March 2005 Mineral of the Month: Spessartine

"With a cheerful array of colors, spessartine garnets are among the most exquisite members of the garnet group. Few orange gems can rival an intense orange spessartine."
–June Culp Zeitner, Gem & Lapidary Materials, 1996

PHYSICAL PROPERTIES

Chemistry: $Mn^{2+}{}_3Al_2(SiO_4)_3$ Manganese Aluminum Silicate, usually with some iron
Class: Silicates Subclass: Neosilicates (Independent Tetrahedral Silicates) Group: Garnet
Crystal System: Isometric (Cubic)
Crystal Habits: Common as 12-sided dodecahedrons, less common as 24-sided trapezohedrons, occasionally as 48-sided hexoctrahedrons; also as granular, lamellar, compact, and disseminated forms.
Color: Orange, brown, yellowish-brown, reddish-orange, red, hyacinth-red, and brownish-red.
Luster: Vitreous
Transparency: Transparent to opaque
Streak: Colorless
Refractive Index: 1.79-1.81
Cleavage: None, but sometimes parts in six distinct directions
Fracture: Uneven; conchoidal; brittle
Hardness: Mohs 6.9-7.2 (varies with composition)
Specific Gravity: 3.8-4.3 (varies with composition)
Luminescence: None
Distinctive Features and Tests: Best field marks are dodecahedral or trapezohedral crystal habits and hardness. Spessartine can be confused with other garnet-group members, as explained under *Composition*. Positive identification of garnet-group members often requires laboratory analysis.
Dana Classification Number: 51.4.3a.3

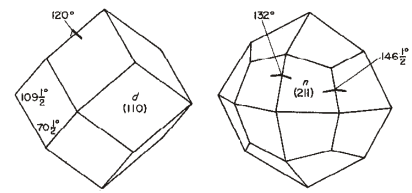

Figure 1. Garnet dodecahedron (left) and trapezohedron (right). Drawings courtesy of Mineralogy by John Sinkankas, used be permission.

NAME

The word "garnet" derives from the Latin *granatus* for pomegranate, a fruit in which the red, pulp-covered seeds resemble small, red garnet crystals. The word "spessartine" stems from the mineral's type locality at Aschaffenburg, Spessart, Bavaria, Germany, and is correctly pronounced SPESS-ar-teen. Spessartine has also been called "spessarite," "spessartin," "Mandarin garnet," "malaia (also 'Malaya' and 'Malaysia') garnet," "manganese garnet," and "orange garnet."

COMPOSITION

It seems we feature marvelous minerals every year in March, as we celebrate our Club's anniversary–fluorescent fluorite from England in '02, diamond in '03, amethyst "Cactus" quartz in '04, and now these striking spessartines, from a new find to boot! This is the second time we've featured this garnet group member, the first time in August 1998 from Garnet Hill, near Ely, White Pines County, Nevada. Other garnets we have featured are almandine from Wrangell, Alaska, in March 1997, uvarovite from the Ural Mountains of Russia in February 2001, and grossular from Coahuila, Mexico in December 2002.

This is now the eighth mineral we've featured from China, after realgar in August 1996, azurite in September 1996, stibnite in February 1998, tektite in November 1999, inesite (with the new mineral hubeite) in August 2001, pyromorphite in July 2002, and cinnabar in February 2004. No doubt as more and more finds come to light from this mineral-rich country, we will feature others!

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Before we get into spessartine's composition, let's look at the garnet group as a whole. Spessartine is one of the 15 members of the garnet group, which is itself one of the silicates, the largest and most abundant class of minerals. Silicates are combinations of silicon and oxygen with one or more metals. The basic silicate structural unit is the silica tetrahedron [$(SiO_4)^{4-}$], which consists of four equally spaced oxygen atoms surrounding a silicon atom. With, the silicon atom at the center, the oxygen atoms form the four corners of a tetrahedron. In silicate minerals, silica anions and metal cations are linked together like polymers (repeating chains) to form seven types of structures. These include the independent tetrahedral silicates (neosilicates), double tetrahedral silicates (sorosilicates), framework silicates (tectosilicates), single- and double-chain silicates (inosilicates), ring silicates (cyclosilicates), and sheet silicates (phyllosilicates).

