

May 2008 Mineral of the Month: Adamite

Our specimens of this month's mineral were collected in Mexico at one of the richest and most historically significant of all colonial-era silver mines—the 410-year-old Ojuela Mine, which ranks high among the top-ten specimen localities in the world.

PHYSICAL PROPERTIES

Chemistry: $\text{Zn}_2(\text{AsO}_4)(\text{OH})$ Basic Zinc Arsenate (Zinc Arsenate Hydroxide), often containing some copper
Class: Phosphates, Arsenates, and Vanadates
Subclass: Basic Phosphates, Arsenates, and Vanadates
Group: Olivenite
Crystal System: Orthorhombic
Crystal Habits: Usually prismatic or horizontally elongated; often as drusy crusts, aggregates, and radiating clusters in wheel-like and wheat-sheaf forms; occasionally botryoidal with a textured surface of crystal terminations.
Color: Light-yellow, honey-yellow, brownish-yellow; pale-green to greenish-blue with increasing copper content; occasionally purple with manganese content or pink with cobalt content; rarely white or colorless.
Luster: Adamantine to vitreous
Transparency: Transparent to translucent
Streak: White to pale green
Cleavage: Good in one direction, poor in a second.
Fracture: Uneven to subconchoidal, brittle.
Hardness: 3.5-3.6
Specific Gravity: 4.3-4.5
Luminescence: Often fluoresces a brilliant yellow-green.
Refractive Index: 1.710-1.768
Distinctive Features & Tests: Best field marks are color; crystal habit; exclusive occurrence in oxidized, arsenic-rich zinc deposits; high specific gravity; and brilliant, yellow-green fluorescence. Can be confused with smithsonite $[\text{ZnCO}_3]$, which does not fluoresce.
Dana Classification Number: 41.6.6.3

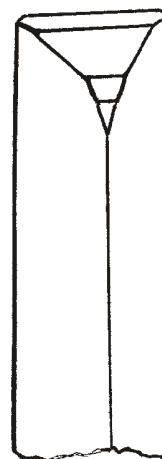


Figure 1. Ideal adamite crystal, typical of Ojuela.

NAME

Adamite, correctly pronounced "ADD-ahm-ite," is named for the French mineralogist Gilbert-Joseph Adam (1795-1881). European mineralogists refer to adamite as "adamine," "adamin," or "adamita." Adamite's aluminum-rich variety is known as "alumino adamite." A cobalt-rich variety is called "cobaltoan adamite," a copper-rich variety "cuprian adamite," a manganese-rich variety "manganoan adamite," and a nickel-rich variety "nickeloan adamite." The fluorescence commonly seen in adamite is dampened by the presence of these additional elements.

COMPOSITION

Putting this write-up together takes us back to 1998, when we were relatively new in Cambria, living on Ellis Street where we started our Club. By May 1998, we had about 190 members and we were late in sending out about half the Deluxe minerals, because we had been promised a delivery that did not arrive on time. At that time, we were not financially able to stockpile minerals for future months, as we do now. But everyone was patient, and we were able to send wonderful specimens, similar in size to what we are sending now to Deluxe and Junior members. (We hadn't even conceived of a Platinum membership at that time.) The 4-page write-up we sent that month focused mainly on fluorescence in minerals, and we

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have used that information a couple of times since. Now we have a highly detailed ten-page write-up with lots of photos and maps, due to kind consideration from the *Mineralogical Record*.

Let's start as usual with the nitty gritty of adamite's atomic structure, which gives it its unique properties. Adamite's chemical formula, $\text{Zn}_2(\text{AsO}_4)(\text{OH})$, identifies its elemental components as zinc (Zn), arsenic (As), oxygen (O), and hydrogen (H). Adamite's molecular weight consists of 45.61 percent zinc, 26.13 percent arsenic, 27.90 percent oxygen, and 0.36 percent hydrogen. The cation (positively charged ion) of the adamite molecule consists of two ions of zinc (2Zn^{2+}) with a collective charge of +4. The compound anion (negatively charged ion) consists of two different radicals (groups of atoms that act as entities in chemical reactions)—the arsenate radical (AsO_4^{3-}) and the hydroxyl radical (OH^{1-}). In the arsenate radical, arsenic is present in the +5 oxidation state and oxygen in the +2 oxidation state, thus producing a collective -3 charge. In the hydroxyl ion, hydrogen has a +1 charge. Together with the single oxygen ion (O^{2-}), the hydroxyl radical has a collective -1 charge. The total anionic charge of -4 balances the total cationic charge of +4 to impart electrical stability to the adamite molecule.

