

# SPESSARTINE GARNET FROM RAMONA, SAN DIEGO COUNTY, CALIFORNIA

By Brendan M. Laurs and Kimberly Knox

For most of the 20th century, the principal source of fine spessartine was the area around the Little Three mine near the town of Ramona in southern California. Two pegmatites—the Hercules-Spessartite and the Spaulding dikes—yielded most of the estimated 40,000–50,000 carats of facet-grade rough mined from 1956 to 1994. Prized for its bright orangy yellow to yellowish orange color, Ramona spessartine has similar R.I. and S.G. values to those of most other pegmatitic gem spessartines. Typical internal features are wavy two-phase partially healed fractures, negative crystals, needles/tubes, growth patterns, and anomalous birefringence; mineral inclusions are rare. The composition of four samples (ranging from light orangy yellow to yellow-orange) was  $\text{Sps}_{94.8-88.8}\text{Alm}_{4.7-11.0}\text{Gro}_{0.5-0.2}$ , and the absorption spectra of all samples showed strong peaks for  $\text{Mn}^{2+}$  and subordinate  $\text{Fe}^{2+}$  bands.

The Little Three mining area near Ramona, California, has produced a variety of pegmatite gems, most notably an intense orange spessartine garnet (figure 1). The Ramona district lies within the extensive southern California pegmatite belt (figure 2). In the early part of the 20th century, San Diego County was one of the world's major gem-producing areas in terms of variety and quantity of material (Tucker and Reed, 1939). The most sought-after gem was tourmaline, recovered principally from the Mesa Grande and Pala districts. Beryl (aquamarine and morganite), spodumene (kunzite, first discovered at Pala), topaz, and smoky quartz were also important, but spessartine was relatively rare—except in the Ramona pegmatites. The bright orangy yellow to yellowish orange color and brilliance of the Ramona spessartines (figure 3), as well as the fact that this was the premier source of top-quality material for decades, have contributed to a premium on their price that was eclipsed only in the late 1990s by fine spessartine from Namibia and Nigeria (S. Robertson, pers. comm., 2001).

Despite the historical importance of Ramona spessartine, very little has been published on its gemological characteristics (see, e.g., Tisdall, 1961). This article describes the history and production,

mining methods, geology, and gemology of spessartine from this historic locality. An explanation of the unique conditions necessary for the formation of gem-quality spessartine in granitic pegmatites also is proposed.

## HISTORY AND PRODUCTION

Spessartine was not well known as a gemstone until relatively recently. There is no history of the mineral before the 19th century (Rouse, 1986). The first pegmatite mine in the Ramona district, the Little Three, was discovered in May 1903 by H. W. Robb of Escondido, California (Kunz, 1905). It was named for Mr. Robb and his partners, Dan MacIntosh and Charles F. Schnack, who purchased the 40 acre (16.2 hectare) parcel of land from a rancher (Foord et al., 1989; LeMenager, 1989). Although this particular mine has never been an important source of spessartine, its yield of fine specimens of topaz, tourmaline, and other minerals has made it the most

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*Figure 1. Spessartine from Ramona is prized for its intense orange color. The 10.25 ct spessartine in the pendant was cut from material recovered at the Spessartite mine in 1975. The spessartine in the ring on the right weighs 4.1 ct, and the spessartines in the earrings weigh about 2.5 ct each. Courtesy of Kerith Graeber; photo © Jeff Scovil.*

important mine in the district. For this reason, Ramona spessartine is often referred to as coming from the “Little Three” mine.

By the end of 1903, several mines and prospects were staked in the Ramona district within an area smaller than 520 hectares (2 square miles). Kunz (1905) provided the best description of the early mines—including the Little Three, A.B.C. (or Daggett), and Hercules (see figure 4). Considerable amounts of topaz, tourmaline, spessartine, and beryl were recovered at the Ramona mines via open cuts and tunnels in the early years (figure 5; see Sterrett, 1908; Tucker, 1925; Tucker and Reed, 1939; Simpson, 1960; Weber, 1963). From 1903 to 1905, Kunz (1905) reported that over 10 kg of spessartine were produced from the district, yielding faceted gems up to 8 ct. By 1909, however, the near-surface deposits at the Little Three mine were considered exhausted (Spaulding, 1977). The collapse of the Chinese tourmaline market in 1912 halted pegmatite mining in southern California (Foord et al., 1989), and there was very little activity for the next four decades.

In 1947, Louis Spaulding and his son, Louis Spaulding, Jr., established several claims in the area (Simpson, 1960). Intensive mining began in 1955 at the Little Three mine, and since then the Spaulding family has been the most important producer of gems and minerals from the Ramona pegmatites. After his father's death in 1973, Spaulding Jr. single-handedly took over work on several of the pegmatites, particularly the Little Three and Hercules-Spessartite dikes.

Although several mines in the Ramona district have produced spessartine, the best sources were the Hercules-Spessartite and Spaulding mines (again, see figure 4). The Spaulding dike was found

in December 1955, and the faceted spessartines produced initially were rather small (0.5–1.5 ct; Sinkankas, 1957). About 3,000 carats of faceting rough were mined over the period 1956–1959 (Sinkankas, 1959; Weber, 1963). From 1964 until shortly before his death, Spaulding Sr. produced 9,000 carats of faceted spessartine from this mine, but only three stones exceeded 6 ct (L. Spaulding Jr., pers. comm., 2001).

The Hercules-Spessartite pegmatite has a longer and more productive history. The Hercules mine was located in August 1903 on the northwest portion of this dike by A. V. Pray, S. G. Ingle, and H. Titus, who worked it for several years (Simpson, 1960). About 15 pounds (6.8 kg) of spessartine were produced during the period 1903–1905 (Kunz, 1905). After mining in the district resumed following the 1912 collapse of the Chinese tourmaline market, owners R. B. Winstead and G. Converse worked the property and even resurveyed it in 1954 (Simpson, 1960), but their production was not recorded. The Hercules was claimed by Elbert McMacken and Herb Walters in the 1960s and early 1970s; for two years during this period (1965–66), a portion was worked by John Sinkankas and his son (Sinkankas, 1967, 1976; figure 6). Bryant Harris purchased the mine in the late 1970s and worked it with E. “Buzz” Gray until 1984, but with little success (E. Gray, pers. comm., 2001).

The southern portion of the Hercules-Spessartite dike was mined by Spaulding Sr. in 1959; these workings were called the Spessartite mine (Simpson, 1963). This area later became the most important source of spessartine in the district—and produced several stones over 10 ct (see, e.g., figure 1)—when Spaulding Jr. expanded the open cut, beginning in 1975. In August 1987, Spaulding Jr. recovered a 72.5

ct piece of rough that was faceted by Buzz Gray into a 39.63 ct gemstone (figure 7), the largest cut spessartine known to date from Ramona and among the more than 2,300 grams of gem rough produced from 1987 to 1990 (L. Spaulding Jr., pers. comm., 2001). More large stones and mineral specimens (figure 8) were recovered from the Spessartite mine in 1993–1994. Among these was the 27.30 ct gem featured in the *objet d'art* called “The Light of Ramona” (figure 9). Additional small finds of spessartine were made by Spaulding Jr. at various Ramona mines up to 1995, and by another group in 1996–1997 (San Diego Mining Co., 2001), but there has been no significant garnet production since then.

Although total production figures are not available, Foord et al. (1989) estimated that about 40,000 carats of facet-grade spessartine have been

recovered from the Ramona district. (Note that Foord et al. [1991] indicated 70,000 carats of spessartine, but this appears to be a misprint.) Spaulding Jr. (pers. comm., 2001) also estimates the total production from the district at 40,000–50,000 carats of facet-grade spessartine. Much of the spessartine obtained by Spaulding Sr. was sold to George Ashley in Pala for cutting and distribution. Spaulding Jr. sold most of his facetable spessartine to Jonté Berlon Gems.

