

March 2011 Mineral of the Month: Axinite-(Fe)

This month's mineral is axinite-Fe, a complex borosilicate from a recently discovered, now classic locality in California. Our write-up details the mineralogy and pleochroism of this uncommon mineral, and also explains how minerals from new localities can create great excitement in the specimen market.

OVERVIEW

PHYSICAL PROPERTIES

Chemistry: $\text{Ca}_2\text{FeAl}_2\text{BO}(\text{OH})(\text{Si}_2\text{O}_7)_2$ Basic Calcium Iron Aluminum Borosilicate, almost always containing varying quantities of manganese.

Class: Silicates

Subclass: Sorosilicates (Double-tetrahedral Silicates)

Group: Axinite

Crystal System: Triclinic

Crystal Habits: Usually as striated crystals in flattened, "ax-head" shapes or as thin lamellae; also massive and granular.

Color: Clove-brown, reddish-brown, violet-brown, purplish-brown, greenish-yellow, olive-yellow, lilac, violet, dark purplish-blue, and pearl-gray. Strongly pleochroic.

Luster: Vitreous

Transparency: Transparent to subtranslucent

Streak: White

Cleavage: Distinct-to-good in one direction, poor in two others.

Fracture: Irregular to subconchoidal, brittle

Hardness: 6.5-7.0

Specific Gravity: 3.27-3.29

Luminescence: None

Refractive Index: 1.672-1.704

Distinctive Features and Tests: Best field marks are hardness; distinctive, striated, ax-head-shaped crystals; strong pleochroism; frequent occurrence in metamorphic environments and association with such minerals as actinolite, prehnite, and epidote.

Dana Classification Number: 56.2.2.1

NAME The name "axinite," pronounced ACKS-in-ite, is derived from the Greek *axinē*, meaning "ax," an allusion to the characteristic ax-head or chisel-like shape of its crystals. In axinite-(Fe), the "Fe" suffix, pronounced eff-ee, refers to the presence of iron (ferrous, Fe^{2+}) in the formula. Until 2007, axinite-(Fe) was formally known as "ferro-axinite." Other names include "axinite," "feraxinite," "iron axinite," "glassy schorl," and "vitreous schorl." In European mineralogical literature, axinite appears as *feraxinita* and *Feraxinit*.

COMPOSITION: Axinite-(Fe) is a basic calcium iron aluminum borosilicate containing the elements calcium (Ca), iron (Fe), aluminum (Al), boron (B), oxygen (O), silicon (Si), and hydrogen (H) in the proportions of 14.06 percent calcium, 9.80 percent iron, 9.47 percent aluminum, 1.90 percent boron, 44.90 percent oxygen, 19.71 percent silicon, and 0.16 percent hydrogen. Axinite-(Fe) is a member of the silicate class of minerals and the sorosilicate or double-tetrahedral subclass. It crystallizes in the triclinic system, which is characterized by three axes of different lengths, none of which are perpendicular. As exemplified by axinite-(Fe), triclinic crystal habits are often wedge- or blade-shaped. As an idiochromatic (self-colored) mineral, axinite-(Fe)'s basic brown color is due to the presence of the essential element iron and the nature of its crystal lattice. Nearly pure axinite-(Fe) is clove-brown, reddish-brown, or purplish-brown. Varying amounts of manganese can introduce yellowish and greenish tones. Axinite-(Fe) is pleochroic and

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exhibits shifts in color when viewed from different angles. Rotating an axinite-(Fe) crystal along all three axes while viewing it will produce color shifts from basic brown to purple or purplish-brown and to yellowish- or greenish-brown. Axinite-(Fe) is uncommon and forms primarily through metamorphic processes. Well-developed axinite-(Fe) crystals occur in tension fractures (alpine clefts), which are voids formed during metamorphic deformation that later fill with hydrothermal fluids that precipitate axinite-(Fe) and other minerals.

COLLECTING LOCALITIES: Axinite-(Fe) is collected in California in Calaveras, Madera, and Riverside counties. Other localities in the United States are in Connecticut, Maine, Montana, Nevada, North Carolina, Virginia, Vermont, and Pennsylvania. Axinite-(Fe) is also collected in France, Germany, Italy, Spain, Switzerland, England, Russia, Canada, Mexico, Morocco, Peru, Pakistan, South Africa, and Japan.