Adamite is one of the approximately 300 members of the Phosphates, Arsenates, and Vanadates, a class of minerals that are built around the phosphate (PO_4^{3-}), arsenate (AsO_4^{3-}), or vanadate (VO_4^{3-}) radicals. All form tetrahedral structures with four oxygen ions surrounding the ion of a metal or semimetal (vanadium is a metal; phosphorus and arsenic are semimetals). In the arsenate ion, the arsenic ion As^{5+} is surrounded by and bonded covalently to four oxygen ions (4O^{2-}). Because the four oxygen ions collectively share the resulting -3 charge, the arsenate radical can bond ionically with many metal cations. In adamite, each arsenate ion bonds ionically to two zinc ions to form the intermediate, octahedral-shaped, zinc-arsenate radical $[\text{Zn}_2(\text{AsO}_4)]^{1+}$. This radical, which is unstable because of its +1 charge, covalently bonds into chains of octahedra that establish adamite's orthorhombic crystal structure. Spaces between these chains of octahedra accommodate hydroxyl ions $[(\text{OH})^{1-}]$ that bond ionically to alternating zinc ions to provide the molecule with electrical balance.

Orthorhombic crystals have three, mutually perpendicular axes of different lengths. The most common orthorhombic forms are the pinacoid (two parallel faces), the dipyramid, the prism, and the dome. Orthorhombic crystals are typically blocky, but variations are common. When one dimension of the unit cell is noticeably longer than the other two, crystals are needle-like; but when one dimension is notably shorter than the other two, crystals are platy. Crystal shape is usually determined by the rate of directional growth. Minerals that are chemically complex, or that have complex bonding (adamite has both covalent and ionic bonding), often crystallize in the orthorhombic system. Because of strong covalent bonding *along* the octahedral chains and weak ionic bonding *between* the chains, adamite exhibits good cleavage only along the single direction of its ionic-bonding plane.

At Mohs 3.5-3.6, adamite is about as soft as a copper penny. This hardness is somewhat directional, being greatest along the planes of strong covalent bonding, and least along the ionic-bonding plane. Weak ionic bonding also explains adamite's brittleness. Adamite is unusually dense for a light-colored mineral, with the high atomic weights of zinc (65.39) and arsenic (74.92) accounting for its relatively high specific gravity of 4.3-4.5, which varies somewhat when copper and other metals substitute for zinc in the adamite lattice. High density also provides adamite with a relatively high index of refraction of 1.710-1.768, which is equal to that of the sapphire and ruby varieties of corundum [aluminum oxide, Al_2O_3].

As an allochromatic or "other-colored" mineral, adamite's colors are caused not by its essential chemical components or the nature of its crystal structure, but by trace amounts of nonessential elements called chromophores (coloring agents). When pure, adamite is colorless or white. But adamite almost always contains some copper, which imparts light green and greenish-blue colors. Traces of cobalt impart pale

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pink colors, manganese produces purple, and ferrous iron creates yellow and gold-brown colors. Because of traces of uranium trapped in its crystal structure, most adamite specimens fluoresce an intense yellowish-green color under short- and long-wave ultraviolet light.

