

# RED BERYL FROM UTAH: A REVIEW AND UPDATE

James E. Shigley, Timothy J. Thompson, and Jeffrey D. Keith

There is only one known commercial occurrence of gem-quality red beryl in the world: the Ruby Violet (or Red Beryl) mine in the Wah Wah Mountains of Beaver County, Utah. The beryl is found mostly along fractures (often clay-filled) in a topaz rhyolite. It crystallized as a vapor-phase mineral from the reaction between rhyolite-derived gases, vapors originating from heated groundwaters, and preexisting minerals and volcanic glass in the rhyolite. Production of red beryl over the past 25 years is estimated to be more than 60,000 carats, of which about 10% was facetable. Exploration and evaluation programs undertaken by two mining companies from 1994 to 2001, combined with field studies by some of the authors and others, have resulted in a greater understanding of the geology of the Ruby Violet deposit and the potential for productive areas beyond the current mine site.

Two decades ago, Shigley and Foord (1984) described the spectacular gem-quality red beryl (figure 1) found at the Ruby Violet mine in the Wah Wah Mountains of southwestern Utah (see also Ream, 1979; Sinkankas, 1976, 1997). Since that time, this material has remained one of the rarest color varieties of gem beryl, with its increased recognition and acceptance in the marketplace being offset by the continued limited scale of production.

Although gem beryls are common in granitic pegmatites (i.e., aquamarine, morganite, heliodor, and goshenite) and in certain metamorphic and metasedimentary rocks (emerald), their occurrence in rhyolites is unusual. Conversely, rhyolites occasionally contain crystals of quartz, topaz, and garnet in lithophysal (gas) cavities, or opal as veins or cavity fillings.

Besides the Ruby Violet mine, several other occurrences of red beryl (all in rhyolites) are known, but none has produced significant quantities of facet-grade material. These include: Utah—Wildhorse Spring, Topaz Valley, and Starvation Canyon, all in the Thomas Range, Juab County (Staatz and Carr, 1964; Ream, 1979; Sinkankas, 1981; Montgomery, 1982; Christiansen et al., 1986; Wilson, 1995; Foord, 1996; Baker et al., 1996); New

Mexico—Beryllium Virgin prospect in Paramount Canyon, Black Range, Sierra County (Kimblér and Haynes, 1980; Sinkankas, 1981, 1997; Foord, 1996; Voynick, 1997), and East Grants Ridge, Cibola County (Voynick, 1997); and Mexico—San Luis Potosí (Ream, 1979).

Red beryl was initially called “bixbite” (Eppler, 1912), but this name never attained widespread usage—in part because of its confusion with bixbyite  $[(\text{Mn,Fe})_2\text{O}_3]$ , a mineral species that also happens to occur in topaz rhyolites in Utah in association with red beryl. More recently, some have attempted to market the gem as “red emerald” to enhance its status among consumers by calling attention to its relation to emerald (see, e.g., Spendlove, 1992; Weldon, 1999; Genis, 2000; Pesheck, 2000). Although this controversial terminology violates generally accepted gemological nomenclature, it has added to the public’s recognition of red beryl (Roskin, 1998).

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See end of article for About the Authors and Acknowledgments.  
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Figure 1. Red beryl from the Wah Wah Mountains of Utah is among the rarest varieties of gem beryl, and crystals suitable for faceting have been found so far only at one locality. These crystals (3.5 and 2.2 grams) are from a collection that was donated to GIA by Rex Harris and Michael and Tina Nielson of Red Beryl Inc., Delta, Utah; the rings (the largest red beryl is 0.54 ct, set with a 0.54 ct emerald) are courtesy of Equatorial Imports, Dallas, Texas. Photo © Harold and Erica Van Pelt.