HISTORY, LORE, & GEMSTONE/TECHNOLOGICAL USES: Axinite, first described in France in 1785, was accepted as a new mineral species in 1800 and named for its ax-head-shaped crystals. The iron-, magnesium-, and manganese-rich forms of axinite were considered to be varieties of a single mineral species until 1909, when mineralogists recognized the iron-rich and manganese-rich varieties as separate species which they respectively named “ferro-axinite” and “manganaxinite.” The atomic structure of these complex, closely related axinite-group minerals were precisely determined in the 1950s. In 2007, the International Mineralogical Association’s Commission on New Minerals and Mineral Names renamed “ferro-axinite” as axinite-(Fe). With a hardness (Mohs 6.5-7.0) approaching that of quartz, axinite-(Fe) gems are suitable for most types of jewelry with the exception of rings. Axinite-(Fe) exhibits pleochroism, in which its basic brown color shifts to purple or purplish-brown to yellowish- or greenish-brown as the viewing angle changes. Because axinite-(Fe) is uncommon and rarely forms crystals that can be cut into gems larger than one carat, it has never become popular in jewelry. Axinite-(Fe) has no technological uses. Modern metaphysical practitioners believe that the axinite-group minerals provide grounding in all endeavors, inspire friendship, supply the energy necessary to stabilize relationships, and facilitate the graceful acceptance of changes in the direction of one’s life.

ABOUT OUR SPECIMENS: Our axinite-(Fe) specimens were collected at the New Melones Dam on the Stanislaus River near Copperopolis in Calaveras County, California, 65 air miles southeast of Sacramento. Axinite-(Fe) was discovered during the final stages of dam construction there in the late 1970s. When the first specimens reached mineral shows in 1980, they were acclaimed as the finest axinite-(Fe) specimens ever found in the United States and the New Melones Dam gained immediate recognition as a classic axinite-(Fe) locality. The country rock at the dam, which is part of a geologically complex metamorphic belt that consists largely of altered gabbro and greenstone, contains numerous tension fractures or alpine clefts that developed some 150 million years ago as regional deformation or strain-related metamorphism “stretched” the rock. This “stretching” of the plastic rock masses created long, longitudinal, string-like voids which filled with mineral-rich, hydrothermal fluids. Later, with decreasing temperatures or chemical changes, these fluids precipitated crystals of axinite-(Fe) and other minerals. Collecting at the New Melones Dam was difficult because of the toughness of the host rock; active spillways also often made the tension-fracture zones inaccessible. Collectors removed the crystals from most of the accessible tension fractures shortly after their discovery. Since early 2002, heightened security measures have banned all mineral collecting at the New Melones Dam. Our specimens were obtained by commercial collectors in 2000, and are some of the last specimens ever collected at the site.

10 YEARS AGO IN OUR CLUB: Imperial Topaz, Capão mine, Ouro Preto, Minas Gerais, Brazil. These were small but beautiful single crystals from a classic locality. We remember working on the write-up in Big Bear, California, while on a snowboarding trip for our son Keenan and his friends—a great memory!

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COMPREHENSIVE WRITE-UP

COMPOSITION

The chemical formula $\text{Ca}_2\text{FeAl}_2\text{BO}(\text{OH})(\text{Si}_2\text{O}_7)_2$ identifies axinite-(Fe) as a basic calcium iron aluminum borosilicate containing the elements calcium (Ca), iron (Fe), aluminum (Al), boron (B), oxygen (O), silicon (Si), and hydrogen (H). Its molecular weight is made up of 14.06 percent calcium, 9.80 percent iron, 9.47 percent aluminum, 1.90 percent boron, 44.90 percent oxygen, 19.71 percent silicon, and 0.16 percent hydrogen. Although axinite-(Fe)'s complex chemical formula can appear confusing, remember that all molecules achieve stability when the cumulative electrical charge of their cations (positively charged ions) equals that of their anions (negatively charged ions). In axinite-(Fe), the compound cation $[\text{Ca}_2\text{FeAl}_2(\text{BO})]^{13+}$ has an electrical charge of +13, which is the sum of the electrical charges of its component ions. Calcium and ferrous ions (Fe^{2+}) have +2 charges, while the aluminum ions each have a +3 charge. In the boron-oxide radical $(\text{BO})^{1+}$, boron has a +3 charge and oxygen a -2 charge. In axinite-(Fe)'s compound anion $[(\text{OH})(\text{Si}_2\text{O}_7)_2]^{13-}$, the hydroxyl ion $(\text{OH})^{1-}$ consists of one oxygen ion with a -2 charge and one hydrogen ion with a +1 charge. The silica ion $(\text{Si}_2\text{O}_7)^{6-}$ contains two silicon ions, each with a +4 charge, and seven oxygen ions, each with a -2 charge. These provide a collective -13 anionic charge to balance the +13 cationic charge to provide the axinite-(Fe) molecule with electrical stability.