The Dana mineral classification number 41.6.6.3 identifies adamite as an arsenate with hydroxyl or halogen ions (41). The subclassification (6) defines it by the general formula $A_2(XO_4)Z_q$, in which “A” is a divalent metal such as zinc, copper, or manganese; “XO₄” is a phosphate, arsenate, or vanadate radical; “Z” is a hydroxyl or halogen ion; and “q” is a variable quantifier. Adamite is assigned to the olivenite group (6) as the third (3) of six members. Other olivenite-group members include olivenite [basic copper arsenate, $Cu_2(AsO_4)(OH)$], libethenite [basic copper phosphate, $Cu_2(PO_4)(OH)$], eveite [basic manganese arsenate, $Mn_2(AsO_4)(OH)$], and zincolibethenite [basic copper zinc phosphate, $CuZn(PO_4)(OH)$]. Adamite is closely related to olivenite and forms a complete solid-solution series in which copper (Cu^{2+}) substitutes for zinc (Zn^{2+}). Olivenite crystallizes in the monoclinic system, is a bit less dense than adamite, and has a consistently green color due to its high copper content. Technically, adamite becomes olivenite when copper replaces 80 percent of the zinc and causes the lattice symmetry to change from orthorhombic to monoclinic. The intermediate phases of this solid-solution series are known as cuproadamite.

Adamite forms only as a secondary mineral in the oxidized zones of zinc- and arsenic-bearing hydrothermal veins and replacement deposits. Adamite usually occurs in close association with such other oxidized minerals as smithsonite [zinc carbonate, $ZnCO_3$], calcite [calcium carbonate, $CaCO_3$], hemimorphite [basic hydrous zinc silicate, $Zn_4Si_2O_7(OH)_2 \cdot H_2O$], limonite [an indefinite mixture of hydrous iron oxides], legrandite [basic hydrous zinc arsenate, $Zn_2(AsO_4)(OH) \cdot H_2O$], mimetite [lead chloroarsenate, $Pb_5(AsO_4)3Cl$], and paradamite [basic zinc arsenate, $Zn_2(AsO_4)(OH)$]. Paradamite is a dimorph of adamite that has an identical chemistry, but crystallizes in a different system (triclinic).

COLLECTING LOCALITIES

Although widely distributed, adamite is rare and has few sources of fine specimens. Our specimens were collected at the classic locality for adamite—the Ojuela Mine at Mapimi in the Mapimi district, Durango, Mexico. Other notable Mexican adamite localities are the Miguel Hidalgo Mine at Zimapán in the Zimapán district of Hidalgo, and the Congreso-León Mine at San Pedro Corralitos near Casas Grandes, Chihuahua. Adamite is still collected at its type locality at the Veta Negra copper-zinc deposit at Chañarcillo, Copiapó Province, in the Atacama Desert region of Chile.

European specimens are found in Austria at the Annaberg mines in the Türritzer Alpen mountains of Lower Austria; in France at the Cap Garonne Mine at Pradet in the Var region of Provence-Alpes-Côtes-d’Azur; in Germany at the Schaar and Strassburger Glück mines in the Erzgebirge area of Saxony; in Greece at the Kamareza mine group in the Lavrion district in Attiki Prefecture; in Italy at the Stregio Valley and Monte Gai mines at Massa Maritima in Grosseto Province, Tuscany; and in Spain at the Las Comenitas Mine at Santa Marta, Badajoz, Extremadura.

African specimens come from the Tsumeb Mine at Tsumeb in the Otjikota Region of Namibia; and the Bou Azzer, Ambed, and Aït Ahmane mines in the Bou Azzer district, Ouarzazate Province, in the Souss-Massa-Draâ Region of Morocco. Adamite is collected in Australia at the Kintore open pit at Broken Hill in Yancowinna County, New South Wales; and in Japan at the Toruko and Mitate mines in Miyazaki Prefecture on Honshu Island.

In the United States, adamite occurs in California at the Mohawk Mine at Santa Cruz in Santa Cruz County, and at Death Valley’s Chloride Cliff in Inyo County; in Arizona at the Grandview (Last Chance)

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Mine in the Grandview district of Coconino County; in Montana at the Black Pine Mine in the Philipsburg district of Granite County; in Nevada at the Simon Mine in the Bell district of Mineral County, and at the San Rafael Mine in the Lodi district of Nye County; in South Dakota in the Galena district in Lawrence County; in New Mexico at the Buckhorn Mine in the Red Cloud district of Lincoln County; and in Utah at the Gold Hill Mine in the Gold Hill district of Tooele County.