## LOCATION AND ACCESS

The Little Three mine area is located in the Hatfield Creek valley, approximately 50 km (31 miles) northeast of metropolitan San Diego, and about 6 km (4 miles) east-northeast of the rural town of

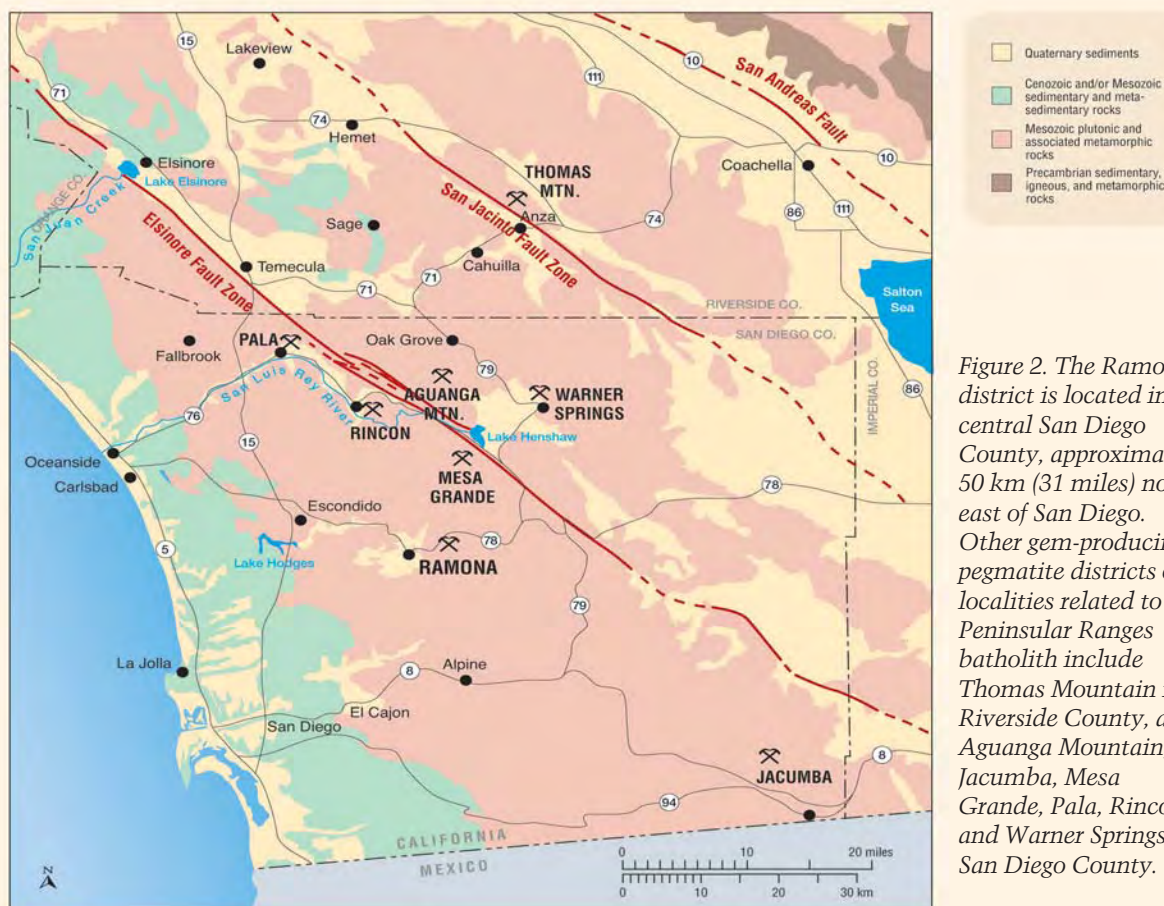


Figure 2. The Ramona district is located in central San Diego County, approximately 50 km (31 miles) northeast of San Diego. Other gem-producing pegmatite districts or localities related to the Peninsular Ranges batholith include Thomas Mountain in Riverside County, and Aguanga Mountain, Jacumba, Mesa Grande, Pala, Rincon, and Warner Springs in San Diego County.



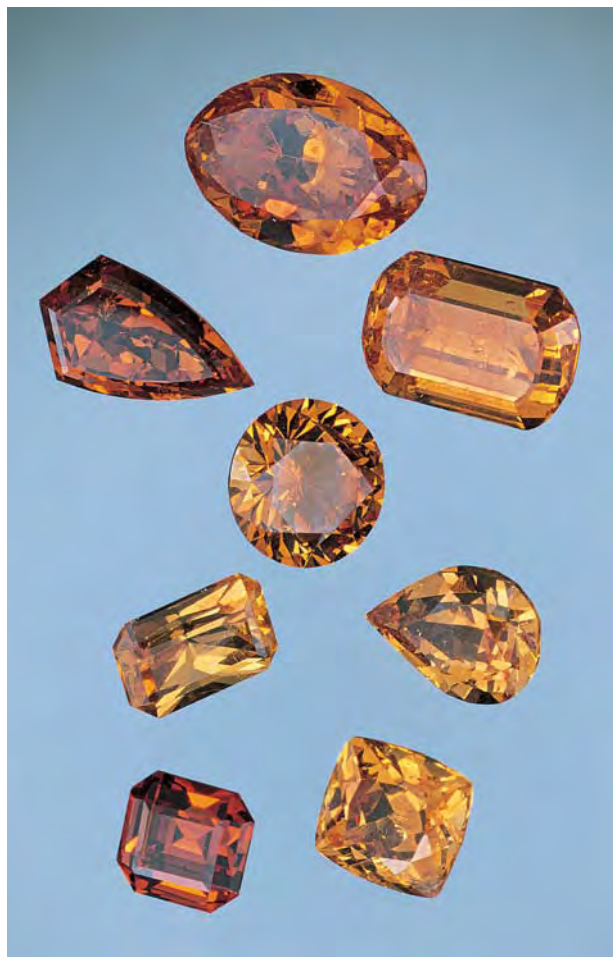


Figure 3. *Ramona spessartine* (here 1.02–5.15 ct) typically ranges in color from orangy yellow to yellowish orange. Courtesy of Buzz Gray and Bernadine Johnston; photo © Harold and Erica Van Pelt.

Ramona. A paved highway leads from Ramona to a private dirt road that is shared by several landowners, and public access is prohibited. The authors visited the area at various times during 1997–2001.

Lying at an altitude of 580–700 m (1,900–2,300 feet), the mining area is a scenic parched terrain with rolling hills, covered with the dense scrub vegetation typical of San Diego County's chaparral regions. The climate includes a little frost in winter, but temperatures can exceed 105°F (40.6°C) in summer. Most mining activity has taken place above ground, and the small diggings eventually become concealed by regrowth of the chaparral.

## GEOLOGY

The geology of the Ramona pegmatites has been documented by numerous researchers, and it remains one of the best-studied pegmatite districts in the world (see, e.g., Merriam, 1948; Sinkankas,

1957; Simpson, 1960, 1963; Stern et al., 1986; Foord et al., 1989; Patterson, 1997; Morgan and London, 1999). The area is characterized by a complex series of intrusions that consist mostly of tonalite, with gabbro-diorite, diorite, granodiorite, and granite. These rocks have been mapped, classified, and named differently by various geologists, as compiled by Patterson (1997); they are all part of the Peninsular Ranges batholith of mid-Cretaceous age (120–100 million years [m.y.] old; Krumenacher et al., 1975). Radiometric dating of the muscovite from the Hercules mine yielded ages between 98.7 and 100 m.y. (Foord et al., 1991).

The Ramona district contains a series of pegmatite dikes in a northwest-trending belt about 4.5 km (2.8 miles) long and up to 1.6 km (1 mile) wide. Overall, the dikes strike northwest, and dip gently to moderately west to southwest. The pegmatites mined thus far typically range in thickness from 0.4 to 1.8 m (1.3 to 6 feet), and can be traced for distances up to 1,060 m (3,500 feet). In the vicinity of the Little Three mine, the dikes form locally undulating dip-slopes (i.e., erosion exposed the top surface of the pegmatites), so they

Figure 4. The Ramona district consists of a series of northwest-trending granitic pegmatites that have intruded tonalite and diorite. The locations of the main productive mines are shown: Little Three, Hercules, Spessartite, Spaulding, and A.B.C. Several other claims and prospects are not shown, owing to minor production and/or complexities in their naming and location. Modified from Simpson (1960), Weber (1963), and Foord et al. (1989).

