposition phases of each of these mineralization events were accompanied by gases that created vugs or cavities in the veins to provide space for unrestricted crystal growth and the development of fine mineral specimens.

High elevations, rugged topography, and poor road access delayed development at Pasto Bueno until 1934, when the Peruvian mining company Fermin Malaga Santolalla y Hijos was established to mine the deposits. After Santolalla had developed the Huayllapon Mine, the camp of Pasto Bueno, and a hydroelectric plant to provide power for mining and milling operations, production began in 1941. By the 1970s, Santolalla had also developed the Tamboras, La Magistral, and Mundo Nuevo mines along the extensive vein system to supplement production from the Huayllapon Mine. A single mill with a capacity of 500 tons of ore per day processed all ores. By 1990, Santolalla had mined approximately six million tons of tungsten ore. But on February 14, 1991, guerillas of *Sendero Luminoso* or Shining Path, a Communist movement committed to the armed overthrow of the Peruvian government, blew up the mine's hydroelectric plant. Production dropped to a mere 50 tons of ore per day. In less than a year, all operations ceased and the mines and camps were abandoned.

In 2005, the Canadian-based mining Company Malaga, Inc. (MLG, Toronto Stock Exchange) acquired part of the Pasto Bueno district and has since invested more than $20 million to reopen the Huayllapon-group tungsten mines, replace the hydroelectric plant, and build a new central camp at the village of Consuzo, along with satellite camps in the Huayllapon, Huaura, Maria Ofelia, and Mundo Nuevo sections of the district. Mine production began in 2007 at the rate of 200 tons of ore per day and has now increased to 375 tons. By 2011, Malaga will increase production to 500 tons of ore per day, construct a second hydroelectric plant, and complete a core-drilling exploration program (involving seven miles of cores drilled through 16 boreholes) to delineate the full extent of the wolframite veins. Malaga has now identified 85 tungsten-bearing veins with an average grade of 0.05 percent tungsten. Total ore reserves and resources (tungsten mineralization projected to be reclassified as ore) is now pegged at 1.8 million tons, enough for at least 12 years of mining. After the tungsten ore has been crushed and ground to a powder, the tungsten-bearing minerals are concentrated by washing in a simple, gravity-separation process. This initial concentrate is dried and passed under powerful magnets that separate the weakly magnetic wolframite particles. The final concentrate contains 75 percent tungsten metal. When working at capacity, Malaga's Pasto Bueno operations will produce concentrate containing about 800 tons of tungsten metal each year.

The Huayllapon Mine and the Pasto Bueno district are famous for fine mineral specimens, especially those of pyrite, hübnerite, and rhodochrosite; both also played an important role in establishing Peru as a commercial specimen source. In the early 1960s, Peruvian entrepreneurs had just begun to sell fine pyrite specimens to foreign visitors and middle-class Peruvian collectors in the marketplaces of the capital city of Lima. The Huayllapon Mine was one of the first important specimen sources for these pyrite marketers, who became known as *piriteros.* In the late 1960s, Huayllapon miners found spectacular specimens of rhodochrosite. *Piriteros* brought these specimens to Lima where they quickly attracted international attention. After dealers and collectors flocked to Peru, the Huayllapon Mine, the Pasto Bueno district, and the nation itself became recognized as a world-class commercial source of mineral specimens.

The Pasto Bueno district again attracted international attention in the mid-1970s when tungsten miners in the Huayllapon Mine and the adjacent Mundo Nuevo Mine blasted into vugs containing spectacular crystals of hübnerite associated with clear quartz prisms. These specimens, among the best hübnerites ever found, made their debut at international mineral shows in 1977 and received prominent mention in *The Mineralogical Record*. Other fine hübnerite specimens were recovered from the Huayllapon and Mundo Nuevo mines during the 1980s. This supply stopped, however, when rebel guerillas destroyed the Pasto Bueno hydroelectric plant in 1991. But with the reopening of the Pasto Bueno mines in 2007, fine hübnerite specimens are again reaching world markets. Our specimens were collected in 2009 by tungsten miners in the Mundo Nuevo Mine. Following the established Peruvian trade channels, miners sold these specimens to *piriteros* who in turn brought them to Lima. We obtained them from a Peruvian family in Tucson who specialize in Peruvian minerals.