JEWELRY & DECORATIVE USES

Because of its softness, small crystal size, and rarity, adamite has no jewelry use. Jewelry designers and wire artists like Cheryl are using drusy crystals on matrix for one-of-a-kind jewelry, and adamite on matrix would look lovely set in this way, but it is not feasible because the matrix crumbles so easily, and because the matrix would stain any garment it touched.

Ever since specimens became available in 1946, adamite has been in high demand among mineral collectors for its colors, rarity, and unusual crystal forms. The finest Ojuela adamite specimens are worth tens of thousands of dollars.

HISTORY & LORE

Adamite was probably discovered in the late 1700s, but was confused with olivenite [basic copper arsenate, $\text{Cu}_2(\text{AsO}_4)(\text{OH})$], the copper-analog end-member of the adamite-olivenite solid-solution series. In 1786, German chemist Martin Klaproth (1743-1817), working with specimens collected in England, first analyzed and described olivenite, but did not preserve the type specimens or name the new mineral. In 1789, German geologist and mineralogist Abraham Gottlob Werner (1750-1817) named the mineral "olivnerz" after its olive-green color, a name that was later changed to "olivenite." In 1824, French mineralogist Gilbert-Joseph Adam (1795-1881) collected specimens of an olivenite-like mineral from the Veta Negra Mine at Chañarcillo, Copiapó Province, in the Atacama Desert region of Chile. Although catalogued, these specimens were never analyzed until 1864, when French chemist and mineralogist Charles Friedel (1832-1899) determined that their cation consisted primarily of zinc, rather than copper, and that their crystal system was orthorhombic and not monoclinic. Friedel correctly concluded that the Chilean specimens actually formed a complete solid-solution series with olivenite and that the zinc-rich end member represented a new mineral species. Friedel published his research in 1866 and named the new mineral "adamine," after his colleague Gilbert-Joseph Adam, who had collected the type specimens. The name "adamine" was later changed to "adamite."

In 1932, X-ray diffraction defined the exact nature of the adamite-olivenite solid-solution series by demonstrating that the crystal structure changed from orthorhombic to monoclinic when copper replaced 80 percent of the zinc in adamite. Adamite was considered extremely rare until 1946, when miners found commercial quantities of adamite specimens at the Ojuela Mine in Mapimi, Durango, Mexico. Mineralogists used high-resolution, gamma-ray-spectroscopy techniques to discern the details of the adamite lattice structure in 1975.

According to modern metaphysical practitioners, adamite coordinates the energies of the heart and mind, provides inner strength to deal with emotional issues and vocalize feelings, and aids in acquiring material possessions.

TECHNOLOGICAL USES

Adamite formerly served as a minor ore of zinc.

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ABOUT OUR SPECIMENS

THE OJUELA MINE, PART I: GEOLOGY AND HISTORY

Our adamite specimens come from the Ojuela (pronounced oh-HWAY-la) Mine at Mapimi in the Mapimi district, Durango, Mexico. The mine has produced continually for 410 years and was a rich source of silver for the Spanish Crown and later the Republic of Mexico. Ojuela is located in north-central Mexico, northwest of the city of Torreón. It is accessible from Torreón by taking Mexico Route 49 north for 25 miles to Bermejillo, then taking Mexico Route 30 west for 12 miles and following the signs south for four miles to Mapimi. This arid region is typical of the Chihuahuan Desert, with rugged mountain ranges separating broad plains. The plains are 5,000 feet in elevation and sparsely vegetated with cacti, thorny brush, and coarse grass; the adjacent mountains rise to about 10,000 feet and host thin, scrub-oak forests. The elevation of Mapimi and the Ojuela Mine is 6,800 feet. If you truly want to “get away from it all,” Ojuela would be a good place to go!

