

## February 2008 Mineral of the Month: Arsenopyrite

Our specimens of this month's mineral, arsenopyrite, were collected at a classic locality in the People's Republic of China. Arsenopyrite is the most abundant of the more than 100 minerals that contain arsenic, several of which we have featured through the years. Read on to learn more about this fascinating and mysterious element.

### PHYSICAL PROPERTIES

Chemistry: FeAsS      Iron Arsenic Sulfide (Iron Arsenosulfide, Iron Arsenide Sulfide, Iron Sulfoarsenide), often containing cobalt

Class: Sulfides

Group: Arsenopyrite

Crystal Class: Monoclinic (previously considered orthorhombic)

Crystal Habits: Distinct prismatic with diamond cross sections and dome-shaped terminations; also massive, granular, compact, and columnar; faces usually striated; twinning common, often forming crosses and stars.

Color: Silver-white to steel-gray, tarnishes dark gray.

Luster: Metallic

Transparency: Opaque

Streak: Grayish-black

Cleavage: Distinct in one direction.

Fracture: Uneven, brittle.

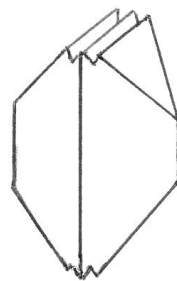
Hardness: 5.5-6.0

Specific Gravity: 5.9-6.2

Luminescence: Triboluminescent

Distinctive Features and Tests: Crystal shape, high density, color and metallic luster, triboluminescence, and emission of a bitter, garlic-like odor when crushed.

Dana Classification Number: 2.12.4.1



**Figure 1.**  
Arsenopyrite crystal.

### NAME

Because of its arsenic content and pyrite-like metallic luster, this mineral was long known as “arsenical pyrite.” The current name “arsenopyrite,” pronounced arr-seh-no-PIE-rite, is a contraction of the original name. Other names for arsenopyrite include “arsenical iron,” “arsenkies,” “arsenomarcasite,” “dalarnite,” “plinian thalheimite,” and “mispickel.” A cobalt-rich variety is known as “danaite” or “cobaltoan arsenopyrite.” In contemporary European mineralogical literature, arsenopyrite appears as *arsenopyrite*, *arsenopyrita*, and *arsenikkis*.

### COMPOSITION

So far, we have featured As<sub>4</sub>S<sub>4</sub> (realgar, August 1996), As<sub>2</sub>S<sub>3</sub> (orpiment, November 1997 and May 2005), and FeS<sub>2</sub> (as the polymorphs pyrite, March 1996, October 2003, and March 2006, and marcasite, February 1997). Now we feature a mineral containing all three elements (FeAsS) and several singular properties as a result. Of arsenopyrite's total molecular weight, iron makes up 34.30 percent, arsenic 46.01 percent, and sulfur 19.69 percent. Within the arsenopyrite molecule, iron is present in the ferric oxidation state Fe<sup>3+</sup>. Molecules consists of cations (positively charged ions) bound to anions (negatively charged ions). In arsenopyrite, the double cation consists of one ion each of trivalent iron (Fe<sup>3+</sup>) and trivalent arsenic (As<sup>3+</sup>), while the anion consists of one ion of sulfur in the -2 oxidation state. The collective +6 cationic charge (Fe<sup>3+</sup> + As<sup>3+</sup>) balances the -6 charge of the sulfur anion S<sup>2-</sup> to provide the arsenopyrite molecule with electrical stability.

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Because arsenic is a semimetal or metalloid (see "About Arsenic"), arsenopyrite might seem to qualify as a sulfosalt, a mineral in which sulfur is combined with one or more metals and one or more semimetals. But because in this case arsenic functions as a cation with a positive oxidation state (although it also has several negative oxidation states), and because arsenic occupies distinctly metallic positions within the crystal lattice, arsenopyrite is classified as a sulfide, a mineral in which sulfur is combined with one or more metals. With its high density, brittleness, generally dark color, and metallic luster, arsenopyrite is typical of most of the 350 sulfide minerals.