Axinite-(Fe) is a member of the silicates, the largest and most abundant class of minerals, in which silicon and oxygen combine with one or more metals. The basic structure of all silicates is the silica tetrahedron $(\text{SiO}_4)^{4-}$, which consists of four equally spaced oxygen ions (4O^{2-}) that surround a silicon ion (Si^{4+}) and are positioned at the four corners of a tetrahedron (a four-faced polyhedron). In silicate minerals, silica anions and metal cations link together like polymers (repeating chains) to form seven different structures: framework silicates (tectosilicates); single- and double-chain silicates (inosilicates); ring silicates (cyclosilicates); sheet silicates (phyllosilicates); independent-tetrahedral silicates (nesosilicates); and double-tetrahedral silicates (sorosilicates).

Until the 1980s, ferro-axinite [now axinite-(Fe)] was considered to be a cyclosilicate or ring silicate. But after reviewing its complex atomic structure in the 1980s, mineralogists reclassified it as sorosilicate or double-tetrahedral silicate. Double-tetrahedral silicates form when a silica tetrahedron shares one of its oxygen ions (O^{2-}) with an adjacent tetrahedron. In this arrangement, two silica tetrahedra $(2\text{SiO}_4)^{4-}$ share a single oxygen ion to form the $(\text{Si}_2\text{O}_7)^{6-}$ radical (a group of atoms that acts as an entity in chemical reactions). The $(\text{Si}_2\text{O}_7)^{6-}$ radical is the core component of the axinite-(Fe) molecule. Within this radical, the single shared oxygen ion is electrically neutral, while the other six each carry a -1 charge. These double-tetrahedral $(\text{Si}_2\text{O}_7)^{6-}$ units are insular, that is, not directly connected. Within the axinite-(Fe) lattice, two double-tetrahedral $2(\text{Si}_2\text{O}_7)^{6-}$ units are linked together by ionic bonding to a boron-oxide ion $(\text{BO})^{1+}$. To visualize this arrangement, picture a dumbbell in which the two large ends represent silica groups and the thin bar linking them represents a boron-oxide unit. This forms the basic borosilicate structure $[(\text{BO})(\text{Si}_2\text{O}_7)_2]^{11-}$. The remaining excess of negatively charged oxygen ions in each silica group attracts and bonds ionically to two calcium ions, one iron ion, and two aluminum ions. These metal cations are positioned within channels in the dumbbell-shaped molecular unit. This still-incomplete molecule has an excess +1 charge, which is satisfied by attracting and bonding to a single hydroxyl ion $(\text{OH})^{1-}$ to form the complete, stable axinite-(Fe) molecule $\text{Ca}_2\text{FeAl}_2\text{BO}(\text{OH})(\text{Si}_2\text{O}_7)_2$.

In the axinite-(Fe) crystal lattice, these individual molecules form continuous chains and a three-dimensional structure in which the silica ends of each dumbbell-shaped unit are bound to others in generally circular configurations. Within the axinite-(Fe) lattice, these circular configurations appear to be stacked—the reason that mineralogists long thought axinite-(Fe) was a cyclosilicate or ring silicate, rather

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than a sorosilicate or double-tetrahedral silicate. Because many different ions can be present within their complex structures, sorosilicate minerals tend to be chemically complex, as is the case with axinite-(Fe).

The Dana mineral-classification number 56.2.2.1 first establishes axinite-(Fe) as a sorosilicate containing silica radicals as $(\text{Si}_2\text{O}_7)^{6-}$ groups and water molecules or oxygen, hydroxyl, or halogen ions (56). The subclassification (2) defines the axinite-(Fe) molecule as having cations present in coordinations of four or less. Axinite-(Fe) is then assigned to the axinite group (2) as the first (1) of four members. The following list of axinite-group members compares their chemistries:

Axinite-(Fe) $\text{Ca}_2\text{FeAl}_2\text{BO}(\text{OH})(\text{Si}_2\text{O}_7)_2$ basic calcium iron aluminum borosilicate (formerly ferro-axinite)

Axinite-(Mg) $\text{Ca}_2\text{MgAl}_2\text{BO}(\text{OH})(\text{Si}_2\text{O}_7)_2$ basic calcium magnesium aluminum borosilicate (formerly magnesio-axinite)

Axinite-(Mn) $\text{Ca}_2\text{MnAl}_2\text{BO}(\text{OH})(\text{Si}_2\text{O}_7)_2$ basic calcium manganese aluminum borosilicate (formerly manganaxinite)

Tinzenite $\text{CaMn}_2\text{Al}_2\text{BO}(\text{Si}_2\text{O}_7)_2$ basic calcium manganese aluminum borosilicate

The chemical differences between axinite-(Fe), axinite-(Mg), and axinite-(Mn) are based on the mutual substitution of iron (Fe), magnesium (Mg), and manganese (Mn). Axinite-(Fe) and axinite-(Mn) form a graded, solid-solution series in which manganese completely replaces iron. Because manganese substitutes readily for iron, virtually all axinite-(Fe) specimens contain at least some manganese.