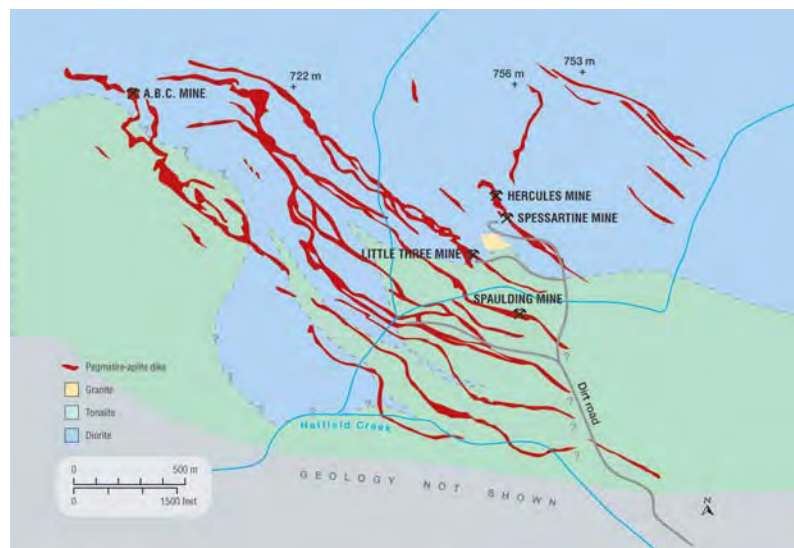






Figure 5. Before the collapse of the Chinese tourmaline market in 1912 halted pegmatite mining in San Diego County, significant gem production was obtained from the Ramona area. The main disturbance is the Little Three mine (left arrow), and the small dumps higher on the hillside are the Hercules mine (right arrow). Photo by D. B. Sterrett, U.S. Geological Survey, circa 1910.

Figure 7. This magnificent necklace was constructed in 1987 with more than 165 carats of Ramona spessartine (Koivula and Kammerling, 1988). The center stone, at 39.63 ct, is the largest cut spessartine known from Ramona. Courtesy of Michael M. Scott; photo © Harold and Erica Van Pelt.



Figure 6. The Hercules dike was mined for spessartine by John Sinkankas and his son John William Sinkankas in the mid-1960s. This photo shows Sinkankas Jr. drilling the pegmatite in preparation for blasting. Photo by John Sinkankas, February 1966.

were well positioned for surface mining.

Both Simpson (1960, 1963) and Stern et al. (1986) presented detailed maps of the mineralogical zoning. The dikes are typically layered, with pegmatite in the upper portion and aplite in the lower. For simplicity, these composite dikes are referred to simply as "pegmatites" throughout this article. The aplite is a fine-grained assemblage of quartz, sodic plagioclase, K-feldspar, schorl, and almandine-spessartine. The upper portion of the aplite is conspicuously banded, which miners refer to as "line rock." The coarse-grained pegmatite is formed mostly of "graphic" quartz-perthite intergrowths (Simpson, 1962) and schorl, almandine-spessartine, and muscovite. Near the contact of these two units is a "pocket" zone that is characterized by relatively large euhedral crystals of quartz, feldspar, and other minerals. These minerals are often intergrown except in cavities where well-formed, free-standing crystals are attached to the pocket walls or suspended in clay. The largest, most economically important pockets in the Ramona district have yielded blue topaz, dark green tourmaline, and pale blue or pink beryl, but no spessartine (see, e.g., Foord et al., 1989).

The Ramona pegmatites show distinct differences in mineralogy and style of mineralization, even within a specific pegmatite (see, e.g., Sinkankas, 1957; Stern et al., 1986; Foord et al., 1989). Some of the pegmatites are mineralized only with spessartine (e.g., the Spaulding mine), whereas



others have only topaz, beryl, and/or colored tourmaline assemblages (e.g., the A.B.C. mine); also, various assemblages may be present in the same pegmatite, but in different areas separated by several meters (e.g., the Little Three and Surprise mines). Kunz (1905) was the first to describe this mineralogical zoning. Sinkankas (1957) reported that gem spessartine has been found only in areas that do not have colored tourmaline, which was confirmed by Spaulding Jr. with continued mining.

Most of the spessartine has been mined from small pockets and a unique vuggy feldspar-rich rock with little or no quartz (see box A). This distinctive rock contains numerous small, irregularly shaped corroded cavities, and has been called “cottonball spar” or “popcorn rock” by miners, who recognized it as a good indication of spessartine mineralization (Simpson, 1960; J. Sinkankas, pers. comm., 1998). The corroded rock locally crosscuts the pocket zone and overlying pegmatite, but is not found in the underlying aplite. It is commonly located in areas of pegmatite that are jointed and fragmented with subsequent recrystallization of quartz on the fracture

*Figure 8. Many large stones and attractive gem crystals of spessartine were recovered from the Spessartite mine during the late 1980s to mid-1990s. The rough and cut (15.93 ct) stones shown here are courtesy of Buzz Gray and Bernadine Johnston; photo © Harold and Erica Van Pelt.*



*Figure 9. “The Light of Ramona” features a 27.30 ct cushion-cut spessartine accented by 62.23 carats of spessartine, all from Ramona, and 3.81 carats of feldspar. The design replicates the natural isometric crystal habit of garnet (see figure 8), as conceptualized by Bernadine Johnston and Buzz Gray. The piece is mounted on a covellite pedestal, with more spessartines at the base. It was designed by Kim Knox, and constructed by her together with Zane A. Gillum and Alan F. Hovey of Golden Pacific Arts, San Diego, California. Photos © Harold and Erica Van Pelt.*

## BOX A: RARITY AND FORMATION CONDITIONS OF SPESSARTINE

What are the conditions necessary to form gem-quality spessartine in granitic pegmatites? Traces of spessartine-almandine garnet are not uncommon in these pegmatites, where they form as small (2 mm or less) fractured crystals that are intergrown with the enclosing feldspars, quartz, and schorl tourmaline. However, very few pegmatites contain facetable spessartine. At the Ramona mines, the common occurrence of gem-spessartine within vuggy, corroded feldspar-rich rock suggests its formation is related to this rock type. This appears to be the case at other gem spessartine pegmatite as well, such as Alto Mirador in northeastern Brazil (figure A-1).

The corrosion and secondary crystallization of minerals (including spessartine) within the vuggy pegmatite at Ramona has been attributed to late-stage hydrothermal fluids that persisted after crystallization of the dikes (Sinkankas, 1957, 1997; Simpson, 1963). Such fluids evolve during the crystallization of all miarolitic (pocket-bearing) pegmatites (Černý, 2000), but only rarely does gem spessartine form. Sinkankas (1997) suggested that the hydrothermal solutions were introduced from “below” via channels created by earth movements. While such “open-system” conditions may have locally contributed to the etching and regrowth of some minerals in the pockets and vuggy rock, stable isotopic studies by Taylor et al. (1979) suggest that pocket minerals sampled from the Little Three and Hercules-Spessartite dikes crystallized under dominantly “closed-system” conditions.

The most important geochemical considerations for spessartine ( $\text{Mn}_3\text{Al}_2\text{Si}_3\text{O}_{12}$ ) crystallization in granitic pegmatites appear to be: (1) pre-enrichment of the melt in Mn, and (2) concentration of Mn via pegmatite crystallization until the late-stage formation of gem-bearing pockets. The generation of Mn-enriched melts was mentioned briefly by London et al. (2001). Mn is not abundant in most granitic melts, and is concentrated (with other rare elements such as lithium, beryllium, and boron) in pegmatites through a process known as fractional crystallization. Mn is incompatible with the feldspars and quartz that constitute the bulk of pegmatite crystallization, so it becomes progressively concentrated during crystallization, particularly in the presence of fluorine (see, e.g., Černý et al., 1985). Together with rare elements and volatiles, Mn accumulates in the late-stage aqueous fluids that form the pegmatite pockets (see, e.g., Shigley and Kampf, 1984; Černý et al., 1985). It has been proposed that some of the Mn needed to form the gem spessartine was derived from the corrosion of previously crystallized almandine-spessartine (Sinkankas, 1997).

Why is spessartine so rarely found in the pockets? During pegmatite crystallization, the concentration of other elements (especially lithium) may stabilize minerals that consume Mn. The late-stage accumulation of Li may stop spessartine from forming in the pockets because the Mn will be preferentially incorporated into lepidolite and elbaite. At the Little Three mine in particular, Morgan and London (1999) and London et al. (2001) suggested that this mechanism halted spessartine crystallization. Likewise,

the accumulation of phosphorus (P) can consume manganese through the crystallization of Mn-Fe phosphates. As expected, the important spessartine-bearing dikes in Ramona (Hercules-Spessartite and Spaulding) do not contain lepidolite, elbaite, or phosphates, but it is conceivable that traces of these minerals could be present in other pegmatites that contain enough Mn to crystallize spessartine at late stages.

The bright orange color of gem spessartine from Ramona and other localities is achievable only with low Fe contents. Iron is typically more abundant than Mn in granitic pegmatites, but it also is depleted from the melt far faster than Mn by the crystallization of mafic minerals such as schorl and biotite (Foord and Kleck, 1993; London et al., 2001). Biotite is rare or nonexistent in the gem spessartine dikes in Ramona, so schorl (which is common) is the mineral responsible for depleting Fe. Indeed, London et al. (2001) reported that Mn is incompatible in schorl, so crystallization of this tourmaline can contribute to an increasing Mn:Fe ratio in the residual pegmatitic melt-fluid system.