Strong covalent bonding with shared electrons dominates throughout the arsenopyrite crystal lattice. Each ferric ion ( $\text{Fe}^{3+}$ ) is covalently bonded to an arsenic ion ( $\text{As}^{3+}$ ) and a sulfur ion ( $\text{S}^{6-}$ ) to create a repeating, three-dimensional structure with more-or-less equal bonding strength in all directions. This structure can also be visualized as ferric ions covalently bonded to diatomic arsenic sulfide anions  $[(\text{AsS})^3]$ . Because of this strong, three-dimensional covalent bonding, arsenopyrite shows only distinct cleavage in one direction and considerable hardness (Mohs 5.5-6.0). Arsenopyrite's unusually high specific gravity of 5.9-6.2 is due close atomic packing within the lattice and to the high atomic weights of iron (55.85) and arsenic (74.92).

As an idiochromatic or "self-colored" mineral, arsenopyrite's basic gray-white to steel-gray color is caused by its essential elemental components and the nature of its crystal structure, rather than by nonessential impurities. Except in very thin section, arsenopyrite is opaque, meaning it reflects but does not transmit light. Arsenopyrite's distinct metallic luster is caused by the limited metallic bonding that exists between the ferric and arsenic ions (which exhibit certain metallic properties), and the inability of the sulfur ions to completely shield this bonding. Metallic bonding creates a pool of free-moving electrons, and the manner in which these electrons interact with light accounts for arsenopyrite's opacity, color, and metallic luster. These surface electrons absorb all incident light to become energized. To return to their normal levels, they release excess energy in wavelengths that we perceive as gray-white to steel-gray. And because of the free electrons' constant motion, arsenopyrite's color appears metallic or silvery. This color varies somewhat when nickel and cobalt replace some of the iron, or when the semimetals bismuth and antimony partially substitute for arsenic.

Crystallographers first believed that arsenopyrite crystallized in the orthorhombic system, which is characterized by three mutually perpendicular axes of different lengths. But they later determined that arsenopyrite actually crystallizes in the monoclinic system, which has three axes of different lengths, only two of which are perpendicular. The third axis makes an angle to form what appear to be deformed orthorhombic crystals. Minerals with complex chemistry or bonding, such as complex sulfides, are commonly monoclinic.

Of the more than 100 arsenic-bearing minerals, most are rare. Arsenopyrite, by far the most abundant, commonly occurs in hydrothermal veins in association with quartz [ $\text{SiO}_2$ ], pyrite [iron disulfide,  $\text{FeS}_2$ ], chalcopyrite [copper iron sulfide,  $\text{CuFeS}_2$ ], acanthite [silver sulfide,  $\text{AgS}$ ], gold [Au], and various ore minerals of tin [Sn] and lead [Pb]. It is also found in certain igneous pegmatites in association with quartz, muscovite [potassium aluminum silicate,  $\text{KAl}_2\text{AlSi}_3\text{O}_{10}$ ], and orthoclase [potassium aluminum silicate,  $\text{KAlSi}_3\text{O}_8$ ]. Arsenopyrite is occasionally found in metamorphic and metasomatic zones (metamorphic areas in which new minerals have been introduced). Arsenopyrite has an unusual affinity for gold and is often found in gold deposits, where it adsorbs microscopic particles of native gold onto its surface.

Arsenopyrite exhibits triboluminescence, one of several types of mineral luminescence. Luminescence occurs at ambient temperatures in certain minerals when the absorption of electromagnetic, thermal, radiant, or mechanical energy excites electrons, boosting them from normal-energy inner orbits to high-energy outer orbits. As these electrons fall back to their normal orbits, they release excess energy in the form of visible light, even after the energy input has been discontinued. Arsenopyrite exhibits

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triboluminescence (also called “mechanoluminescence” or “fractoluminescence”) when scratched, broken, crushed, or cleaved. As the mechanical energy breaks atomic bonds, it also excites electrons which release excess energy as tiny, bright flashes of white and yellow light.

Another of arsenopyrite’s diagnostic properties is the emission of a garlic-like odor when crushed. This occurs when mechanical stresses break the arsenic-sulfur bonds leaving free arsenic ions, some of which immediately combine with atmospheric oxygen to form arsenic trioxide [As<sub>2</sub>O<sub>3</sub>], which has that distinctive, garlicky odor.