During the past decade, field studies of the Ruby Violet mine have provided new insights into the geologic conditions of red beryl formation (see, e.g., Keith et al., 1994; Christiansen et al., 1997). In addition, systematic exploration and sampling by two different mining companies (Kennecott Exploration Co. and Gemstone Mining Inc.) provided estimates of red beryl distribution and ore grade at the deposit. The present article reviews this new information on the geology of the Ruby Violet red beryl occurrence and the activities of these two mining companies. Also included is a brief gemological update on this unique American gemstone.

### GEOGRAPHIC SETTING

Although red beryl was first reported nearly a century ago—from the Thomas Range, at a locality about 90 miles (145 km) north of the Ruby Violet mine (Hillebrand, 1905), it was discovered along the eastern flank of the Wah Wah Mountains in the late 1950s (Sinkankas, 1976). The Ruby Violet mine is situated approximately 40 km (25 miles) west-southwest of the town of Milford and is accessible for much of the year by paved and dirt roads (figures 2 and 3). The entrance to the property is secured by locked gates. Local elevations vary from 2,042 to 2,165 m (6,700 to 7,100 feet) above sea level. Average temperatures range from 38°C (100°F) in the summer to -12°C (10°F) in the winter. The area is uninhabited and has few landmarks. This portion of Utah lies within the “Basin and Range” physiographic province, which takes its name from the

alternating parallel mountain ranges and valleys that dominate the topography.

### GEOLOGY AND GENESIS

**Geology.** Topaz rhyolites of Cenozoic age are widely distributed across the western U.S. and Mexico. They are characteristically enriched in fluorine, and also contain elements such as Li, Rb, Cs, U, Th, and Be (Burt et al., 1982; Christiansen et al., 1983). The Thomas Range rhyolite, recognized as a source of topaz for over a century (Ream, 1979; Wilson, 1995), is located adjacent to Spor Mountain, the world’s largest economic source of beryllium (Shawe, 1968; Christiansen et al., 1984; Barton and Young, 2002). At that deposit, the ore consists of disseminated bertrandite— $\text{Be}_4\text{Si}_2\text{O}_7(\text{OH})_2$ —and fluorite ( $\text{CaF}_2$ ) in a water-deposited rhyolitic tuff (Lindsey, 1977). The geochemical association of beryllium and fluorine in some ore deposits has long been recognized, with fluorine bonding with—and acting to transport—beryllium as Be-F complexes in magmatic and hydrothermal systems (Ringwood, 1955; Levinson, 1962).

Rocks that predated the rhyolite and other volcanic rocks in the Wah Wah Mountains consist of Paleozoic and Mesozoic sediments that were deposited on Proterozoic crystalline basement rocks, and then were folded and thrust-faulted eastward during the Cretaceous-age Sevier Orogeny (Best et al., 1987; Keith et al., 1994). Volcanism in this part of Utah began during the middle Tertiary Period, about 34 million years (My) ago. Beginning about 23 My ago, extensional

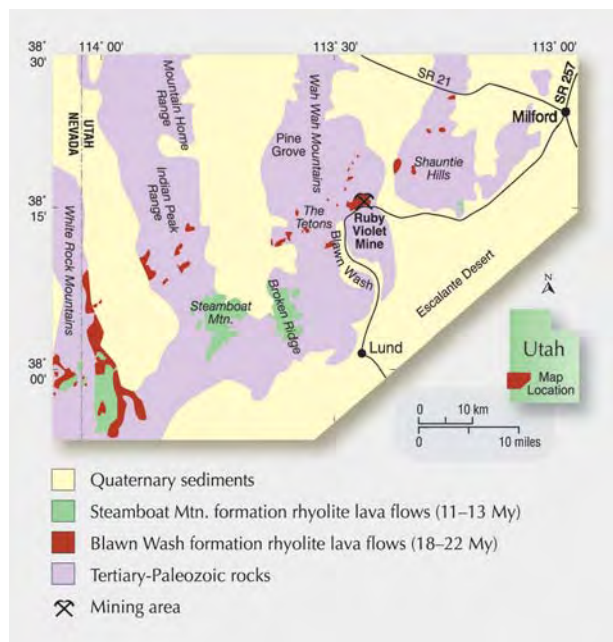


Figure 2. This simplified geologic map shows the location of the red beryl deposit on the eastern flank of the Wah Wah Mountains in southwestern Utah (approximately equal distances from both Salt Lake City, Utah, and Las Vegas, Nevada), as well as the general geology of the area. Both the Blawn Wash and Steamboat Mountain formations represent Cenozoic-age rhyolitic lava flows that occurred at several locations in this portion of Utah. Modified from Keith et al. (1994).