The rarity of commercially important pegmatitic deposits of gem spessartine is apparently due to the strong geochemical correlation between Mn and Li in granitic pegmatites (Černý et al., 1985). Spessartine is common within the inner zones of “complex” granitic pegmatites that contain lithium (Baldwin and von Knorring, 1983), although it typically is not gem quality. The crystallization of facetable spessartine requires unusual conditions favoring enrichment of Mn, but not Li (and P), as well as the depletion of Fe in the late stages of pegmatite evolution.

*Figure A-1. Gem spessartine is commonly associated with vuggy, corroded pegmatite. At the Alto Mirador pegmatite in northeastern Brazil (see Johnson and Koivula, 1999), facetable spessartine was recovered from a gem pocket and associated corroded pegmatite in the area shown here—particularly to the left of the large feldspar crystal (marked by a partial rim of schorl) above the hammer. The quartz core zone of the pegmatite is visible to the upper right. Photo by Brendan M. Laurs.*





surfaces (J. Sinkankas, pers. comm., 1998).

Simpson (1960, 1963) noted that spessartine is found in a blue-gray clay (containing tourmaline needles) in the vugs or in larger cavities and fractures, sometimes with quartz, albite, potassium feldspar, and schorl (see also Sinkankas, 1997); rarely, it occurs with pale blue-to-pink beryl or pink apatite (L. Spaulding Jr., pers. comm., 2001). Although the spessartine in the "popcorn rock" is always corroded, the garnet crystals in the larger cavities may be either euhedral or corroded. In some places, such as in the productive open cut of the Spessartite mine, the feldspar-rich rock in the center of the pegmatite was altered to a 40-cm-thick layer of pink clay, in which the gems were "floating" (L. Spaulding Jr., pers. comm., 2001). Further north in this pegmatite (which was productive over about 45 m) spessartine from the Hercules mine typically formed in pockets with little or no associated corrosion of the surrounding pegmatite; here, the spessartine was not etched and well-formed mineral specimens were recovered, with the orange garnet commonly perched on cleavelandite (bladed albite) associated with schorl and smoky quartz (J. Sinkankas, pers. comm., 1998).

## MINING

As is the case with most pegmatites, experience and intuition are key to determining where to dig for spessartine and other gems in the Ramona district. Most of the mining has been surficial, accomplished by "peeling" away the upper portion of the pegmatites that lie exposed on the hillside. This was initially done with a pry bar and occasional explosives. In addition to small open cuts, a few tunnels explore portions of the pegmatites that lie further underground. Most of the work done by Spaulding Jr. has been accomplished in open cuts using a bulldozer, backhoe (figure 10), and a minimal amount of drilling and blasting.

The gem-bearing pockets are carefully excavated using chisels, ice picks, and wooden sticks (figure 11). The pocket contents are carefully cleaned in oxalic acid to remove iron staining. Mineral specimens—rather than gem rough—are most sought after. The spessartine crystals attain sizes up to 3–4 cm and form showpieces when attached to a matrix of white cleavelandite and black schorl tourmaline (see, e.g., figure 12 here and figure 3 of Foord and Kleck, 1993). Only broken, damaged, or otherwise non-specimen-quality crystals are faceted. According to Spaulding Jr., only about 1% of the spessartine found in the pockets has been facetable.



Figure 10. Most of the spessartine production from Ramona came from the Spessartite mine, which was expanded with a backhoe. The pegmatite is dipping into the open cut from the right side. Courtesy of Louis Spaulding Jr.

Figure 11. Spessartine-bearing pockets are carefully excavated by hand, as shown here at the Spessartite mine. Courtesy of Louis Spaulding Jr.







*Figure 12. Fine mineral specimens from the Ramona pegmatites are prized by collectors. The aesthetic combination of orange spessartine, black schorl, and white cleavelandite are unrivalled by spessartine specimens from other localities. Gemstones such as the fine 5.15 ct example shown here are faceted only from broken, damaged, or otherwise non-specimen-quality crystals. Photo © Harold and Erica Van Pelt.*

## MATERIALS AND METHODS

The Ramona study samples consisted of 14 faceted spessartines (0.47–15.93 ct) loaned by Jonté Berlon Gems, and 16 faceted (0.27–1.26 ct) and two mineral specimens (with a total of four garnets on matrix) from the GIA collection. The two matrix samples were typical of dozens of Ramona spessartine mineral specimens examined by the senior author over the past several years. Standard gemological properties were obtained on all the faceted stones. A Duplex II refractometer with a near-sodium equivalent light source was used for refractive index readings. Specific gravity was determined by the hydrostatic method, and a desk-model spectroscope was used to examine the absorption spectra. Reaction to ultraviolet radiation was viewed with four-watt long- and short-wave UV lamps. Internal features and anomalous birefringence were observed with a standard gemological microscope; the latter was

also viewed with a polariscope. Laser Raman microspectrometry was performed using a Renishaw 2000 Ramascope on selected faceted samples to identify mineral inclusions.

Four of the samples—ranging from light orangy yellow to medium yellow-orange, which is representative of most faceted material from Ramona (figure 13)—were analyzed further. Their chemical composition was measured by electron microprobe (Cameca SX-50), and UV-Vis-NIR absorption spectra were obtained in the region 250–2500 nm with a Hitachi U4001 spectrophotometer. Grain mounts (one per sample) of spessartine from selected worldwide localities (i.e., Minas Gerais and Rio Grande do Norte, Brazil, and Maevatanana and the Sahatany Valley in Madagascar) were also analyzed by electron microprobe for comparison with the Ramona samples. Data for spessartine from other localities were taken from the literature.

## RESULTS

**Description of the Rough.** The two mineral specimens consisted of gem-quality spessartine crystals on a matrix of cleavelandite feldspar; one specimen also had schorl. The spessartine was light yellowish orange to medium brownish orange with no eye-visible color zoning. The crystals were transparent in areas between fractures, some of which were partially healed. All of the spessartines on one of the specimens showed corrosion features consisting of lustrous micro-stepped surfaces (see, e.g., figure 14). These etch features appear similar to those observed on spessartine from other pegmatites (see, e.g., figure 1 of Sinkankas and Reid, 1966). Both dodecahedral and trapezohedral faces were observed on the crystals. The dodecahedral faces showed subtle diamond-shaped growth hillocks, while the trapezohedral faces were smooth on the specimen that was not corroded.

**Visual Appearance and Gemological Properties.** The results of the gemological characterization are presented in table 1, together with data for spessartines from other localities for comparison.

The samples ranged from light orangy yellow to dark brownish orange; most were light orangy yellow to medium yellow-orange (again, see figure 13). These samples represent the range of color of gem spessartine from the Ramona district. None of the stones showed eye-visible color zoning. The samples were transparent with relatively few inclusions visible with the unaided eye.

Refractive indices ranged from 1.799 to 1.808, although samples in the commercially most desirable orangy yellow to yellow-orange color range had R.I. values of 1.799–1.803. Overall, the lightest orange samples had lower R.I. values. S.G. values fell within 4.19–4.26, and showed no correlation to color or R.I. value. All stones were inert to both short- and long-wave UV radiation.

Microscopic observation revealed wavy planes of one- or two-phase (liquid-gas) inclusions in nearly all stones (see, e.g., figure 15), as documented in spessartine by Gübelin and Koivula (1986), Rouse (1986), and Webster (1994). Individual inclusions within these partially healed fractures and “fingerprints” appeared as points, subparallel elongate and needle-like forms, and irregular bodies. In five samples, we saw linear arrays of tiny particles forming wisps and clouds; these were typically associated with the fingerprint-like features. Flat, isolated two-phase (liquid-gas) inclusions were present in two samples (see, e.g., figure 16). Three-phase (solid-liquid-gas) inclusions also were seen in a few samples. Fractures (i.e., “feathers”) were rare, and showed jagged outlines.

Several samples had relatively large negative crystals and/or elongate etch channels. These channels typically showed striated surfaces and irregular angular shapes (see, e.g., figure 17), although one had a rectangular cross-section that tapered lengthwise into a tube. A swarm of minute, parallel needles (probably hollow tubes) was seen in two samples. Mineral inclusions were rare. Raman analysis identified irregular-shaped, colorless inclusions with a rough texture in three samples as albite (see, e.g., figure 18), and a black tapered crystal in one sample as columbite (figure 19). Another sample contained three minute colorless crystals surrounded by tension fractures and subtle dark halos (figure 20); these appeared to be zircon, but they could not be identified by Raman analysis due to their small size and position in the stone.