The Dana classification number 2.12.4.1 first establishes arsenopyrite as a sulfide (2). Arsenopyrite is subclassified (12) by the general formula A<sub>m</sub>B<sub>n</sub>X<sub>p</sub>, in which “A” can be a metal such as iron, cobalt [Co], nickel [Ni], or the platinum-group metals iridium [Ir], ruthenium [Ru], or osmium [Os]; “B” is the semimetal arsenic or antimony [Sb]; and “X” is sulfur. In the general formula A<sub>m</sub>B<sub>n</sub>X<sub>p</sub>, the ratio of m+n:p can be 1:2 or 2:1, the latter being apparent in the arsenopyrite formula FeAsS. Finally, arsenopyrite is a member of the arsenopyrite group (4) as the first (1) of six members. Other group members include gudmundite [iron antimony sulfide, FeSbS], osarite [osmium ruthenium arsenide, (Os,Ru)As<sub>2</sub>], ruarsite [ruthenium arsenic sulfide, RuAsS], iridarsenite [iridium ruthenium arsenide, (Ir,Ru)As<sub>2</sub>], and clinosafflorite [cobalt iron nickel arsenide, (Co,Fe,Ni)As<sub>2</sub>].

**While arsenopyrite is toxic because of its arsenic content, it is chemically stable and does not constitute a health hazard under normal conditions of storage and display. Never ingest arsenopyrite particles or inhale arsenopyrite dust, and wash hands after handling the specimen. Never attempt to heat or crush an arsenopyrite specimen.**

### *COLLECTING LOCALITIES*

Our specimens were collected at a classic arsenopyrite locality—the Yaogangxian tungsten mine near Yaogangxian in Yizhang County, Chenzhou Prefecture, Hunan Province in the People’s Republic of China. China’s Chenzhou Prefecture has other notable arsenopyrite sources, among them the mines of the Xiandong tungsten-tin-copper deposit in Anren County, the Huangshaping lead-zinc-tungsten deposit in Guiyang County, the Chisang and other mines in the Xianghualing tin-polymetallic ore field in Linwu County, the Rucheng Mine in Rucheng County, and the Furong and Shizhuyan tin mines in the Dong Po ore fields in Yizhang County. Other important Hunan localities are the Woxi and Xiangxi gold-antimony-tungsten deposits at Xiangxi in Huaihua Prefecture. In other parts of Asia, arsenopyrite specimens are collected at the Iname Mine at Kita-Shidora-gun in Aichi Prefecture on Japan’s Honshu Island, and at the Dodo and Puiva mines in Tyumenskaya Oblast’ in Russia’s Western-Siberian Region.

In Africa, arsenopyrite specimens are found at the Waaikraal gold deposit at Rustenburg in the Western Bushveld Complex of South Africa’s Northwest Province; in Namibia at the Kombat Mine, Grootfontein District, Otjozondjupa Region, and the Klein Spitzkopje tin mine, Swakopmund District, Erongo Region; and in Morocco at the El Hammam Mine at Meknès, Meknès Prefecture, Meknès-Tifilalet Region.

In Australia, arsenopyrite occurs at the Biggenden Mine, Biggenden Shire, Queensland, and at the Dome Rock copper mine in the Kalibity Homestead area, South Australia. In Papua New Guinea, specimens are collected at the Kainantu gold-bismuth-tungsten-tellurium deposit. South American arsenopyrite specimens come from Bolivia and Peru. Bolivian sources include the Siglo Veinta and Llallagua mines at Llallagua, Bustillos Province, Potosí Department; and the Cerro Tazna Mine in the Atocha-Quechisla Province, Potosí Department. Peruvian specimens come from the Hercules Mine in the Ticapampa District, Recuay Province, Ancash Department; the Julcani Mine in the Julcani District, Angaraes

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Province, Huancavelica Department; and the Huaron District mines at Cerro del Pasco, Alcides Carrión Province, Pasco Department.

Europe's best arsenopyrite specimens come from the Panasquiera Mine at Panasquiera in Portugal's Castelo Branco District. Other notable localities include the mines of the Callington, Cambourne-Reduth-St. Day, Liskeard, Mount's Bay, and St. Agnes mining districts in Cornwall, England; the Madan mines in the Rhodope Mountains in Bulgaria's Plovdiv Oblast; the Konstantin Shaft in the Freiburg District and the Breitenbrunn mines at Altenburg, both near Erzgebirge in Saxony, Germany; and the Baccuolacci Mine at Villaputzu, Sardinia, and the Lacatelli Quarry on Mont Camoscio at Verbano, both in the Verbano-Cusio-Ossolo Province of Piemonte, Italy.