Figure 3. This view, looking westward, shows the Ruby Violet mine site in the mid-1990s, at the height of exploration activity. Since then, the site has been partially reclaimed, with most of the pits filled in to recreate the original shape of the hillside. Note that a dirt road leads directly to the site. Photo courtesy of William Rohtert.



(pulling apart) tectonism produced large, regional faults and associated volcanism in the area. The volcanism generated small-volume andesitic and rhyolitic domes, subvolcanic intrusions, and lava flows—including the red beryl-bearing rhyolite flow at the Ruby Violet deposit.

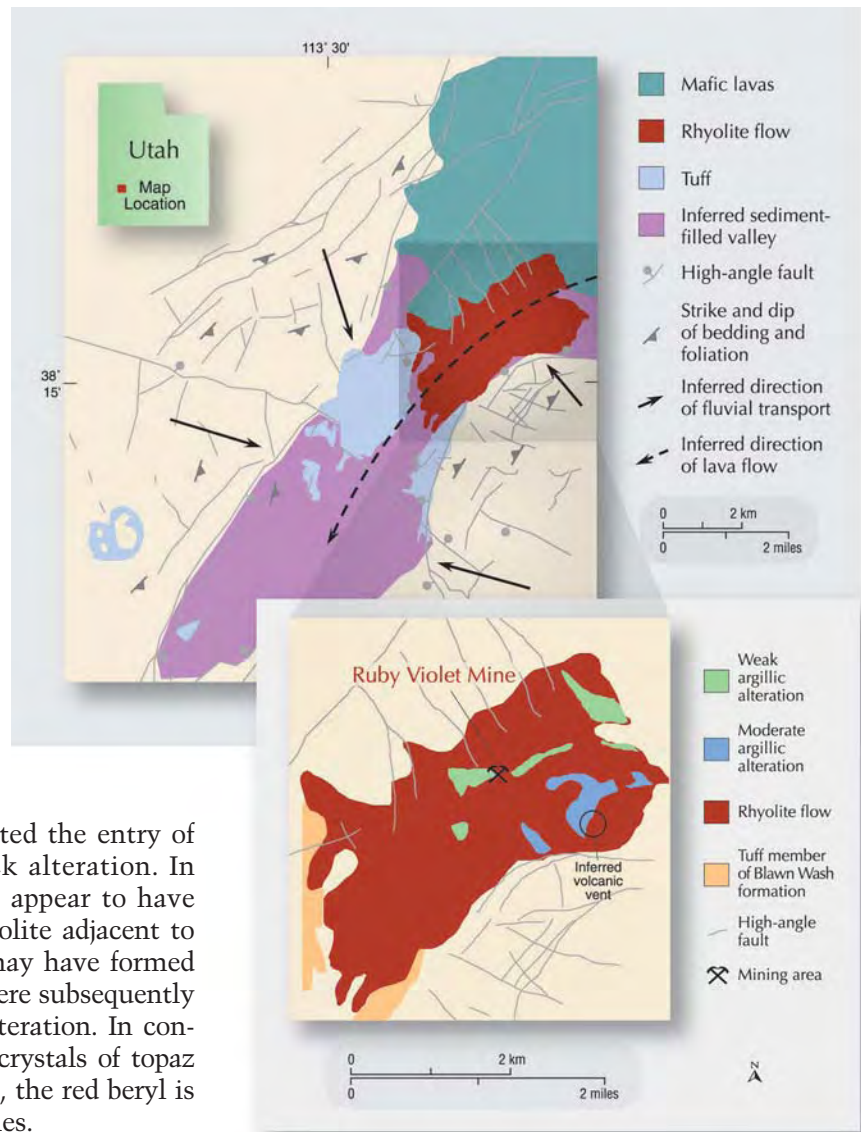
The red beryl forms hexagonal crystals that are hosted by a flow-banded, porphyritic, topaz rhyolite (figure 4). This light gray rock contains occasional crystals (phenocrysts) of alkali feldspar, quartz, and minor biotite mica in a fine-grained groundmass of these same minerals along with volcanic glass. At the mine site, this rock is exposed over an area of about 9 km<sup>2</sup>, although portions may lie concealed beneath geologically younger rocks (Keith et al., 1994). The rhyolite forms part of the Blawn Wash formation (Abbott et al., 1983).