The garnet-group minerals are neosilicates. In neosilicate molecules, metal cations are packed tightly between silica tetrahedra. The tetrahedra are isolated and have no direct mutual bonding. Neosilicate crystal lattices are rigid arrangements with bonding only between the anionic tetrahedra and the cationic metallic ions. Because of dense atomic packing and a combination of ionic and strong covalent bonds between the silica tetrahedra and the metallic cations, neosilicates are hard, relatively dense, and form short, blocky, somewhat square crystals.

Garnet-group minerals share very similar atomic structures. The garnet-group's general chemical formula is $A_3B_2(SiO_4)_3$, with "A" representing such divalent metallic ions as calcium^{2+}, magnesium^{2+}, ferrous iron^{2+}, and manganese^{2+}, and "B" representing such trivalent metallic ions as aluminum^{3+}, chromium^{3+}, ferric iron^{3+}, and manganese^{3+}. In some rarer garnet-group members, "B" can also represent vanadium^{3+}, titanium^{3+}, or zirconium^{3+} ions. In the following list of garnet-group minerals, notice how the molecular structure, despite the chemical diversity, adheres rigidly to the general chemical formula $A_3B_2(SiO_4)_3$.

The so-called "common" garnet-group include:
pyrope (magnesium aluminum silicate) $Mg_3Al_2(SiO_4)_3$
almandine (iron aluminum silicate) $Fe_3Al_2(SiO_4)_3$
spessartine (manganese aluminum silicate) $Mn_3Al_2(SiO_4)_3$
grossular (calcium aluminum silicate) $CA_3Al_2(SiO_4)_3$
andradite (calcium iron silicate) $CA_3Fe_2(SiO_4)_3$
uvarovite (calcium chromium silicate) $Ca_3Cr_2(SiO_4)_3$.

The less-common members of the garnet group are:
calderite (manganese iron silicate) $Mn_3Fe_2(SiO_4)_3$
goldmanite (calcium vanadium silicate) $Ca_3V_2(SiO_4)_3$
hibschite (basic calcium aluminum silicate) $Ca_3Al_2(SiO_4)_{3-x}(OH)_{4x}$ (x = <1.5)
katoite (basic calcium aluminum silicate) $Ca_3Al_2(SiO_4)_{3-x}(OH)_{4x}$ (x = >1.5)
kimzeyite (calcium zirconium titanium silicate) $Ca_3(Zr,Ti)_2[(Si,Al,Fe)_3O_{12}$
knorringite (magnesium chromium silicate) $Mg_3Al_2(SiO_4)_3$
majorite (magnesium iron aluminum silicate) $Mg_3(Fe,Al,Si)_2(SiO_4)_3$
morimotoite (calcium titanium iron silicate) $Ca_3TiFe(SiO_4)_3$ (ferrous iron)
schorlomite (calcium titanium iron silicate) $Ca_3(Ti,Fe)_2(SiO_4)_3$ (ferric iron)

The common garnet-group members are further divided into the "pyralspite" (an acronym derived from PYRope, ALmandine, and SPessartine) subgroup and the "ugrandite" (from Uvarovite, GRossular, and ANDradite) subgroup. Each subgroup's minerals form extensive, graded solid-solution series through substitution of metal cations. Because composition falls somewhere between that of the end members, garnet-group chemical formulas are ideal and rarely, if ever, express exact chemical composition. Positive identification between garnet-group members can often, therefore, be difficult, as members share similar densities and refractive indices, and color is only a general guide to identification. Often only X-ray diffraction and other qualitative-analysis methods can positively distinguish between members.