Despite the presence of weak ionic bonding, the axinite-(Fe) lattice is dominated by the strong covalent bonding between the shared oxygen ions within its double-tetrahedral units, which provides a substantial hardness of Mohs 6.5-7.0 (nearly as hard as quartz). The largely omnidirectional bonding throughout the three-dimensional lattice structure limits axinite-(Fe)'s cleavage to distinct-to-good in one direction and poor in two others. Because the silica tetrahedra completely shield the metal ions, axinite-(Fe) exhibits no metallic properties. Close atomic packing and the relatively heavy atomic weights of iron (55.85) and manganese (54.94) explain axinite-(Fe)'s moderately high density (specific gravity 3.27-3.29). Axinite-(Fe) crystallizes in the triclinic system, which is characterized by three axes of different lengths, none of which are perpendicular. As seen in axinite-(Fe), triclinic crystals tend to form in wedge- or blade-shaped habits. Chemically complex minerals such as Axinite-(Fe) often crystallize in the triclinic system.

As an idiochromatic (self-colored) mineral, axinite-(Fe)'s basic brown color is caused by the essential element iron and the nature of its crystal lattice. When nearly pure, axinite-(Fe) is clove-brown, reddish-brown, or purplish-brown. The varying amounts of manganese that are usually present can introduce yellowish and greenish tones. Trace amounts of such metals as chromium can also impart color variations. A diagnostic feature of axinite-(Fe) is pleochroism, an optical phenomenon that causes certain mineral crystals to exhibit different colors when viewed from different angles. The word "pleochroism," which stems from the Greek *pleiōn*, meaning "more," and *chrōs*, "color," came into use in its mineralogical context in the 1850s. Pleochroism is caused by the absorption of different wavelengths of light as it travels through different sections of doubly refractive mineral crystals. All transparent or translucent mineral crystals refract or bend light. Doubly refractive mineral crystals also divide it into two polarized beams that each travel in planes perpendicular to each other. These divided, polarized light beams follow different paths and travel at different speeds through the crystal lattice. As each path absorbs different wavelengths of white light, the beams that emerge from the crystal exhibit different colors or different intensities of the same color.

Pleochroism can be *dichroic* or *trichroic*, depending upon crystal structure. Dichroic mineral crystals exhibit two color changes; trichroic crystals exhibit three color changes. The seven basic crystal systems

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are isometric, tetragonal, trigonal, hexagonal, orthorhombic, monoclinic, and triclinic. Isometric minerals do not exhibit pleochroism because their geometrically uniform structures have the same light-absorbing properties in all directions. Tetragonal, trigonal, and hexagonal crystals are dichroic because their single secondary structural direction off the major axis permits only two pleochroic shifts. Orthorhombic, monoclinic, and triclinic crystals are trichroic because their three unique axes of symmetry can absorb light in three different ways. As a triclinic mineral, axinite-(Fe) exhibits trichroism. Rotating axinite-(Fe) crystals along all three axes while viewing will produce shifts of color from the basic brown to purple or purplish-brown and yellowish- or greenish-brown. This phenomenon can be difficult to observe in small crystals.

Axinite-(Fe) is an uncommon mineral that forms primarily through metamorphic processes. In low- to high-grade, regionally-metamorphosed calcareous rocks and in contact-metamorphosed rocks, axinite-(Fe) is associated with diopside [calcium magnesium silicate, $\text{CaMgSi}_2\text{O}_6$], prehnite [basic calcium aluminum silicate, $\text{Ca}_2\text{Al}_2\text{Si}_3\text{O}_{10}(\text{OH})_2$], andradite [garnet group, calcium iron silicate, $\text{Ca}_3\text{Fe}_2(\text{SiO}_4)_3$], epidote [basic calcium iron aluminum silicate, $\text{Ca}_2\text{Al}_2(\text{Fe,Al})(\text{Si}_3\text{O}_{12})(\text{OH})$], actinolite [basic calcium magnesium iron silicate, $\text{Ca}_2(\text{Mg,Fe})_5\text{Si}_8\text{O}_{22}(\text{OH})_2$], albite [sodium aluminum silicate, $\text{NaAlSi}_3\text{O}_8$], calcite [calcium carbonate, CaCO_3], and quartz [silicon dioxide, SiO_2]. Unusually well-developed axinite-(Fe) crystals occur in tension fractures or alpine clefts in metamorphic rocks when deformation creates voids that fill with hydrothermal fluids (see "About Our Specimens"). Axinite-(Fe) also occurs, usually in massive or granular forms, in granite pegmatites and in hydrothermal veins in association with quartz and calcite.