Ojuela is a textbook example of the carbonate-replacement deposits that occur in a 900-mile-long belt of folded carbonate rocks known as the Mexican Fold Belt. The sediments in the Mexican Fold Belt, all of marine origin, were laid down between 150 and 65 million years ago and lithified into limestone and dolomite. Limestone is a rock that consists primarily of calcite [calcium carbonate, CaCO_3]. Dolomite, in its petrological context, is a rock consisting mainly of the mineral dolomite [calcium magnesium carbonate, $\text{CaMg}(\text{CO}_3)_2$]. In early Tertiary time 60 million to 40 million years ago, stresses generated by colliding tectonic plates deformed these limestone and dolomite formations into the folds and thrusts of today's Mexican Fold Belt. Finally, between 40 and 25 million years ago, regional volcanism and deep magmatic intrusions forced mineral-laden, hydrothermal solutions into the circulation systems within the Fold Belt.

Mineralization then occurred by replacement when saline, superheated, acidic solutions dissolved sections of the folded limestone and dolomite formations. The dissolving carbonate minerals neutralized the acidic solutions, precipitating sulfide and silicate minerals that “replaced” the carbonates. At Ojuela, this replacement mineralization formed seven vertical structures called “chimneys,” which fed overlying, horizontal mineralized zones called “mantos” (literally “cloaks”), as seen in the map in Figure 2. These deposits, rich in silver, lead, and zinc with lesser amounts of gold and copper, originally formed several thousand feet below the surface but were exposed by surface erosion millions of years later.

In 1534, Spanish prospectors in what is now Mexico discovered



Figure 3. Hauling ore from Ojuela via cogwheel train in the 1890's.

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silver at Taxco, Guerrero. This was the first of a series of major strikes that extended northward for 500 miles and culminated in the discovery of rich outcrops of chlorargyrite [silver chloride, AgCl] and argentiferous cerussite [silver-bearing lead carbonate, PbCO₃] at Ojuela in 1598. Using Native American slave labor, the Spanish quickly depleted the surface ores at Ojuela and turned to underground mining. By 1640, Ojuela had become a major source of silver. The Spanish reduced the crushed ores to lead-silver alloys in adobe smelting furnaces, then separated the silver using a simple cupellation process. By the early 1800s, Ojuela had produced nearly 100 million troy ounces of silver (about 3,200 metric tons) along with huge amounts of lead.

The Mexican war of independence that began in 1811 sharply curtailed production at Ojuela. By the time Mexico gained its independence in 1821, the Ojuela Mine and its smelters were largely in ruins. Operations then resumed, but production was limited by outdated mining technology, lack of roads, raids by outlaws, and government instability. In the late 1870s, after newly elected Mexican president General Porfirio Díaz (1830-1915) reduced government restrictions to encourage foreign investment in mining, the United States-based Durango-Mapimi Mining Company purchased the Ojuela Mine and invested \$100,000 to boost silver output, but failed to produce more than a mere 20 tons of ore per day.

When Durango-Mapimi went bankrupt in 1890, Compañía Minera de Penoles, backed by both American and European capital, bought Ojuela and brought in American mining engineers to modernize the operation. Penoles replaced the colonial-age adobe furnaces with a modern smelter, built a 15-mile-long railroad to link Mapimi with the Mexican national railroad at Bermejillo, electrified Mapimi and the Ojuela mine, constructed employee housing, and hired the firm of the American civil engineer Washington Augustus Roebling (1837-1926), famed for completing construction of New York's Brooklyn Bridge, to construct a narrow, 1,000-foot-long cable-suspension bridge over a 250-foot-deep arroyo between the town and the mine. The company also increased the depth of the mine 770 feet to more than 1,800 feet and began exploiting large volumes of previously-ignored zinc ores.



Figure 4. The miner's village as seen decades ago, with the original ore discovery hole at bottom center. This bridge was replaced by the Roebling cable-suspension bridge.

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By 1910, Ojuela was Mexico's most profitable mine. More than 1,200 miners turned out 500 tons of high-grade ore per day from which the smelter recovered one million troy ounces of silver per year, along with large tonnages of lead and zinc. But hard times were just around the corner. When President Díaz ran for yet another term in 1911, deep resentment about his "selling out to foreign interests" exploded into full-scale revolution. The following year, 7,000 rebel troops under revolutionary leader Francisco "Pancho" Villa (1878-1923) mounted bloody attacks on federal strong points at Mapimi and Torreón. Although Mapimi saw no additional military action during the Mexican Revolution, Ojuela managed only token production until peace returned in 1920.