The garnet group is isostructural, meaning all members share the same basic crystal structure. Garnets crystallize in the isometric (cubic) system, as symmetrical, cube-based crystals, most often as dodecahedrons, or twelve-sided crystals with rhombic (diamond-shaped) faces. This basic shape is characteristic of the entire garnet group.

Spessartine's chemical formula, $Mn_3Al_2(SiO_4)_3$, shows that it contains manganese (Mn), aluminum (Al), silicon (Si), and oxygen (O). The atomic weight of each spessartine molecule is made up of 33.29 percent manganese, 10.90 percent aluminum, 17.03 percent silicon, and 38.78 percent oxygen. Within the spessartine molecule, the combined +12 cationic charge of three manganese (Mn^{2+}) ions and two aluminum (Al^{3+}) ions balances the -12 charge of the three silica $(SiO_4)^{4-}$ anions. Spessartine usually contains variable amounts of iron, which substitute readily for manganese within the crystal lattice.

In the spessartine molecule, three manganese (Mn^{2+}) and two aluminum (Al^{3+}) ions are positioned between three silica tetrahedra $(SiO_4)^{4-}$. Each manganese ion is therefore surrounded by eight oxygen ions, and each aluminum ion by six oxygen ions. This dense atomic packing, together with the high atomic weight of manganese, accounts for spessartine's relatively high specific gravity of 3.8-4.3, among the highest in the garnet group. Because the ionic and strong covalent bonding between molecules is generally equal in all directions within the crystal lattice, spessartine and other garnet-group members are quite hard at Mohs 6.9-7.2 and have no cleavage. This uniform directional bonding strength within the lattice also explains why spessartine and other garnet-group members form short, blocky crystals.

Although brown, orange, and red colors are most prominent, the garnet-group members actually occur in all colors except blue. Garnet-group members can also be either allochromatic (other-colored) or idiochromatic (self-colored). An example of an allochromatic garnet-group member is grossular. When nearly pure, grossular is colorless. But the trace presence of such chromophoric (color-causing) elements as iron, titanium, and chromium create a wide range of color that includes white, brown, green, yellow, orange, pink and red.

But spessartine is idiochromatic, because its basic color is caused by one of its essential elemental components, in this case, the powerful chromophore manganese. When nearly pure, spessartine is bright orange. But when iron and other metals replace manganese within the crystal lattice, its colors range from brown, orange-brown, and yellowish-brown to reddish-orange, red, and hyacinth-red.

Spessartine's color also varies with the degree of gradation within its solid-solution series, especially in the series with pyrope and almandine. These solid-solution series are common because the radii of the magnesium, iron, and manganese ions are similar in size and thus easily interchangeable. Spessartine also forms a solid-solution series with grossular, a member of the ugrandite subgroup, and even with several less-common garnet-group members.

Among the six common garnet-group members, uvarovite is the least abundant, with spessartine next in order of rarity. The garnet-group members occur in a wide variety of mineralogical environments which are often a key to identification. Some are of igneous origin, but most are formed through metamorphism. Spessartine occurs with albite and muscovite in pegmatites of granitic intrusions, with topaz in vugs of extrusive rhyolite, and with quartz in regionally metamorphosed schists. Because of their relatively high specific gravity, spessartine and other garnet-group members, after weathering free from their original igneous or metamorphic environments, also concentrate in alluvial deposits.

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COLLECTING LOCALITIES

Although spessartine is not abundant, its occurrences are widespread. Africa produces fine spessartine crystals from several localities. The bright-orange “mandarin garnet” variety of spessartine occurs in mica and mica slate in northwestern Namibia near the Kunene River and the Angolan border. Similar gem-quality crystals are mined in the Ibadan area, Oyo state, Nigeria. Nice spessartine crystals are also collected at Ampanivana, Madagascar.