Canadian localities include the Nickel Plate Mine at Hedley in British Columbia's Osoyoos Mining Division; the Cross Lake-O'Brien Mine in the Timiskaming District, Coleman Township, Ontario; and the Lac Nicolet Mine at South Ham, Wolfe County, Québec. Among Mexico's localities are the San Antonio Mine in the Santa Eulalia district, Aquiles Serdán, Chihuahua; the Bonanza and Cobre mines, Concepción del Oro, Zacatecas; the Belém Mine, Onavas, Sonora; and the San Pedro Mine, Real de Catorce, San Luis Potosí.

In the United States, notable arsenopyrite specimens occur at the Flambeau Mine, Ladysmith, Rusk County, Wisconsin; the Lewis and Keeseville mines at Keeseville, Essex County, New York; the Otto, Poor Boy, and Valley mines at Gilham, Sevier County, Arkansas; the lead mines at Bixby in the Viburnum Trend district, Iron County, Missouri; and the Ball Hill quarries at Franklin, Sussex County, New Jersey. Western-state localities include the Zaca and Colossus mines on Colorado Hill in the Monitor-Mogul district, Alpine County, California; the Haines-Stellite cobalt mine in the Blackbird Mining District, Lemhi County, Idaho; and the Mahoney mines in the Tres Hermanas Mining District, Luna County, New Mexico. In Colorado, specimens are found at the El Dorado Mine in the Sneffels Mining District at Ouray in Ouray County, and at Iowa Gulch and Printer Boy Hill in the Leadville Mining District at Leadville in Lake County. Arsenopyrite is also found in many mines in the disseminated-gold belts of Elko and surrounding counties in northern Nevada.

### *JEWELRY & DECORATIVE USES*

Arsenopyrite does not serve as a gemstone. Because of its distinctive crystal form and importance as the most abundant arsenic-containing mineral, arsenopyrite has long been popular among mineral collectors for display and study purposes as both individual and composite specimens.

### *HISTORY & LORE*

Arsenopyrite has been known since antiquity as a source of elemental arsenic. Subjecting arsenopyrite to the heat of a drafted charcoal furnace will break the arsenic-sulfur bonds to yield elemental arsenic according to the formula  $\text{FeAsS} (700^\circ\text{C.}) \rightarrow \text{FeS} + \text{As}$ . The arsenic is freed as a gas and condensed as a solid. Arsenopyrite was known as "arsenical pyrite" from the 14<sup>th</sup> century until 1868, when it received its current name. Although its atomic structure was defined in the 1920s by X-ray diffraction, its crystal system was incorrectly characterized as orthorhombic. Mineralogists did not correctly recognize its monoclinic structure until the late 1960s. Older mineralogical literature and some newer mineral guidebooks continue to list arsenopyrite under the orthorhombic system.

Interestingly, arsenopyrite is among the few common minerals that have acquired little or no metaphysical lore, probably because it contains the "dark" element arsenic. Arsenopyrite has been featured on the Portuguese 2.50-escudo postage stamp of 1971.

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### **TECHNOLOGICAL USES**

Arsenopyrite is a former ore of arsenic (see “About Arsenic”). At some deposits, it is a minor ore of gold. Exploration geologists consider arsenopyrite an “indicator” mineral in the search for disseminated-gold deposits.

### **ARSENIC**

*Over the centuries, arsenic has acquired perhaps the darkest reputation of any element. Even today, the word “arsenic” can conjure images of poisonous potions, murders, and “who-done-it” mysteries. And its reputation is not unjustified: Arsenic and its compounds have been the poison of choice in countless murders and assassinations for at least three thousand years.*

*On the periodic table of elements, arsenic joins nitrogen, phosphorus, antimony, and bismuth under column V a. Of these, arsenic, antimony, and bismuth (some researchers also include selenium and tellurium) are classified as semimetals or metalloids, elements that share the properties of both metals and nonmetals. Elemental arsenic has an atomic number of 33, an atomic weight of 74.92 (somewhat higher than that of zinc), and commonly occurs in the -3, +3, and +5 oxidation states. Unlike most elements, the boiling point of arsenic (614° C., 1137° F.) is lower than its melting temperature (817° C., 1503° F.). When heated, arsenic sublimates directly to a gas, then condenses directly to a solid.*