By 1922, core-drill exploration had discovered new ore bodies at depth, powerful new pumps were dewatering the deeper workings, and high zinc prices and the new flotation-separation milling process were making it economical to mine lower grade ores. Silver, lead, and zinc production soared during the late 1920s, but profits were again cut short, this time when metal prices plummeted during the Great Depression. Further problems arose when the mine's lower levels flooded in 1934. Although metal prices rose sharply again during World War II, the Ojuela Mine never approached its former production rates. In 1946, Compañía Minera de Penoles relinquished direct operational control and began leasing underground sections of the mine to independent cooperatives of miners. Although this lease-mining system has yielded only minimal amounts of ore, it still survives today.

The Ojuela Mine has more than 200 miles of underground workings, the deepest of which are flooded. Throughout its 410-year-long history, the mine has produced an estimated seven million tons of ore. On average, a ton of this remarkably rich ore contained 15 troy ounces of silver, 15 percent lead, 12 percent zinc, 0.1 troy ounce of gold, and small amounts of copper. Encouraged by today's high metal prices, Compañía Minera de Penoles, which still owns the mine, is now studying the feasibility of resuming full-scale operations to recover silver-lead sulfide ores and previously overlooked zinc ores, which we hope will lead to another outpouring of fine adamite and other specimens.

THE OJUELA MINE, PART II: MINERALOGY AND SPECIMENS

The Ojuela Mine ranks among the world's top-ten specimen-producing localities of all time. It has yielded 126 individual mineral species, is the type locality for six minerals, and is famed as the source of the finest adamite specimens along with dozens of other rare arsenate minerals. The mine was not recognized for its mineralogy and superb specimens, however, until the 1927 visit of geologist William F. Foshag (1894-1956) and mineralogist Harry Berman (1902-1944). In just a few weeks, Foshag, representing the Smithsonian Institution, and Berman, the curator of the Harvard Mineralogical Museum, amassed a superb collection of specimens that included several previously unknown minerals.

Ojuela's fame as a world-class specimen locality is due to two factors, the first being its extraordinarily large volume of oxidized mineralization. Metal-ore minerals are usually emplaced as deep sulfide deposits, the upper sections of which are sometimes later exposed by erosion. As erosion reduces the surface, the subterranean water table is lowered, thus exposing the metal-sulfide minerals to free atmospheric oxygen and initiating the chemical process of oxidation. In the proper chemical environment and with the presence of free atmospheric oxygen, sulfides will oxidize or alter into such secondary, oxygen-bearing minerals as carbonates, oxides, phosphates, and arsenates, many of which are basic [containing the hydroxyl radical (OH)⁻] or hydrated (containing attached water molecules). Depending upon the chemistry of the original sulfides, the resulting secondary minerals can make rare and colorful specimens. Most deposits have shallow water tables not exceeding a few hundred feet in depth, which greatly limits the extent of oxidation. But at Ojuela, an unusual water-table depth of 1,200 feet has enabled huge volumes of overlying sulfide ores to oxidize into secondary minerals.

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The second factor that sets Ojuela (in Spanish, *Mina Ojuela*) apart from most other ore deposits is its unusual chemistry. Unlike most deposits, the original sulfides at Ojuela were extremely rich in arsenopyrite [iron arsenic sulfide, FeAsS (our Mineral of the Month for February 2008)], which accounts for as much as 20 percent of total sulfide weight. The primary sulfide-ore minerals are pyrite [iron disulfide, FeS_2], argentiferous galena [silver-bearing lead sulfide, PbS], pyrrhotite [iron sulfide, Fe_{1-x}S], sphalerite [zinc sulfide, ZnS], and chalcopyrite [copper iron sulfide, CuFeS_2]. These sulfides typically oxidize into goethite [basic iron oxide, $\text{FeO}(\text{OH})$], argentiferous cerussite [silver-bearing lead carbonate, PbCO_3], malachite [basic copper carbonate, $\text{Cu}_2(\text{CO}_3)(\text{OH})_2$], and smithsonite [zinc carbonate, ZnCO_3]. But because arsenic was readily available in the Ojuela oxidation chemistry, these sulfides oxidized instead into a much more varied array of secondary iron, lead, zinc, and copper arsenate minerals that are rare, unusual, and colorful.