In China, fine orange-red crystals come from Fujian Province, as we will see, and from Sanyeshan in Guangdon Province. The Shigar Valley in Baltistan, northern Pakistan also yields nice spessartine crystals. Fine yellow-orange spessartine-almandine is collected in the Darre Pech area of Afghanistan’s Kunar Province. In Australia, spessartine in syenite is found at Cygnet, Tasmania, while spessartine-in-quartz specimens come from Broken Hill in New South Wales. In Brazil, large, fine spessartine crystals are found at Lavra do Navegador Mine at Conselheiro and the Tres Meninas Mine at Pehodo Norte in Minas Gerais state. Spessartine crystals also occur in pegmatites at Berilanda in Brazil’s Ceara state. The type locality at Aschaffenburg, Spessart, Bavaria, Germany, still yields a few specimens.

In the United States, large, bright-orange spessartine crystals are mined at the Rutherford No. 2 Mine in Amelia County, Virginia. The Little Three and Hercules pegmatite mines in the Ramona district of California’s San Diego County have produced exceptional orange-red crystals of the spessartine-almandine solid-solution series as large as one inch in diameter. Three rhyolite occurrences that are popular collecting locales are Garnet Mountain near Ely in Nevada’s White Pine County, Ruby Mountain near Nathrop in Colorado’s Chaffee County, and the Ash Creek area near Hayden in Arizona’s Gila County, all of which yield small, but brilliant, reddish spessartine crystals, some of gem quality.

JEWELRY & DECORATIVE USES

Spessartine is valued both as a collector specimen and as a gemstone for jewelry use. With their durability, transparency, relative hardness, high refractive indices, absence of cleavage that aids cutting, and attractive colors, the common garnet-group members have served as gemstones since antiquity. Red garnet is the birthstone for January. While most garnet-group gems are fashioned from the more abundant pyrope, almandine, and grossular species, spessartine has a special appeal as one of the very few true-orange gemstones, and is usually faceted into oval-, cushion-, trillion-, or emerald-cut gems.

Orange spessartine has come of age as a marketable gem just within the last 20 years. While orange spessartine gems free of heavy brownish or reddish overtones were always valued because of their unique color, their rarity delayed their acceptance as “mainstream” gems. But in 1991, quantities of orange spessartine crystals were discovered in Namibia near the Kunene River and the Angolan border. These stones, which showed exceptional transparency and bright orange colors, were initially sold under the name of “Kunene spessartine,” although the more popular name “Mandarin garnet” soon became the marketing standard. Some Mandarin garnets are included with microscopic fibers of the new, rare amphibole mineral parvowinchite (formerly tirodite, a basic sodium magnesium manganese iron silicate), which creates a subtle, “sleepy” effect that enhances the orange color. Mandarin-garnet gems, while beautifully colored, rarely exceed five carats in weight.

In 1994, stones very similar to Mandarin garnet were discovered in Nigeria’s Oyo state. Their bright orange color and greater availability impacted gem markets worldwide. In one- to four-carat weights, Nigerian spessartine gems currently sell for $100 to $250 per carat. In the much rarer, larger sizes up to 20 carats, they sell for as much as $1,000 per carat.

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Another interesting orange spessartine gemstone is the "malaia" (also "Malaya" and "Malaysia") garnet. Malaia garnet is an intermediate phase of the spessartine-pyrope solid-solution series and usually also shows significant grossular substitution. Spessartine gems as large as 100 carats have been cut from crystals mined in Brazil and Madagascar. In the United States, the most valuable spessartine gems have been cut from crystals mined at the Ramona pegmatite district of California's San Diego County. In rare six- to eight-carat sizes, these gems bring as much as $2,400 per carat.

HISTORY & LORE

Spessartine and other common garnet-group members were among the first colored mineral crystals ever used as gemstones. Egyptians used garnet-group crystals in jewelry and as amulets and talismans as early as 3100 B.C. Archaeologists have excavated garnet jewelry from Swedish cultural sites dating to 2100 B.C. A garnet-group member, possibly pyrope, may have been one of the 12 gemstones of biblical breastplate of Aaron. Medieval European crusaders wore garnets for protection in battle and to aid in their safe return. Medieval physicians believed that garnet-group crystals protected their wearers from poisons and helped cure infections and blood-related maladies.