*Of arsenic's several allotropic (different) forms, the most common is “gray arsenic,” a dense, extremely brittle, metallic-gray semimetal with a specific gravity of 5.73 and poor electrical and heat conductivity. “Black metallic arsenic” is also dense and has an unusual, layered crystal structure. Another allotrope is “yellow arsenic” which has a much lower specific gravity of 2.0. All the arsenic allotropes occasionally occur in elemental form in nature. Arsenic is about as common as tin, ranking 52<sup>nd</sup> among the elements in crustal abundance. Other than arsenopyrite, other familiar arsenic-bearing minerals are realgar [arsenic sulfide,  $\text{As}_4\text{S}_4$ ], orpiment [arsenic trisulfide,  $\text{As}_2\text{S}_3$ ], cobaltite [cobalt arsenic sulfide,  $\text{CoAs}_3$ ], skutterudite [cobalt triarsenide,  $\text{CoAs}_3$ ], and mimetite [lead chloroarsenate,  $\text{Pb}_5(\text{AsO}_4)_3\text{Cl}$ ].*

*The word “arsenic” derives from the Persian word zarnikh, meaning “yellow orpiment.” The Greeks adopted this word as arsenikon, meaning “masculine” or “potent,” an allusion to the toxicity of arsenic compounds. During the Bronze Age, arsenic compounds were alloyed with bronze to increase its hardness. During Roman and medieval times, arsenic compounds were commonly used, with varying levels of success, in medicinal potions. The German philosopher and theologian Albertus Magnus (Albert the Great, Albert von Boll-städt, 1200-1280) first isolated elemental arsenic in 1250. Later, physicians realized that arsenic compounds could indeed have beneficial medicinal effects, but only when administered in very small and closely regulated doses. By the mid-1700s, arsenic compounds were the standard drugs to treat such diseases as syphilis.*

*Although traces of arsenic occur naturally in the human body and in many foods, ingesting larger amounts—as little as one-tenth of a gram—can be fatal. This notorious toxicity is due to arsenic's chemical similarity to phosphorus. Phosphorus is vital to the cellular chemistry of both animals and plants, especially to the production of adenosine triphosphate (ATP), which provides the necessary energy for biochemical processes. But because of arsenic's chemical similarity, it can partially substitute for phosphorus in ATP and other cellular compounds where even tiny amounts can disrupt normal cellular functions. Arsenic was long considered the “perfect” poison, both because of its toxicity and the fact that it*

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*could not be detected in the tissues of its victims. In 1836, the Marsh Test, developed by English chemist James Marsh (1794-1846), finally enabled forensic investigators to detect excessive traces of arsenic in human tissue. After the Marsh Test became a standard forensic procedure, the incidence of criminal arsenic poisonings dropped sharply.*

*Despite their toxicity, arsenic compounds have high-volume industrial applications. Each year, industries in the United States use some 7,300 tons of arsenic (as contained in compounds), mostly in the form of arsenic trioxide [As<sub>2</sub>O<sub>3</sub>]. About 4,000 tons are used in wood preservatives that are toxic to fungi and boring insects. Another 1,500 tons go into agricultural herbicides, fungicides, and pesticides. Smaller amounts of arsenic compounds are used to manufacture chemical-warfare agents, to decolorize glass, and to formulate drugs to treat psoriasis and certain forms of cancer. Elemental arsenic is alloyed with lead to make stronger terminal posts and grids for automotive batteries, while gallium arsenide [GaAs] semiconductors are standard components in lasers, solar cells, light-emitting diodes, and the circuit boards of computers and cell phones.*

*Until the 1950s, arsenic came from mining, milling, and smelting arsenopyrite, orpiment, and realgar ores. But since then, the entire world's supply has been obtained solely as a by-product of smelting and refining ores of copper, lead, zinc, silver, and tin. Today, China supplies three-quarters of the world's arsenic. For its industrial needs, the United States depends entirely upon imports from China, Morocco, and Belgium.*

*Arsenic trioxide now sells for about 60 cents per pound. Arsenic use is declining steadily, thanks to heightened environmental and health awareness and the phasing out of many arsenic-preserved wood products.*

### ***ABOUT OUR SPECIMENS***

As noted previously, our arsenopyrite specimens were collected at the Yaogangxian (pronounced yow-gong-ZHAN) tungsten mine near the mining town of Yaogangxian in Yizhang County, Chenzhou Prefecture, Hunan Province in the People's Republic of China. This site in southern China is about 250 miles north-northwest of Hong Kong and 20 miles southwest of the city of Chenzhou in southeastern Hunan Province. Yaogangxian, population 10,000, is located at an elevation of 4,200 feet on 5,735-foot-high Yaogangxian Mountain. The climate is humid and subtropical, and dense pine forests cover the mountainsides.