Most samples showed faint growth zoning, with planar, angular, and irregular patterns. Strong planar growth zoning was seen in a few samples (see, e.g., figure 21), where it corresponded to sharply defined planar zones of anomalous birefringence that were visible in certain orientations. All samples displayed anomalous birefringence (see, e.g., figure 22), typically as light gray areas that appeared cloud-like with diffuse boundaries, or as irregularly shaped zones that were centered around points or nodes when the samples were rotated. In some samples, patches of birefringence had a cross-hatched appear-



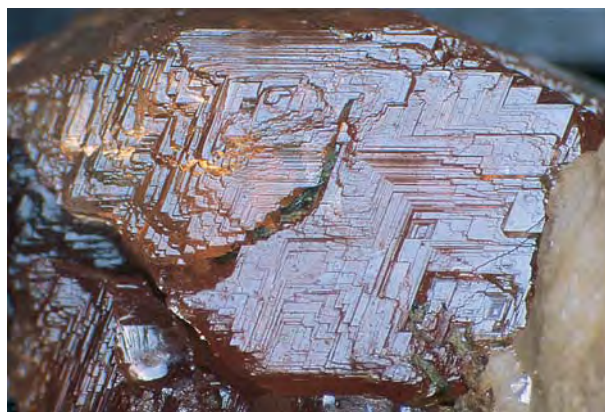
Figure 13. These four orangy yellow to yellow-orange spessartines (0.48–1.15 ct), part of the study sample, show the range of color that is most representative of faceted material from Ramona. Photo by Maha Tannous.

ance. With the exception of the strong planar pattern mentioned above, the birefringence frequently did not show any relation to the growth features seen with plane polarized light. When viewed with the polariscope, anomalous double refraction was visible in most of the samples; the birefringence formed gray patches or linear zones with subtle to obvious intensity.

#### Chemical Composition and Absorption Spectroscopy.

The four samples analyzed by microprobe showed a consistent decrease in manganese and increase in iron as the color varied from light orangy yellow to medium yellow-orange (table 2). The greatest manganese concentration (40.67 wt.% MnO) was recorded in the lightest orangy yellow sample, and falls near the highest values found in the literature for gem-quality spessartine. Traces of titanium and calcium were detected in all four samples, but magnesium was below the

Figure 14. Corroded spessartine crystals typically show a series of lustrous micro-stepped surfaces. Photomicrograph by John I. Koivula; magnified 2×.





**TABLE 1.** Properties of spessartine from various localities.<sup>a</sup>

Property	Ramona, California	Ramona, California <sup>b</sup>	Minas Gerais, Brazil <sup>c</sup>	Madagascar	Mozambique
Reference/no. of samples	This study/30	Tisdall (1961)/4	Unpublished GIA research/1	Tisdall (1962)/nr	Bank et al. (1998)/nr
Color	Orangy yellow to brownish orange	Yellowish orange	Orange	Orange-red, dark to pale	Brownish orange
Optic character	ADR	nr	Slight ADR	nr	Strong ADR
Refractive index (range)	1.799–1.808	>1.81	1.800	>1.81	>1.81
Specific gravity	4.19–4.26	4.17	4.20	4.17	4.15–4.18
Internal features	Wavy partially healed fractures, growth patterns, negative crystals, etch channels, needles/tubes, linear clouds, isolated fluid inclusions, feathers, mineral grains (albite, columbite)	Angular three-phase inclusions, "fingerprints"	Subparallel reflective stringers, irregular needles, small transparent crystals, parallel planar growth zoning	No three-phase inclusions; fine, close striae (like synthetic ruby)	Growth zoning; feathers of film-like fluids; minerals observed as needles or platelets with high birefringence
Absorption spectra (nm) <sup>d</sup>	Cutoff at 435–440; bands at 460, 480–485, and 520–525; 504 line and 570 band in some samples	Cutoff at 439; wide band at 461, wide, very strong band at 482; faint shadow at 502, faint broad band at 527	Spessartine spectrum, with very strong band at 430	Absorption in blue-violet, with strongest band centered at 432; intense bands centered at 461 and 484; weak bands at 505 and 527	Absorption features at 408, 422, 428, 460, 483, and 524

<sup>a</sup> Abbreviations: ADR=anomalous double refraction, nr=not reported, SR=singly refractive. In addition, 50 spessartine-almandine garnets from Amelia, Virginia, ranging from dark red-brown to pale orange, had R.I.'s of 1.795–1.809 and S.G.'s of 4.16–4.19 (Sinkankas and Reid, 1966).

<sup>b</sup> See also Anderson (1961).

<sup>c</sup> 4.81 ct sample; see also Bank et al. (1970) and Johnson and Koivula (1999).

<sup>d</sup> Also known as Mandarin garnet; from the "original" mining area in northwest Namibia that was discovered in 1992; see also Koivula et al. (1993).

<sup>e</sup> Also known as Mandarin garnet; from a different mining site about 30 km south of the original site, discovered in 1995; see also Kammerling et al. (1995), Bank et al. (1996).

<sup>f</sup> Also known as Kashmirine.

<sup>g</sup> Determined by either spectroscopic or spectrophotometric means; values reported for this study are as observed with the spectroscope.

detection limit (<0.01 wt.% MgO). The composition of these Ramona spessartines can be summarized as  $\text{Sps}_{94.8-88.8}\text{Alm}_{4.7-11.0}\text{Gro}_{0.5-0.2}$ .

The spectroscope revealed a cutoff at 435–440 nm in all samples. Weak to moderate bands were centered at approximately 460 nm and 520–525 nm, and a strong band was present at approximately 480–485 nm. The latter band formed a region of general absorption with the 504 nm band in the darkest samples. In lighter samples, the 504 nm band was

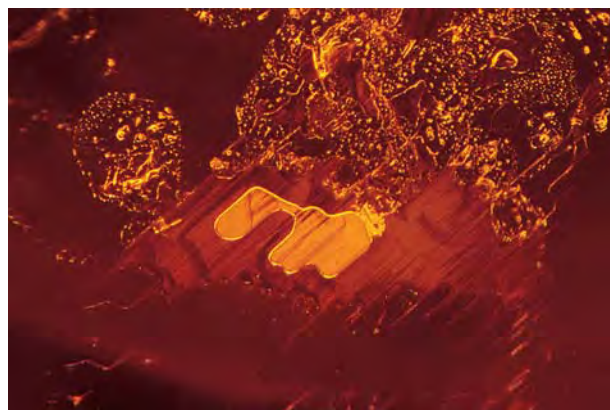
very weak or nonexistent. Another band at 570 nm could be seen in all but the lightest stones.

All four Ramona samples showed similar absorption spectra with the spectrophotometer in the UV-Vis-NIR range. The strongest peak was located at approximately 409 nm; on the shoulder were two additional strong peaks at approximately 421 and 430 nm (figure 23). Also present in the visible range were bands at approximately 460, 483, 504, 525, and

Figure 15. "Fingerprints" consisting of wavy planes of variously shaped two-phase (liquid-gas) inclusions were commonly observed in the Ramona spessartine. Photomicrograph by John I. Koivula; magnified 35 $\times$ .



Figure 16. Flat, isolated two-phase (liquid-gas) inclusions were seen in only two spessartine samples. Note also the partially healed fractures consisting of minute two-phase inclusions in the upper part of the photo. Photomicrograph by John I. Koivula; magnified 20 $\times$ .



Namibia <sup>d</sup>	Namibia <sup>e</sup>	Iseyin, Nigeria	Pakistan <sup>f</sup>	Lundazi, Zambia
Koivula et al. (1993)/3; Lind et al. (1994)/13 Orange	Johnson and Koivula (1996a)/7 Orange	Milisenda and Zang (1999)/6, Zang et al. (1999)/9 Orange-yellow	Henn (1996)/n.r.; Johnson and Koivula (1996b)/4 Orange-red to "cherry" red; slight yellowish orange to brownish orange or red-orange	Johnson et al. (1999)/5 Orange
nr 1.790–1.797	SR 1.789–1.790	nr 1.801–1.803	Weak ADR 1.798–1.802	nr 1.799–1.800
4.09–4.15 Angular and roiled growth structures, curved fibers, rounded crystals, dark angular crystals	4.12–4.14 Quartz, fibrous amphibole, oxides (ilmenite, hematite, senaite), barite	4.18–4.23 Two-phase inclusions along healed fractures, zircon with tension cracks	4.05–4.18, 4.19–4.20 "Fingerprints," growth zoning, K-feldspar, acicular inclusions	4.20–4.25 Typical garnet growth bands and "fingerprints"
Cutoff at 445, distinct diffused band above 460; stronger, wider diffused band at 480–490; weak diffused band at 525–545. Also lines at 408, 421, and 430	Lines at 412, 424, 432 (edge), 462, 485, and 495	"Typical spessartine absorption features" plus local maxima at 469, 482, and 527	Mn <sup>2+</sup> bands at 408, 421, 430, 460, and 482; Fe <sup>2+</sup> bands at 503, 524, and 564	Cutoff at 435, bands at 460, 480, and 530; weak 504 line

570 nm. Within the near-infrared region were broad regions of absorption centered at about 1300 and 1700 nm (the latter being very subtle), and two bands of low intensity around 2300 nm.