Because of their similar physical properties, prevalent orange-to-red colors, and tendency to form complex, solid-solution series, mineralogists only began to unravel the garnet-group identities in the 1800s. Positive differentiation of garnet-group species was not always possible until the introduction of X-ray diffraction analytical techniques in the 1920s. Because of many centuries of confusion, the unqualified word "garnet" still serves as a collective term for any of the garnet-group species, a usage which continues to a large extent in today's retail jewelry trade.

Metaphysicists believe that garnet-group members generally enhance compassion, love, imagination, and creativity, while teaching patience and strengthening the mind and body in times of need. Spessartine specifically is thought to help initiate analytical processes of the mind and to ease the negative effects of bad dreams, depression, and anger. Modern-day crystal healers believe that spessartine works to alleviate deficiencies in calcium metabolism.

TECHNOLOGICAL USES

Although several minerals of the garnet group, notably almandine, pyrope, and grossular, are used as industrial abrasives and filtration mediums, spessartine is not mined commercially because of its relative rarity and tendency to occur in small deposits of limited economic importance.

ABOUT OUR SPECIMENS

The 2005 Tucson Gem & Mineral Show had as its theme "Minerals of China." This proved to be quite fortuitous for us, as it inspired the mineral magazines to give more than the usual attention to China, with the *Mineralogical Record* devoting an entire issue to Chinese minerals and localities. The exact localities for new finds made in China are commonly and deliberately misrepresented by dealers and collectors trying to protect their claims, and so it is often several years before the correct information becomes known. This proved true in the case of our garnets, which is why we were so glad to see an article on the spessartine locality in the new *MR*, making it possible to get accurate information.

The article gives a first-person account by a German dealer who visited the area, and he reports that spessartine comes from two localities, namely Tongbei and Yunling, in the Zhangzhou Prefecture of southern Fujian Province, China, as seen on the map in Figure 2. Our specimens evidently come from both localities, and because it is not possible to differentiate them, we have listed both localities on our labels. The original discovery was made about fifteen years ago at Tongbei, a little village of 600 inhabitants, when some of the locals began collecting weathered quartz to sell to glass-making companies. When garnets were first found on the quartz and brought to the attention of a dealer, the sales potential was immediately recognized. Now, more than thirty collectors work several sites about one kilometer north of Tongbei, and garnet dealers have sprung up in town. Specimens also come from near Yunling, about 25 kilometers north of Tongbei as the crow flies, though no roads connect the two.

Figure 2. Location map.

Both localities exist in granite, the most common rock of Coastal Fujian Province. Chinese geologists believe the granite formed as intrusions about 80-139 million years ago, especially during intense periods of magmatism when the Paleo-Pacific plate was subducted under the continental plate of southeastern China. The magma slowly cooled over a period of more than fifty million years, allowing plenty of time for the garnets to crystallize! Matrix specimens like ours usually consist of spessartine on crystals of cream-colored orthoclase feldspar, occasionally with or even on smoky quartz, a highly aesthetic combination! Other minerals found here include octahedrons of blue fluorite [CaF_2], which has only been found at Yunling, (and which we have never seen), small pale green crystals of beryl [$Be_3Al_2Si_6O_{18}$], hematite [Fe_2O_3], pyrite [FeS_2], minute colorless topaz [$Al_2SiO_4(F,OH)_2$] crystals (only at Tongbei), unidentified mica and tourmaline group minerals, and small crystals of the rare minerals milarite [$KCa_2AlBe_2Si_{12}O_{30}\cdot 0.5H_2O$] and helvite [$Mn^{2+}_4Be_3(SiO_4)S$]. Under shortwave UV light, we noticed green fluorescence coming from hyalite opal on a few of our pieces. How happy we are to add these to our collection, and we hope you feel the same way!

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