COLLECTING LOCALITIES

Although uncommon, axinite-(Fe) occurs in metamorphic environments worldwide. Well-developed crystals are relatively rare. Our specimens were collected at the New Melones Dam on the Stanislaus River near Copperopolis in Calaveras County, California. Other California localities are the ridges north of Coarsegold in Madera County and the Jensen Quarry in the Jurupa Mountains of Riverside County. Across the United States, axinite-(Fe) is collected at the Route 2 road cut at Glastonbury, Hartford County, Connecticut; the Bath Town Quarry at Bath, Sagadahoc County, Maine; the Pruett feldspar claim in the Boulder Batholith region of Jefferson County, Montana; the Luning area of Mineral County, Nevada; the Foote Lithium Mine in the Kings Mountain district, Cleveland County, North Carolina; the Shadwell Quarry in Charlottesville, Albemarle County, Virginia; the Belvedere Mountain asbestos quarries at Lowell and Eden in Orleans and Lamoille counties, Vermont; and the Kibblehouse Quarry in Marlborough Township, Montgomery County, Pennsylvania.

In Europe, axinite-(Fe) is collected at the type locality at St. Christophe-en-Oisans, Bourg d'Oisans, Isère, Rhône-Alpes, France; the Frassgraben Quarry at Frassgraben in the Koralpe Mountains, Carinthia, Austria; the Bärenstein Quarry at Bad Harzburg in the Harz Mountains, Lower Saxony, Germany; the Suela (Montecatini) Quarry at Mount Camoscio near Baveno, Verbana-Cusio-Ossola Province, Piemonte, Italy; the Monchi Mine at Burguillos de Cerro, Badajoz, Extremadura, Spain; the Brunni Valley and Chatchtal Glacier areas near Uri, Ticino, Switzerland; and the Tremore Quarry near Lanivet in the St. Austell district, Cornwall, England. Russian specimens come from Mount Puiva near Saranpaul, Tyumenskaya Oblast', Western Siberian Region.

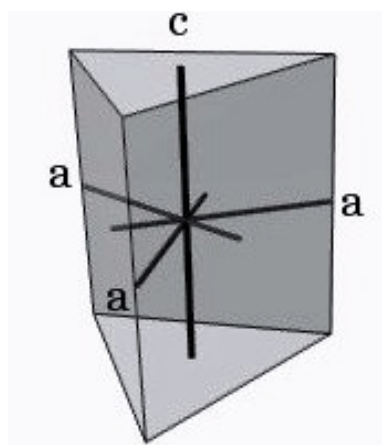


Figure 1. Trigonal crystal axes and typical crystal. Image courtesy of gemologyproject.com.

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Other localities include the Dome Mine at Kirkland Lake in the South Porcupine district, Ontario, and the Stargazer claim in the O'Grady Lake area in the Northwest Territories, both in Canada; the Olivia and Fenómeno mines at Laguna Hansen near Tecate, Baja California Norte, Mexico; the mines at Vittoria do Conquista in Bahia, Northeast Region, Brazil; the El Hammam Mine at El Hammam near Meknès, Meknès Prefecture, Meknès-Tafilalet Region, Morocco; Dassu and Alchuri villages in the Shigar Valley, Skardu district, Baltistan, Northern Areas, Pakistan; the Paracas Quarry at Espinal, Ica Department, Peru; the NababEEP tungsten mines in the Okiep copper district, Namaqualand, Northern Cape Province, South Africa; and the Obira Mine at Ono-gun in Oita Prefecture and the Toroku Mine at Takachiho in Miyazaki Prefecture, both in Japan's Kyushu Region.

JEWELRY & DECORATIVE USES

Axinite-(Fe) has many qualities of a fine, semiprecious gemstone. With hardness (Mohs 6.5-7.0) approaching that of quartz, axinite-(Fe) gems are suitable for most jewelry uses with the exception of ring stones. Axinite-(Fe)'s colors, usually browns similar to those of smoky quartz, have an intriguing pleochroism (see "Composition") in which the basic brown shifts with changes in the viewing angle to yellowish-brown and an eye-catching purplish-brown. Unfortunately, because it is uncommon and only rarely forms crystals that can be cut into gems larger than one carat, axinite-(Fe) has never become popular in jewelry use. Axinite-(Fe) collector gems, however, are in considerable demand for their rarity and pleochroic colors. The few axinite-(Fe) gems that weigh as much as five carats are considered museum pieces. One-carat axinite-(Fe) gems now sell for about \$100. Axinite-(Fe) specimens with well-developed crystals are popular among mineral collectors for their rarity, crystal shape, and pleochroism.