The Yaogangxian tungsten mine is one of the hundreds of small, underground metal mines in the greater Nanling nonferrous metallogenic zone. The Nanling zone, the world's richest tungsten area, extends for more than 200 miles through parts of Hunan, Xiangxi, Guangxi, and Guangdong provinces. In Hunan Province, the zone is divided into four sections: the Yaogangxian and Shizhuyuan tungsten-polymetallic districts and the Huangshaping and Xianghualing lead-zinc districts. (Our fluorite specimens in October 2007 were collected at the Huangshaping lead-zinc mine in the Xianghualing district, which is only eight miles from the Yaogangxian mine.)

The emplacement of the Yaogangxian mineralization is linked to crustal deformation resulting from the Yanshanian Orogeny, a mountain-building episode that began about 180 million years ago with the tectonic collision of the South China and North China cratons (stable sections of the continental crust). Subsequent crustal stresses uplifted and fractured sections of the basement rock, enabling magma to surge upward into older carbonate sedimentary rocks. Yaogangxian hosted two different types of mineralization, both emplaced by the mineral-rich hydrothermal solutions that accompanied the magmatic intrusions: vein deposits and skarns.

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In the vein deposits, mineral-rich hydrothermal solutions surged through well-fractured country rock to emplace extraordinarily complex mineralization consisting mainly of ferberite [iron tungstate,  $\text{FeWO}_4$ ] and quartz. These veins are of six mineralogical types: those rich in ferberite and scheelite [calcium tungstate,  $\text{CaWO}_4$ ]; beryl [beryllium aluminum silicate,  $\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$ ] and molybdenite [molybdenum disulfide,  $\text{MoS}_2$ ]; sulfides of bismuth, arsenic, iron, and copper; cassiterite [tin dioxide,  $\text{SnO}_2$ ]; sulfides of tin, lead, zinc, antimony, and silver; and carbonate minerals. The skarn deposits formed from metasomatism (the introduction of new minerals into rock) during contact metamorphism. At Yaogangxian, tungsten-rich hydrothermal solutions penetrated the contact zone between a magmatic intrusion and sedimentary country rock to create a scheelite-rich skarn 5-to-25-feet thick and nearly a mile in length.

German and Swedish geologists discovered the rich tungsten mineralization at Yaogangxian early in the 20<sup>th</sup> century, just as metallurgists were realizing the extraordinary ability of tungsten to harden steel alloys. Mining at Yaogangxian began in 1914, immediately following the outbreak of World War I in Europe that sent tungsten demand soaring. The town of Yaogangxian was built specifically to serve the mine and mill. Mining has continued more-or-less steadily to the present time. Miners have now encountered more than 200 tungsten-quartz veins, the largest eight feet thick and more than a half-mile long. Their depth has ranged from surface outcrops to 1,300 feet below the surface. Over the decades, mining has progressed downward from the outcrops and is now nearing the 1,300-foot level. The configuration of the mine workings is as erratic as the veins themselves. Numerous adits access the mine by proceeding horizontally into the side of Yaogangxian Mountain, then branching off into a confusing array of narrow haulage drifts, crosscuts, winzes, raises, and inclines with an estimated total extent of more than 30 miles.

Tungsten mining became increasingly important in the late 1970s when China's steel industry began growing rapidly. Anxious to avoid the need to import foreign tungsten for alloying purposes, the Chinese government began offering incentives to increase domestic tungsten production. Many new, small tungsten mines opened, while Yaogangxian and other established mines expanded operations. By the mid-1980s, the Yaogangxian mine, flotation-separation mill, and related facilities employed nearly 5,000 workers. Currently, the mine employs about 2,000 workers, 400 of whom are underground miners. In recent years, the mine-mill complex has annually produced some 1,500 tons of ferberite-scheelite concentrate containing 40 percent tungsten by weight, along with smaller amounts of by-product tin.