## DISCUSSION

For several decades, the Ramona area was the principal source of the world's high-quality spessartine gemstones. Other historic localities for gem-quality spessartine include Madagascar (Tisdall, 1962); Amelia, Virginia (Sinkankas and Reid, 1966; Sinkankas, 1968); Ceará, Brazil (Pough, 1965; Cassedanne and Cassedanne, 1977b); Minas Gerais and Rio Grande do Norte, Brazil (Bank et al., 1970; Cassedanne and Cassedanne, 1977a; Johnson and Koivula, 1999; Ferreira et al., 2000); Kenya

(Medenbach et al., 1978); and Sri Lanka (Noor Deen, 1984). Myanmar and India have also been reported as spessartine sources (Webster, 1994). More recently, gem spessartine has been recovered from Pakistan (Henn, 1996; Johnson and Koivula, 1996b) and Mozambique (Bank et al., 1998). Particularly fine material has been produced from Namibia (Koivula et al., 1993; Lind et al., 1994; Johnson and Koivula, 1996a), Nigeria (Milisenda and Zang, 1999; Zang et al., 1999), and Zambia (Johnson et al., 1999). All of these deposits probably have a common geologic origin (granitic pegmatites), except for those in Namibia. The gemological and chemical characteristics for spessartine from Ramona are discussed below and compared to data from other localities.

Ramona spessartine that is most likely to be seen in the gem trade is characterized by an intense

Figure 17. This irregular-shaped etch channel in a 0.61 ct spessartine is bounded on both sides by strong growth lines. Photomicrograph by John I. Koivula; magnified 15×.

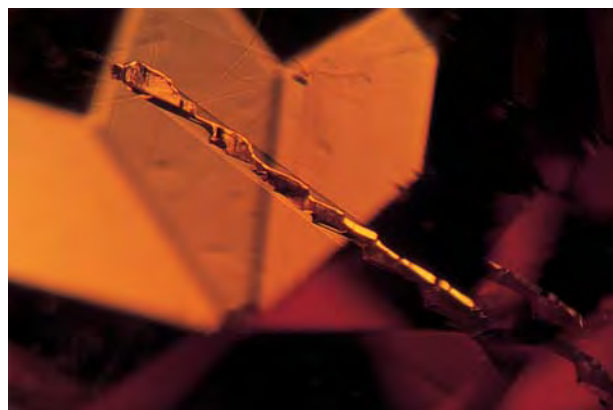
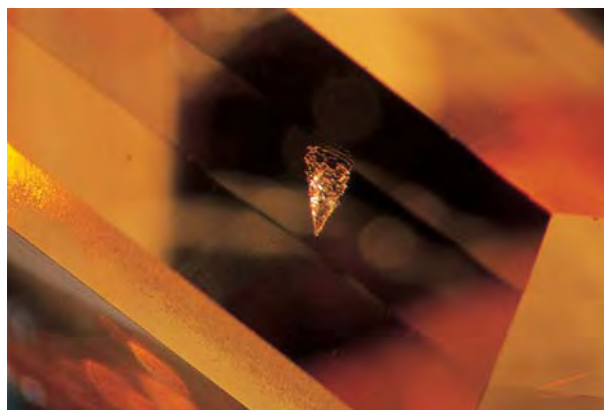


Figure 18. Raman analysis confirmed that this rough-surfaced, irregular platy inclusion is albite. Photomicrograph by John I. Koivula; magnified 15×.





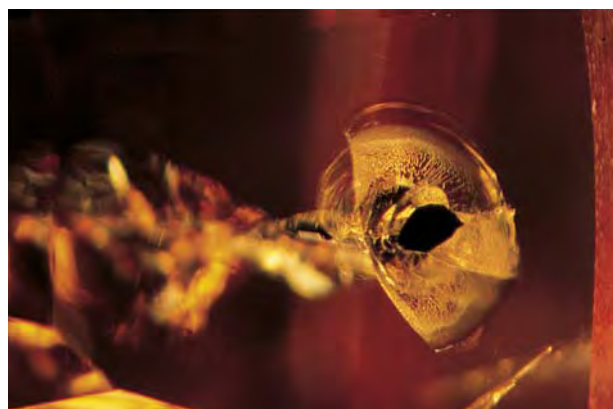


Figure 19. Surrounded by a stress fracture, this black inclusion in spessartine was identified as columbite by Raman analysis. Photomicrograph by John I. Koivula; magnified 10×.

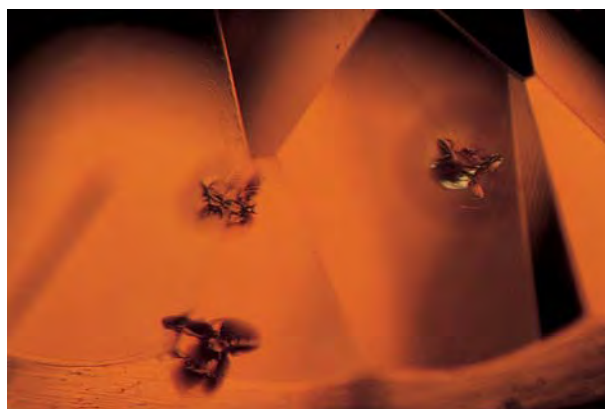


Figure 20. These three minute colorless crystals surrounded by tension fractures appear to be zircon, but they could not be identified by Raman analysis due to their size and position within the stone. Photomicrograph by John I. Koivula; magnified 20×.

**TABLE 2.** Chemical composition of gem-quality spessartine from various deposits.<sup>a</sup>

	Ramona, California <sup>b</sup>				Minas Gerais, Brazil <sup>c</sup>	Rio Grande do Norte, Brazil <sup>d</sup>	Sahatany Valley, Madagascar <sup>e</sup>	Maevatanana, Madagascar
Reference Description	This study Lt. orangy yellow, 0.48 ct, R.I.=1.799	This study Med.-lt. orangy yellow, 0.70 ct, R.I.=1.800	This study Med.-lt. orange- yellow, 1.15 ct, R.I.=1.801	This study Med. yellow- orange, 0.92 ct, R.I.=1.802	This study Orange-yellow, fragment	This study Lt. orangy yellow to yellowish orange, fragments	This study Orange-yellow, fragment	This study Orange-yellow, fragment
Oxides (wt.%)								
SiO <sub>2</sub>	36.30	36.58	36.71	36.32	36.36	36.57–36.72	36.52	36.35
Al <sub>2</sub> O <sub>3</sub>	20.56	20.38	20.28	20.49	20.78	20.15–20.85	20.78	20.86
TiO <sub>2</sub>	0.07	0.06	0.07	0.04	na	0–0.16	na	na
MnO	40.67	40.02	38.33	37.16	39.09	34.97–41.25	35.81	35.89
MgO	<0.01	<0.01	<0.01	<0.01	<0.01	0.44–1.48	<0.01	<0.01
FeO <sup>f</sup>	2.06	2.89	3.62	4.64	3.04	1.03–4.83	4.23	3.39
CaO	0.18	0.07	0.06	0.06	0.57	0.39–0.40	1.81	2.85
Total	100.01 <sup>g</sup>	100.05 <sup>h</sup>	99.07	98.71	99.84	99.76–99.69	99.15	99.34
End members (mol.%)								
Spessartine	94.8	93.2	91.3	88.8	91.3	82.0–94.6	84.7	83.8
Almandine	4.7	6.6	8.5	11.0	7.0	2.4–10.9	9.9	7.8
Grossular	0.5	0.2	0.2	0.2	1.7	1.2	5.4	8.4
Pyrope	—	—	—	—	—	1.8–6.0	—	—

<sup>a</sup>Abbreviations: lt.=light, med.=medium, na=not analyzed, nr=not reported. Analyses performed for this study used a Cameca SX-50 electron microprobe, with minerals or synthetic compounds as standards, an accelerating voltage of 20 kV, sample current of 15 mA, and the data correction procedure of Pouchou and Pichoir (1985). The following elements also were sought but not detected (detection limits shown are wt.%): F=0.21, Na<sub>2</sub>O=0.02, P<sub>2</sub>O<sub>5</sub>=0.02, Sc<sub>2</sub>O<sub>3</sub>=0.05, TiO<sub>2</sub>=0.03, V<sub>2</sub>O<sub>5</sub>=0.05, Cr<sub>2</sub>O<sub>3</sub>=0.04, ZnO=0.09, SrO=0.02, Y<sub>2</sub>O<sub>3</sub>=0.07, SnO<sub>2</sub>=0.05. All other analyses were by electron microprobe, except for the Nigerian spessartine (by SEM-EDS). In addition, 50 electron microprobe analyses of spessartine from the Amelia, Virginia, yielded Sps<sub>50</sub>Alm<sub>40</sub>Gro<sub>7</sub> to Sps<sub>95</sub>Alm<sub>3</sub>Gro<sub>2</sub> (Sinkankas and Reid, 1966). Major- and trace-element data for spessartine-almandine garnets from several localities is presented in Taylor (1998).