HISTORY & LORE

The French crystallographer Jean-Baptiste de L'Isle (1736-1790) first described axinite crystals in 1785. In 1897, French mineralogist and crystallographer René Just Haüy (1743-1822) visited the Alps and collected specimens at St. Christophe-en-Oisans, Bourg d'Oisans, Isère, Rhône-Alpes, France. Initially, Haüy erroneously identified his specimens as "vitreous schorl," a name that stills persists. In 1800, Haüy corrected his error by determining the true chemical composition of his specimens and realizing that they represented a new mineral which he named "axinite," after its ax-head-shaped crystals. Although mineralogists later identified iron-, magnesium-, and manganese-rich forms of axinite, all were considered as varieties of a single mineral species until 1909 when United States Geological Survey chemist and geologist Waldemar Theodore Schaller (1882-1968) confirmed both the iron-rich and manganese-rich varieties as distinct minerals, which he respectively named "ferro-axinite" and "manganaxinite." The atomic structure of the axinite-group minerals was determined precisely in the 1950s. In 1975, mineralogists, using advanced quantitative-analysis methods, identified yet another member of the axinite group—a magnesium-rich member that was named "magnesio-axinite." In 2007, the International Mineralogical Association's Commission on New Minerals and Mineral Names renamed "ferroaxinite" as axinite-(Fe), "manganaxinite" as axinite-(Mn), and "magnesio-axinite" as axinite-(Mg). Much current mineralogical literature and many specimen descriptions continue to refer to axinite-(Fe) as "ferro-axinite."

Modern metaphysical practitioners believe that the axinite-group minerals provide grounding in all endeavors, inspire friendship, supply the energy necessary to stabilize relationships, and facilitate graceful acceptance of changes in the directions of one's life.

TECHNOLOGICAL USES

Axinite-(Fe) has no technological uses.

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HOW NEW DISCOVERIES IMPACT THE MINERAL-SPECIMEN MARKET

The appearance of specimens from new localities often creates great excitement in the world of mineral collecting. This excitement is shared by dealers and collectors, and extends to gem-and-mineral shows, museums, scientific institutions, and the mineral-collecting media. Although specimens from several new localities reach the market every year, not all are noteworthy. But when specimens appear with the right degrees of rarity, mineralogical interest, aesthetic appeal, and collector demand, specimen markets can literally be turned upside down.

That happened when specimens of our Mineral of the Month—axinite-(Fe) from California's New Melones Dam—hit the market in late 1979 (see "About Our Specimens"). These specimens were widely acclaimed at gem-and-mineral shows, studied by research institutions, acquired by museums, and publicized by the mineral-collecting media. The result was strong collector demand that sent prices soaring. Within two years, these specimens had completely restructured the market for axinite-(Fe) and continue to dominate that market today. Here are the various factors that combined to make New Melones Dam axinite-(Fe) one of the hottest items to ever impact the specimen market.

Mineralogical Interest and Aesthetic Appeal: *Mineral collectors tend to seek out specimens that exhibit the characteristics that best represent a particular species or those that are unusual or rare for that species. Collectors also have an eye for specimens that have great aesthetic appeal. The brilliant luster, superb crystal development, and rich, brown base color of New Melones Dam axinite-(Fe) specimens immediately attracted collector attention as the finest of their species ever found in the United States.*

Comparison with Specimens from Other Localities: *When specimens from a new locality reach the market, dealers and collectors immediately compare them with those from other localities. Although the New Melones Dam axinite-(Fe) crystals are somewhat smaller than those from certain other localities, their rich color and exceptional degree of crystal development generated great collector interest.*

Scientific Study: *Mineralogical study of specimens from new localities always stimulates collector interest and provides a measure of credibility in the market. Soon after they were discovered, New Melones Dam axinite-(Fe) specimens had been studied by mineralogists from the United States Geological Survey and the University of California who published their results in technical papers.*

Supply: *Specimen supply or relative availability is often a critical factor behind collector appeal. Although an abundance of specimens can lower prices, oversupply can also dampen collector interest. Conversely, great rarity of specimens can cause overpricing that also limits collector appeal. While the initial supply of New Melones Dam axinite-(Fe) specimens was more-or-less adequate, many collectors and dealers, realizing that the future supply was clearly limited, acquired quantities of specimens as investments.*

Media, Museum, and Exhibition Attention: *To generate broad collector demand, specimens from new localities must be publicized. In the world of mineral collecting, this means exposure at gem-and-mineral shows and museums, and in mineral-collecting publications. Because a number of dealers handled the initial supply of New Melones Dam axinite-(Fe) specimens, they quickly appeared at many gem-and-mineral shows in the United States and Europe. Specimens were also acquired by the National Museum of Natural History (Smithsonian Institution) and other major museums. Furthermore, within two years of their discovery a detailed, feature article on these specimens appeared in the prestigious *Mineralogical**

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Record. This article had two effects on the specimen market. First, it greatly stimulated collector interest in, and demand for, these specimens. Second, the article recognized the New Melones Dam as a classic axinite-(Fe) locality, which further increased collector demand.