Figure 5. One of the adit entrances. Map and photos courtesy of *Mineralogical Record*, used by permission.

Ojuela specimens did not attract collector attention until 1946, when lease miners, working 1,000 feet below the surface, encountered large vugs or “grottos” filled with extraordinary adamite crystals. These crystals came to the attention of specimen-savvy retired Americans living in the region who sent them to dealers in the United States. As dealers began clamoring for additional specimens, Ojuela’s lease miners discovered that they could earn more by collecting and selling adamite specimens than by mining ore. Upon realizing just how much adamite had been collected and sold (it amounted to several tons), Compañía Minera de Pinos officials demanded that the mining cooperatives give the company ten percent of the specimen sale price. Few miners complied, choosing instead to smuggle their adamite specimens out of the mine.

As Ojuela’s reputation as a world-class specimen source continued to grow, numerous rock shops opened in Mapimi, Bermejillo, and Torreón to sell Ojuela specimens. Throughout the 1950s and 1960s, magazine articles about the specimens’ rarity and superb quality heightened demand. Serious collectors and leading dealers from the United States began visiting the mine regularly to buy directly from miners or to pay Compañía Minera de Pinos for permission to collect their own specimens in the underground. A 1969 find of two tons of colorless and blue-green adamite was reported in the inaugural issue of *The Mineralogical Record* in January-February 1970. A succession of notable finds followed. In 1979, miners found vugs lined with spectacular crystals of the rare mineral legrandite [basic hydrous zinc arsenate, $\text{Zn}_2(\text{AsO}_4)(\text{OH})\cdot\text{H}_2\text{O}$]. We have seen the finest sprays of this yellow legrandite specimens on display at the Tucson Gem & Mineral Show in past years, and they are stop-in-your-tracks, breathtakingly beautiful!

Miners then recovered superb crystals of purple manganoan adamite, cabinet specimens of which sold for \$10,000 each at the 1982 Tucson Gem & Mineral Show. The September-October 2003 special edition of the *Mineralogical Record* is entirely devoted to this prolific mine, and contains photos of awesome purple adamite. In 1988, a notable recovery of turquoise-blue cuprian adamite was made, and in 1992, golden crystals of ferrous adamite came to light. Finally, in 1996, the loose arrangement of specimen collecting

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and buying at Ojuela ended when Tucson, Arizona-based Top Gem Minerals signed agreements with both Compañía Minera de Penoles and the miners' cooperatives, making Top Gem the sole authorized buyer and distributor of Ojuela specimens. Our adamite specimens were collected under this agreement, which remains in effect today.

In testimony to its diverse mineralization, Ojuela is recognized as the type locality for five rare arsenates:

Paradamite [basic zinc arsenate, $\text{Zn}_2(\text{AsO}_4)(\text{OH})$, the monoclinic polymorph of adamite]
Lotharmeyerite [basic hydrous calcium zinc manganese arsenate, $\text{Ca}(\text{Zn,Mn})_2(\text{AsO}_4)_2(\text{OH},\text{H}_2\text{O})_2$]
Metaköttigite [basic hydrous zinc iron arsenate, $(\text{Zn},\text{Fe}^{3+})(\text{Zn},\text{Fe}^{3+}\text{Fe}^{2+})_2(\text{AsO}_4)_2 \cdot 8(\text{H}_2\text{O},\text{OH})$]
Mapimite [basic hydrous zinc iron arsenate, $\text{Zn}_2\text{Fe}_3(\text{AsO}_4)_3(\text{OH})_4 \cdot 10\text{H}_2\text{O}$]
Ojuelaite [basic hydrous zinc iron arsenate, $\text{Zn},\text{Fe}_2(\text{AsO}_4)_2(\text{OH})_2 \cdot 4\text{H}_2\text{O}$].