<sup>b</sup>Chemical data on Ramona spessartine is found in several publications. Taylor et al. (1979) determined an oxygen isotope value (δ<sup>18</sup>O) of +5.4‰ for a pocket crystal from the Hercules-Spessartite dike. In a sample containing 3.0% Fe, Foord et al. (1989) recorded the following trace elements by emission spectrometry: 0.07% Ca, 0.05% Ti, 0.0015% Mg, 70 ppm Sc, 70 ppm Ge, 150 ppm Y, 50 ppm Zr, 30 ppm Nb, 70 ppm Gd, 50 ppm Dy, and 3 ppm Yb. Taylor (1998, p. 37) recorded average values of 0.39 wt.% P<sub>2</sub>O<sub>5</sub> and 0.17 wt.% TiO<sub>2</sub>, and no Zr or F, in two electron microprobe analyses of a sample with an average composition of Sps<sub>83.9</sub>Alm<sub>14.7</sub>Gro<sub>1.4</sub>; additional trace elements were measured by direct-coupled plasma emission spectrometry (ppm)—Li=21, Nb=83.5, Cs=1.5, Ta=27.5, Pr=0.3, Nd=1.8, Eu=0.5, Gd=1.5, Tb=0.3, and Dy=6.1. See also Foord and Kleck (1993).

<sup>c</sup>See also Bank et al. (1970).

<sup>d</sup>Range from 21 analyses of three samples from the Alto Mirador mine.

<sup>e</sup>See also von Knorring and Baldwin (1969) and Schmetzer et al. (2001).

<sup>f</sup>All iron is reported as FeO.

<sup>g</sup>Also contained 0.17 wt.% P<sub>2</sub>O<sub>5</sub>.

<sup>h</sup>Also contained 0.05 wt.% P<sub>2</sub>O<sub>5</sub>.

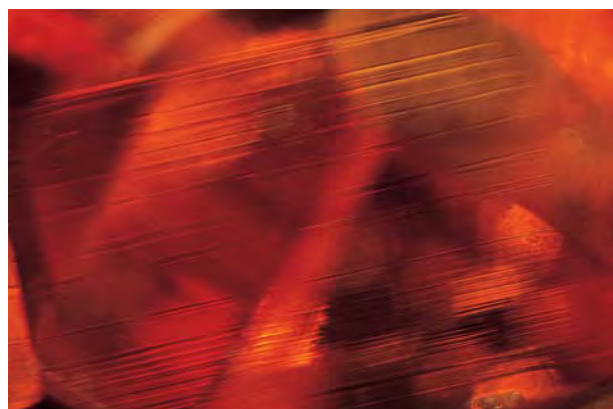


Figure 21. Parallel planar growth zoning was conspicuous in a few of the spessartines, with angular and irregular growth patterns also noted. Photomicrograph by John I. Koivula; magnified 10 $\times$ .

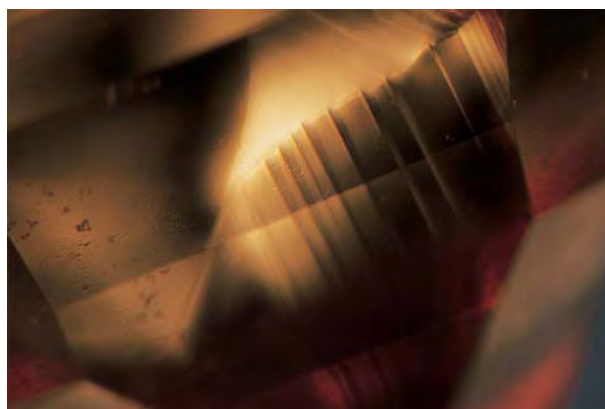


Figure 22. Anomalous birefringence was evident as irregular patterns with diffuse boundaries in all the spessartine samples. Here, planar growth zoning transects an area showing anomalous birefringence. Photomicrograph by John I. Koivula; magnified 10 $\times$ .

Namibia	Nigeria	Pakistan	Zambia
Lind et al. (1994)	Zang et al. (1999)	Henn (1996)	This study
Orange	Orange-yellow	Orange-red to "cherry" red	Orangy yellow, fragment
33.93–36.70	36.1	36.39	36.51
18.87–20.35	21.4	20.60	20.79
up to 0.11	nr	nr	nr
37.63–42.60	40.6	36.98	40.86
2.71–3.20	0.94	nr	<0.01
0.89–1.08	0.64	4.45	1.53
0.41–0.58	0.27	1.58	0.22
99.18–100.47	99.95	100.00	99.91
84.0–87.0	up to 94	85.3	95.8
1.9–2.0	1.5–11	10.1	3.5
1.1–1.4	nr	4.6	0.7
9.8–12.6	3.5	—	—

orangy yellow to yellowish orange color; R.I. values of 1.799–1.803; S.G. values of 4.19–4.26; internal features consisting most commonly of wavy planes of partially healed fractures, negative crystals, and growth patterns (planar, angular, and irregular); and absorption bands at approximately 460, 480–485, 504, 520–525, and 570 nm, with a cutoff at 435–440 nm.

To the best of our knowledge, Tisdall (1961) published the only other article on the gemology of Ramona spessartines. He reported a higher R.I. value (>1.81) than we measured in our samples. However, our values are similar to those reported for spessartine by Stockton and Manson (1985: 1.798–1.808), as well as by Liddicoat (1989) and

Webster (1994): 1.790–1.797 or 1.789–1.790. Our R.I. values also are consistent with those reported for other localities (see table 1), with the exception of Namibian spessartine with its lower range (1.789–1.797). Also, reported values for samples from Madagascar and Mozambique were over the limits of a standard refractometer (>1.81). Sinkankas and Reid (1966) documented somewhat lower R.I. values of 1.795–1.798 for near-end-member spessartine from Amelia, Virginia, and a general increase in R.I. with increasing iron content and darker color (e.g., approximately 1.808 for compositions around  $\text{Sps}_{62}\text{Alm}_{38}$ ). We also recorded a general increase in R.I. with darker color. In the four chemically analyzed samples, there was a systematic correlation of R.I. with spessartine-almandine content: 1.799 to 1.802 for  $\text{Sps}_{94.8}\text{Alm}_{4.7}\text{Gro}_{0.5}$  to  $\text{Sps}_{88.8}\text{Alm}_{11.0}\text{Gro}_{0.2}$ .

The S.G. values we obtained, 4.19–4.26, were higher than the 4.17 value determined by Tisdall (1961) using ethylene dibromide, and also higher than the general range given by Liddicoat (1989) and Webster (1994) for spessartine: 4.12–4.18 and 4.12–4.20, respectively. However, our values fall within the range Stockton and Manson (1985) determined for spessartine (4.18–4.27), and they are comparable to those reported for spessartine from some other localities (i.e., Brazil, Nigeria, and Zambia; see table 1).

The features we observed with magnification are consistent with the "fingerprints" (partially healed fractures) and angular three-phase inclusions that Tisdall (1961) found in his four samples of Ramona spessartine. The negative crystals and growth zoning seen in our samples also have been previously noted (Rouse, 1986 and Liddicoat, 1970, respectively; see also table 1). However, the linear clouds and



inclusions of albite and columbite identified in this study have not been reported in spessartine from other localities. It was not surprising to find albite inclusions, since Ramona spessartine is commonly intergrown with albite (cleavelandite). Also, Nb-Ta oxides such as columbite are relatively common in late-stage albitic mineral assemblages in granitic pegmatites (see, e.g., Černý, 1992). Inclusions of schorl also have been reported in spessartine from Ramona (E. Gray, pers. comm., 2001), but not from other localities.