Because no significant, new localities for axinite-(Fe) have since been discovered, specimens from the New Melones Dam, despite their limited availability, continue to dominate the market. Collector demand and prices remain high, especially since the locality was formally closed to collecting in 2002. We were fortunate to be able to obtain these specimens in the quantity necessary to feature as our Mineral of the Month. No one knows whether another domestic site will ever provide axinite-(Fe) specimens that will equal or surpass those from the New Melones Dam—an uncertainty that is one of the most intriguing and fascinating aspects of mineral collecting.

ABOUT OUR SPECIMENS

Our axinite-(Fe) specimens were collected at the New Melones Dam on the Stanislaus River near Copperopolis in Calaveras County, California. The New Melones Dam is located in central California, 65 air miles southeast of Sacramento. The Stanislaus River is the boundary between Calaveras County to the north and Tuolumne County to the south. The nearest town, five air miles to the west, is the old copper-mining town of Copperopolis, population 2,400. The elevation at the dam is about 1,000 feet; the adjacent low hills are covered with chaparral and scrub oak, while watercourses sustain growths of willow and cottonwood.

The original Melones Dam was constructed in the 1930s to provide irrigation water to the northern San Joaquin Valley 40 miles to the west. The New Melones Dam, 578 feet high, was built at the same site to impound a much larger, 20-square-mile reservoir and power a “peak-use,” 300-megawatt hydroelectric plant. As the project neared completion in 1979, engineers blasted spillways on the north side of the dam (Calaveras County). Displacement of the metamorphic country rock exposed a system of long, hollow voids, some of which contained well-developed crystals of quartz and axinite-(Fe). These crystals were first noticed by a bulldozer driver who heard “crunching noises” under his tracks as he bladed the newly blasted rock. Inspecting the rock, he noticed “lots of big quartz crystals and some funny brown crystals,” which he reported to local mineral collectors. Soon hundreds of collectors had flocked to the site to screen loose crystals from the blasted rock and dig in situ crystals from the exposed voids. Just weeks later, authorities from the United States Bureau of Reclamation, which controls the dam, closed the site to collectors for fear of accidents and damage to the new spillway. By then, more than 4,000 fine specimens of axinite-(Fe) had been collected.

Collectors sold many of these specimens to dealers who, in turn, introduced them at a number of gem-and-mineral shows. Some experienced collectors acclaimed as the finest axinite-(Fe) specimens ever found in the United States and even equated them with the superb specimens then coming from Russia. After *The Mineralogical Record* reported the find and the quality of the specimens in 1981 (“Ferro-axinite from New Melones Lake, Calaveras County, California: A Remarkable New Locality,” D. Pohl, R. Guillemett, J. Shigley, and G. Dunning, *The Mineralogical Record*, September-October 1981), the New Melones Dam was firmly established as a classic axinite-(Fe) locality.

By then, mineralogists and geologists had already visited the locality to piece together the geological origin of the axinite-(Fe) specimens. The country rock is part of the geologically complex Western Sierra Nevada Metamorphic Belt, in which extensive regional metamorphism has deformed and faulted the original igneous (both intrusive and extrusive) and sedimentary rocks. This metamorphic country rock consists largely of greenstone, a dull, microcrystalline, gray-green rock that derives its color from a high content of

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the green minerals epidote [basic calcium aluminum iron silicate, $\text{Ca}_2\text{Al}_2(\text{Fe},\text{Al})\text{Si}_3\text{O}_{12}(\text{OH})$] and actinolite [basic calcium magnesium iron silicate, $\text{Ca}_2(\text{Mg},\text{Fe})_5\text{Si}_8\text{O}_{22}(\text{OH})_2$]. The greenstone at the New Melones Dam is laced with numerous tension fractures, structures that are also known as “alpine clefts,” “alpine gashes,” or “alpine fissure veins,” terms that derive from the alpine elevations of Switzerland where they were first studied in the 1800s. Tension fractures, which are sometimes filled with well-developed mineral crystals, form during regional deformation (often tectonic in origin) or strain-related metamorphism in which rock expands and stretches. This “stretching” of semi-fluid rock masses can create long, longitudinal, string-like voids which fill with mineral-rich, hydrothermal fluids. Later, with decreasing temperatures or chemical changes, these fluids can precipitate such minerals as quartz and axinite-(Fe). Given sufficient space for free growth, these crystals can be extraordinarily well-developed.

The tension fractures at the New Melones Dam were formed some 150 million years ago during the late Jurassic Period and the beginning of the Nevadan Orogeny that later uplifted the Sierra Nevada. Most of these narrow fissures have limited space and are filled with massive forms of quartz and axinite-(Fe). Some fissures, however, did have sufficient space for the growth of superbly formed, ax-head-shaped, axinite-(Fe) crystals. Along with axinite-(Fe), these tension fractures also contain actinolite, albite [sodium aluminum silicate, $\text{NaAlSi}_3\text{O}_8$], calcite [calcium carbonate, CaCO_3], epidote, and quartz. The New Melones Dam is one of the very few sites worldwide where axinite-(Fe) has been found as inclusions *within* quartz crystals! Mineralogists believe that this rare occurrence was caused by a late-stage surge of silica-rich hydrothermal solutions that precipitated quartz within the tension fractures *after* axinite-(Fe) had already crystallized!