Our composite specimens consist of hübnerite and clear quartz crystals, a common mineralogical association in hübnerite specimens from the classic Pasto Bueno locality. Our specimens have three distinct parts: a base of wall rock; a layer of massive, white quartz; and a section of finely developed crystals of hübnerite and clear quartz. The base of the specimen is a cream-colored, medium-grained quartz monzonite, a silica-rich, igneous rock that is chemically and structurally similar to granite. At Pasto Bueno, quartz monzonite is the country rock that hosts the wolframite veins. In our specimens, the quartz monzonite is part of the wall of the vug that provided the space for the growth of internal crystals. This wall rock is covered by a layer of massive, white quartz, atop which are the hübnerite and quartz crystals.

In studying your specimen, note first the flattened, blade-like prisms of near-black hübnerite with their wedge-like terminations. Note also the longitudinal striations that appear as parallel lines on the prism faces—a diagnostic feature of hübnerite. The near-black color and near opacity of the crystals indicate a significant iron content that exceeds 10 percent, a composition that is typical of Pasto Bueno hübnerite specimens. Despite this dark color, it may still be possible to detect some translucency and deep-red, internal reflections in thin crystals with the help of strong backlighting. Now turn your attention to the superbly developed, terminated prisms of clear quartz. In the hydrothermal deposition sequence, hübnerite was deposited first and quartz second, a sequence that is apparent as the quartz crystals overgrow the hübnerite crystals. Some quartz crystals may be phantoms—crystals that exhibit the internal outlines of smaller crystals. Backlighting may reveal these phantom structures within certain quartz prisms—an indication that the final silica deposition occurred in separate, multiple phases.

MINERAL COLLECTING AND THE ECONOMIC MELTDOWN

Has there been any upside to the economic turmoil unleashed on all of us since October 2008? One positive effect may be that it has forced many of us to downsize our spending and focus on what is most important in life–family, friends, our relationship with our Creator, and of course, mineral collecting. One has only to travel to Tucson in February to see that mineral sales in general are down significantly, particularly on the wholesale level. This makes sense, since if retail buyers are buying less at stores, than stores will usually be buying less from wholesale dealers and importers. This leaves wholesale dealers and importers with excess inventory on their hands, and the best (and sometimes only) way to move the material is by discounting it. This is where we as Club members have benefitted from current conditions: more supply, less demand equals better prices for us collectors!

November 2010 Mineral of the Month: Hübnerite

As you can probably imagine, we spend a considerable amount of time every year in Tucson looking for large lots of minerals we can purchase for use in our Club. We need five to six hundred pieces of the same mineral from the same locality in order to feature it. And we need pieces of roughly similar size and quality for our Gold- and Silver-level members, and as we usually explain to prospective suppliers, our Club members are spoiled–that is, they are used to receiving a mineral that would typically sell for considerably more than what they cost through our Club.

Pre-collapse, many dealers were unwilling to work with us, perhaps confident they could sell their material for more elsewhere. But due to current economic conditions, we have been able to obtain several minerals that would normally have been well outside our price range. If you think back to the minerals we have sent you this year, and what we have coming up, you may appreciate some of the bargains you have received!

And as you gradually build your collection, keep in mind that if you keep it organized and in good condition, the value of your collection may grow substantially over the years. Let's use this month's specimen as an example. Right now, the mines of the Pasto Bueno district are producing a fair quantity of collectible specimens. But how long will they continue doing so? Some areas continue to produce for decades, while others shut down abruptly, for financial or other reasons. Each deposit is by definition finite. When the Pasto Bueno district eventualy stops producing, as it will, then your hübnerite specimen will begin to increase in value. As the years go by with no more Peruvian hübnerite on the market, it will continue to appreciate. We have seen specimens purchased for a few dollars in the 1940's and 1950's that have sold for thousands now! Of course, such great increases are the exception rather than the rule.

Longtime Club members, think back on some of the minerals we have sent you from mines that are now closed or have stopped producing–Sweet Home rhodochrosite, Wah Wah Mountains Utah red beryl, Chinese realgar, Brushey Creek marcasite on calcite, Russian charoite, Naica anhydrite, African diamonds, to name just a few. All of these have no doubt increased in value since you received them ten years ago or so, and will continue to do so, unless somehow these localities start producing again. (We hear from our Russian sources that the charoite locality, for example, still contains lots of exceptional material, but that no one wants to spend the money necessary to restart production in the remote part of Siberia where it is found.)

But to keep your collection increasing in value you must keep it in good order! Do you keep your labels with your minerals? Do you store or display them in such a way that they cannot get damaged? Have you created a database (or at least a log) of what you have in your collection, where it is from, where you obtained it, and for how much? Most specimens that are resold along with their original label sell for more that they would otherwise. Even a full set of Mineral of the Month Club minerals may have a high value someday! Regardless of how much our collection might appreciate, it brings us satisfaction now to examine our specimens and contemplate their unique history and properties!

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