The four Ramona samples we analyzed by electron microprobe were similar in chemical composition to those from the other pegmatite localities in table 2 (i.e., all but Namibia), although higher calcium contents were recorded in spessartines from most of the other deposits. The highest Mn contents (i.e., spessartine component) were measured in samples from Ramona, Zambia, Brazil (Rio Grande do Norte), and Nigeria. The lowest Fe contents (i.e., almandine component) were found in material from Nigeria and Namibia. The compositions of samples analyzed from Madagascar and Pakistan are similar to one another, and show higher Ca and lower Mn than the others. The Namibian spessartine is enriched in magnesium compared to the others, reflecting its unique geologic environment within metamorphic rocks. Magnesium is not typical of granitic pegmatites (Černý et al., 1985), although traces may be derived from host rocks surrounding a pegmatite.

The visible absorption features we observed are comparable to data reported by Tisdall (1961) for

Ramona spessartine. The  $\text{Mn}^{2+}$  bands (at approximately 409, 421, 430, 460, and 483 nm) recorded in our samples also are consistent with those measured by Lind et al. for spessartine from Ramona and Namibia (see also Manning, 1967; Stockton and Manson, 1985). Also,  $\text{Fe}^{2+}$ -related bands at approximately 504, 525, and 570 nm in our samples are consistent with those reported by Lind et al. and Stockton and Manson. However, additional  $\text{Fe}^{2+}$ -related bands at 610 and 690 nm recorded in Ramona spessartine by Lind et al. were not evident in the samples we analyzed (again, see figure 23).

Overall, the absorption spectra of the four Ramona samples were similar, as expected from their relatively narrow range in color and composition (again, see figure 13 and table 2). The spectra were dominated by an intense  $\text{Mn}^{2+}$  absorption at approximately 409 nm (again, see figure 23); this peak is actually the result of combined strong absorptions at 407 and 411 nm (Stockton and Manson, 1985). The darker samples showed a subtle increase in the strength of the 504 and 570 nm peaks, as expected from the spectroscopy and chemistry results. The  $\text{Mn}^{2+}$  peaks at approximately 430, 460, and 483 nm in the darkest sample were less defined than in the other samples.

The broad regions of absorption in the near-infrared region (at about 1300, 1700, and 2300 nm) may be due to traces of hydroxyl groups (compare to Lind et al., 1994). Hydrous components in garnet are most easily detected in the infrared spectra (as absorption bands in the  $3600\text{ cm}^{-1}$  region), which were not collected in this study; traces of hydrogen

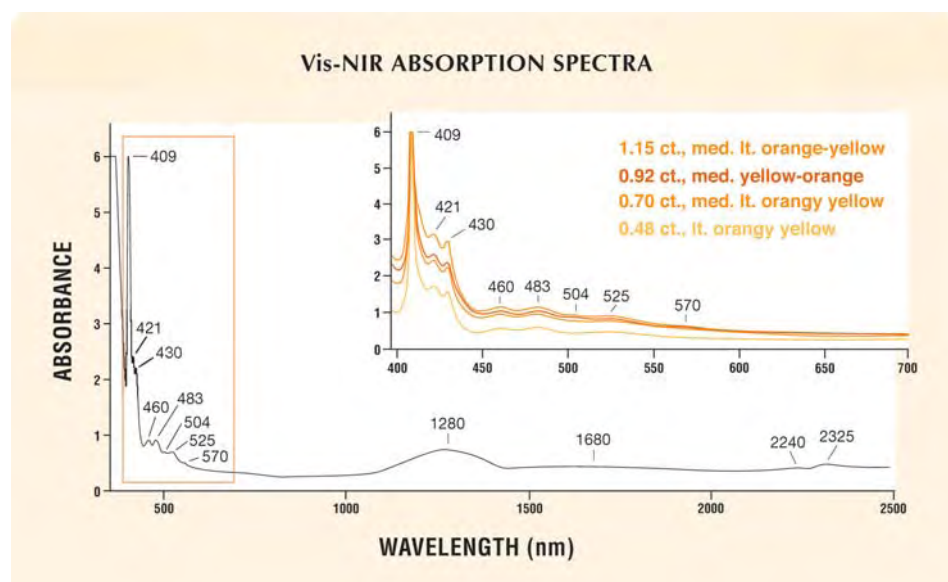


Figure 23. This UV-Vis-NIR absorption spectrum of a 0.70 ct medium-light orangy yellow spessartine is representative of the Ramona material. It shows a dominant peak at 409 nm, with additional strong peaks at 421 and 430 nm and several smaller peaks; broad regions of absorption in the near-infrared are located at around 1300, 1700, and 2300 nm. The inset shows the absorption spectra of all four samples pictured in figure 13 in the visible region (400–700 nm). Note the subtle increase in the strength of the 504 nm peak in the darker samples. The four samples measured 2.9–4.3 mm from table to culet; path distances of the beam could be significantly longer.

(expressed as 0.038 wt.% H<sub>2</sub>O) were found in Ramona spessartine by Rossman et al. (1988) by nuclear reaction analysis.

According to Fritsch and Rossman (1987), the orange color of spessartine is caused by Mn<sup>2+</sup> in a site with distorted cubic coordination. Iron causes the intrinsic yellow-orange color of spessartine to darken into red and brown hues (Sinkankas and Reid, 1966). The orangy yellow to brownish orange color seen in Ramona spessartine is due to a combination of absorptions from Mn<sup>2+</sup> and Fe<sup>2+</sup>.

**Identification.** Our review of the literature revealed no report of the growth of gem-quality spessartine in the laboratory, and we know of no treatments done to the natural material. Spessartine may resemble orange grossular, and at one time the Ramona material was thought to be hessonite (Sinkankas, 1959); it was called "hyacinth" (a varietal name for orange grossular) by the locals in the early years of mining (L. Spaulding Jr., pers. comm., 2001). Stockton and Manson (1985) studied three types of reddish orange garnet that could be confused with one another—"malaya," grossular, and spessartine-almandine—and found they could be separated by their R.I. values and spectroscopic spectra.

Spessartine also may resemble zircon, sphene, topaz, and citrine (Liddicoat, 1989), but these can be separated easily with standard gemological testing. Federman (1994) noted the similarity between spessartine and Mexican fire opal, but also pointed out their obvious gemological differences. Spessartine also resembles the rare gem clinohumite, but the two minerals can be readily separated on the basis of optical properties and UV fluorescence (Hyrsl, 2001).

## CONCLUSION

The historic Little Three mining area in Ramona, California, was the principal source of gem-quality spessartine for most of the 20th century. Most of the spessartine production occurred sporadically from 1956 to 1994. An estimated total of 40,000–50,000 carats of facetable rough was mined chiefly from the Hercules-Spessartite and the Spaulding dikes, within vuggy corroded pegmatite and small "pockets."

Ramona spessartines characteristically are a bright orangy yellow to yellowish orange, with few (if any) eye-visible inclusions. Internal features such as wavy planes of partially healed fractures, anomalous birefringence, and growth patterns are comparable to spessartine from other localities, but linear clouds, inclusions of albite and columbite, and the common occurrence of negative crystals in the study samples appear unique to Ramona. Four analyzed samples of the characteristic color range were spessartine rich: Sps<sub>94.8</sub>Alm<sub>4.7</sub>Gro<sub>0.5</sub> to Sps<sub>88.8</sub>Alm<sub>11.0</sub>Gro<sub>0.2</sub>. Absorption spectra showed corresponding strong peaks for Mn<sup>2+</sup> and subordinate Fe<sup>2+</sup> features.

Because the most accessible portions of the Ramona spessartine-bearing pegmatites have been mined, a significant investment in time and work will be necessary before commercial production can resume. Also, in recent years, the Ramona locality has been overshadowed by abundant production of spessartines from Namibia and Nigeria. Nevertheless, the price of fine spessartine (as reported by *The Guide*) appears to be stable, and the highest-quality material is gradually increasing in value. With the greater popularity of spessartine in both high-end jewelry and mass-produced goods (Henricus, 2000), the stone is in strong demand by the gem trade. Certainly any future production of Ramona spessartine will find a ready market.

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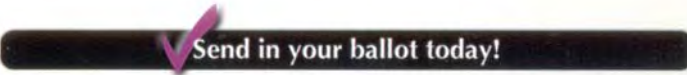


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