The easiest and most productive collecting at the New Melones Dam took place in the few weeks between the discovery of the crystals in 1979 and the Bureau of Reclamation’s initial closure of the site. When the site was reopened in 1982, a rush of collecting ensued, but collecting now required greater effort and time. Most crystals in the easily accessible, exposed tension fractures had already been collected, and extracting the remaining crystals intact was extremely difficult because of the hardness and toughness of the host rock. Finally, when the New Melones Dam went into full operation in 1982, the periodic release of water down the spillways made many of the exposed tension fractures inaccessible. Nevertheless, collectors, usually commercial collectors working with permission from the Bureau of Reclamation, were able to gather limited quantities of specimens over the next 20 years. But after the attacks on New York City’s World Trade Center and the Pentagon in Washington, D.C. in September 2001, heightened domestic security regulations placed the New Melones Dam off-limits to all further mineral collecting. Our specimens, obtained by commercial collectors shortly before the new security regulations went into effect in early 2002, are likely among the last specimens to ever come from this locality!

When examining your specimen, first note the matrix rock atop which the axinite-(Fe) crystals have grown. This matrix rock consists of almost entirely of massive axinite-(Fe), along with small amounts of massive quartz, clear quartz needles, small coatings of yellow-brown hematite [iron oxide, Fe_2O_3], and occasional small, green crystals of actinolite and epidote. Mineralogists believe that the massive axinite-(Fe) in our specimens was precipitated relatively early in the creation of the tension fractures when insufficient space precluded the growth of individual crystals. The final precipitation of axinite-(Fe) came later when the tension fractures had enlarged sufficiently to provide the free space necessary for the growth of well-formed crystals atop the massive material.

Turning your attention to the crystals, note first the brilliant, vitreous luster and the ax-head or chisel-like shapes that are characteristic of axinite-(Fe). The striated crystal faces are another diagnostic feature of axinite-(Fe). The basic brown color of these crystals is similar to that of deeply colored smoky quartz. Pleochroism, another diagnostic property of axinite-(Fe), can be observed by studying the crystals closely

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in bright sunlight or intense artificial light. Choose a relatively large, thin crystal and note how the colors shift as you rotate the specimen in your hand. A two-color shift from brown to brown-purple is most apparent. The third shift to brownish-yellow is less apparent. Though small, your axinite-(Fe) specimen is a fine example of an uncommon mineral from a classic American locality—from which, as the years go by, fewer and fewer specimens will be available!

This month's featured mineral marks the fifteenth anniversary of our Club—our 181st month and mineral! March 1996 was our first month, when we featured the amazing cubic pyrite from the Victoria Mine at Navajún, La Rioja, Spain. Our first member joined via telephone in February 1996, while we were selling in Tucson at the same location as we are now (though it was a Ramada hotel then), after seeing our first ad in the Lapidary Journal, as seen in Figure 2. By the end of March, we had about eleven members, most of whom had seen us at shows and joined as a result.

Our Club grew steadily as the years passed, and we gained a large influx of new members when we advertised in the now-defunct Earth magazine in 1997, at the suggestion of one of our suppliers. For more details on the growth of our Club and its history, check out the article from the August 2003 Rock & Gem that is reprinted on our web site. (Dozens of new members joined in its wake.) Before the economic collapse in 2008, our membership was approaching 600; since then, it has contracted to about 485. How we appreciate all those members who have been able to stick with us in these difficult years! In the past few years, our Platinum-level membership has grown tremendously, which has more than made up for the decrease in overall membership. The downturn had a couple of unexpected benefits for us, particularly in the Gold-level size, where we had to obtain 250 to 300 specimens to suit our needs—you wouldn't believe how much easier it is to obtain just the 200 to 250 we now need! Also, collectors and wholesalers are much more eager to work with us, as their sales have slowed like everyone else's. This has resulted in us being able to feature minerals that prior to the collapse were way out of our price range, such as the hübnerite, hematite after magnetite, and Boulder opal we featured last year, and the Peruvian rhodonite, barite, and Namibian aquamarine we'll be featuring this year, to name just a few examples. We hope that the Mineral of the Month Club will go on forever—thank you so much for making it possible!

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Figure 2 Our first ad in the February 1996 Lapidary Journal. The price listed was for our "Basic Membership," which later became our "Junior Membership," and is now known as our "Silver Membership." Note that in fifteen years the price has only increased from \$69 to \$88!

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