Yaogangxian miners had always encountered large numbers of well-developed crystals of various minerals within voids in the ferberite-quartz veins. But it was not until the early 1990s, when Chinese minerals began appearing on the world collector markets in quantity, that the mine began gaining recognition as a world-class specimen source. Yaogangxian is now known for its superb specimens of lustrous, silvery, striated arsenopyrite crystals in association with quartz; clusters of needle-like crystals of boulangerite [lead antimony sulfide,  $\text{Pb}_5\text{Sb}_4\text{S}_{11}$ ]; bournonite [lead copper antimony sulfide,  $\text{PbCuSbS}_3$ ]; purplish-blue cubes of fluorite [calcium fluoride,  $\text{CaF}_2$ ]; black, hexagonal tabular crystals of wurtzite [zinc iron sulfide,  $(\text{Zn},\text{Fe})\text{S}$ ]; and striated, gray-black crystals of stannite [copper iron tin sulfide,  $\text{Cu}_2\text{FeSnS}_4$ ]. With its designation as a classic locality, Yaogangxian specimens command premium prices on collector markets. Yaogangxian mine managers now employ specially trained miners capable of recovering large numbers of collector-quality specimens with little or no damage. Today, most Yaogangxian specimens end up with mineral dealers in the provincial capital of Changsha, 160 miles to the north, where they are cleaned and trimmed before being exported to foreign mineral markets.

The future of the government-owned Yaogangxian mine is uncertain. China, which mines three-quarters of the world's tungsten, has been reorganizing its tungsten-mining industry. To increase control, improve safety and operating efficiency, and drive up the market price of tungsten, it is decreasing production by closing many of its older and smaller mines. Because its ore reserves and production have decreased in recent years, Yaogangxian, one of China's oldest tungsten mines, is now a candidate for closure.



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Recently reclassified into the monoclinic crystal system, arsenopyrite tends to form stubby sharp prismatic crystals, striated parallel to the c axis. Our specimens consist mainly of intergrown or almost parallel crystals with curved or stepped faces, typical for arsenopyrite. Some contain twinned crystals, sometimes repeated, as seen in Figure 1, like the coxcomb pattern of some marcasite crystals. As usual, examination with a magnifying glass or 10x loupe allows us to take note of these distinctive crystal forms. You might spend some time enjoyably looking for interesting crystal forms on your specimen.



Figure 2. Town of Yaogangxian.

Some specimens contained associated minerals, mainly quartz, and to a lesser degree, fluorite, mica, dolomite, and chalcopyrite. Some pieces are on a matrix of massive arsenopyrite. Noteworthy too, is the bright luster of the crystals, the cause of which was explained under *Composition*. Yes, there is a lot to love when considering this month's mineral and the lethal element it contains!



Figure 3. Working underground at Yaogangxian Mine.

References: *Dana's New Mineralogy*, Eighth Edition; *Encyclopedia of Minerals*, Second Edition, Roberts, et al, Van Nostrand Reinhold Co.; *2004 Fleischer's Glossary of Mineral Species*, Joseph Mandarino and Malcolm Back, The Mineralogical Record Company; *Mineralogy*, John Sinkankas, Van Nostrand Reinhold Co.; *Manual of Mineralogy*, Cornelius Hurlbut and Cornelia Klein, Twenty-first Edition, John Wiley & Sons; "Arsenic," William E. Brooks, *2006 Minerals Yearbook*, United States Geological Survey; "Realgar, Orpiment, Arsenopyrite—Arsenic," Steve Voynick, *Rock & Gem*, November 1999; "The Yaogangxian Tungsten Mine, Yizhang County, Chenzhou, Hunan Province, China," Berthold Ottens and Robert B. Cook, *Rocks & Minerals*, January-February 2005; "Yaogangxian Tungsten Mine," Berthold Ottens, *Rocks & Minerals*, July-August 2004; "Connoisseur's Choice: Bournonite from the Yaogangxian Mine, Chenzhou, Hunan Province, China," Robert B. Cook, *Rocks & Minerals*, January-February 2005; *Mineralogy of Tungsten Deposits in Nanling and Neighboring Areas, China*, Y. Li and X. Yan, Wuhan (Beijing) and Geoscience Press, 1991; "Arsenopyrite," R. J. King, *Geology Today*, March 2002.