Other unusual arsenate minerals at Ojuela include:

Scorodite [hydrous iron arsenate, $\text{FeAsO}_4 \cdot 2\text{H}_2\text{O}$]
Carminite [basic lead iron arsenate, $\text{PbFe}_2(\text{AsO}_4)_2(\text{OH})_2$]
Villyaellenite [basic hydrous manganese calcium zinc arsenate, $(\text{Mn,Ca,Zn})_5(\text{AsO}_4)_2(\text{AsO}_3)(\text{OH})_2 \cdot 4\text{H}_2\text{O}$]
Arsenosiderite [hydrous calcium iron oxyarsenate, $\text{Ca}_2\text{Fe}_3(\text{AsO}_4)_3\text{O}_2 \cdot 3\text{H}_2\text{O}$]
Dussertite [basic hydrous barium iron arsenate, $\text{BaFe}_3(\text{AsO}_4)_2(\text{OH},\text{H}_2\text{O})_6$]
Köttigite [hydrous zinc arsenate, $\text{Zn}_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$].

Although best known for its arsenates, Ojuela has also yielded wonderful specimens of such other collectible minerals as:

Hemimorphite [basic hydrous zinc silicate, $\text{Zn}_4\text{Si}_2\text{O}_7(\text{OH})_2 \cdot \text{H}_2\text{O}$]
Rosasite [basic copper zinc carbonate, $(\text{Cu,Zn})_2(\text{CO}_3)(\text{OH})_2$]
Aurichalcite [basic zinc copper carbonate, $(\text{Zn,Cu})_5(\text{CO}_3)_2(\text{OH})_6$]
Calcite [calcium carbonate, CaCO_3]
Fluorite [calcium fluoride, CaF_2]
Malachite [basic copper carbonate, $\text{Cu}_2(\text{CO}_3)(\text{OH})_2$].

One could easily devote a portion of their collection, or even the whole collection, to minerals from *Mina Ojuela*, and would have a tremendous diversity of colors and crystal forms! We urge you to examine your specimen closely, especially under magnification, to see what fascinating habits your adamite crystals have taken. Can you see crystals that resemble the ideal crystal form in Figure 1? Take a look for small crystals of others minerals, too. And check it under an ultraviolet lamp if you have access to one. The adamite fluoresces particularly well under longwave UV light. In the meantime, we'll keep an eye out for more Ojuela minerals to feature in the future!

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; "Mapimi: Mineral Collectors' Capital of Mexico," P. W. Johnson, *The Mineralogist*, May-June 1962; "Adamite Found," H. C. Dake, *The Mineralogist*, August 1947; "Connoisseurs' Choice: Adamite, Ojuela Mine, Mapimi, Durango, Mexico," Robert B. Cook, *Rocks & Minerals*, January-February 1999; "High-Temperature, Carbonate-Hosted Lead-Zinc-Silver Massive Sulfide Deposits of Mexico," Peter Megaw and Juan Ruíz, *Economic Geology*, Volume 83, 1988; "What's New in Minerals: Tucson Show 1998," Tom Moore, *The Mineralogical Record*, May-June 1998; *Gem & Crystal Treasures*, Peter Bancroft, Western Enterprises, 1984; "Refinement of the Crystal Structure of Adamite," F. C. Hawthorne, *American Mineralogist*, October 1976; "World News of Mineral Occurrences," V. T. King, *Rocks & Minerals*, May-June 1979; "What's New in Minerals: Tucson Show 1989," Wendell Wilson, *The Mineralogical Record*, May-June 1989; "Tales from Mexico (Parts I and II)," B. Smith and C. Smith, editors, *Rocks & Minerals*, January-February and March-April 1999; "What's New in Minerals," John S. White, *The Mineralogical Record*, January-February 1970; *Mines and Minerals of Mexico, Volume Two: The Ojuela Mine*, Thomas Moore and Peter Megaw, *The Mineralogical Record*, September-October 2003.