At the mine site, red beryl has been found within an area measuring 900 × 1,900 m, where the host rhyolite shows an unusual amount of argillic (clay) hydrothermal alteration (as compared to other topaz rhyolites; Keith et al., 1994). The more mineralized section of the deposit (figure 5) occupies a 50 × 850 m area that is currently exposed over an elevation range of about 90 m. This zone appears to lie within the central portion of the rhyolite flow (figure 6), which exhibits more prominent flow banding and phenocrysts (Keith et al., 1994).

The gem-grade red beryl mineralization occurs along or near discontinuous, near-vertical fractures that formed as a result of the cooling and contraction of the rhyolitic lava (figures 7 and 8). Not all fractures, or all portions of the same fracture, contain beryl. Within a productive fracture, the red beryl often occurs in locally dense concentrations of crystals that can extend over vertical distances of several meters and horizontal distances of 30 m or more. White (kaolinite) and brown (smectite-illite) clays, locally stained yellow-brown or black, fill many fractures, and often mark concentrations of red beryl crystals. The clay-filled fractures are also known to contain other vapor-phase minerals such as bixbyite, manganese-containing hematite, tridymite, cristobalite, and (rarely) topaz.

The walls of most of the beryl-bearing fractures have been altered to kaolinite over a width of several centimeters (Keith et al., 1994; Thompson et al., submitted). Some productive fractures lack clay alteration, possibly because they were sealed by the deposition of silica minerals (quartz, cristobalite, tridymite), oxide minerals (bixbyite and hematite),

Figure 4. This simplified geologic map shows the location of the Ruby Violet mine within the rhyolite flow. Following its eruption, the lava is thought to have flowed southwestward through a valley, where it crystallized. Red beryl mineralization is locally concentrated along sets of near-vertical fractures that are oriented approximately parallel or perpendicular to the sides of this valley. These fractures resulted from the cooling and contraction of the solidifying rhyolite lava. Modified from Keith et al. (1994).



and alkali feldspar, which prevented the entry of fluids that produced the wallrock alteration. In addition, some red beryl crystals appear to have grown within the clay-altered rhyolite adjacent to the mineralized fractures; these may have formed along very narrow fractures that were subsequently obscured by mineral growth or alteration. In contrast to the typical occurrence of crystals of topaz and garnet in other topaz rhyolites, the red beryl is not found in lithophysal (gas) cavities.

#### Genesis of the Host Rhyolite and the Red Beryl.

According to Keith et al. (1994) and Christiansen et al. (1997), after eruption the molten rhyolite flowed into a valley, where it solidified (again, see figure 4). The fractures that formed during cooling acted as conduits for the escape of gases released by the solidifying lava, as well as points of entry for surface waters into the flow (again, see figure 6).

Figure 5. In this mineralized section of the Ruby Violet mine, a number of discontinuous, near-vertical fractures are exposed in the rhyolite host rock. The rhyolite is excavated with earth-moving equipment and hand tools to expose productive areas for red beryl that occur along these fractures. Mine owner Rex Harris is shown for scale; photo courtesy of William Rohtert, taken in 1995.



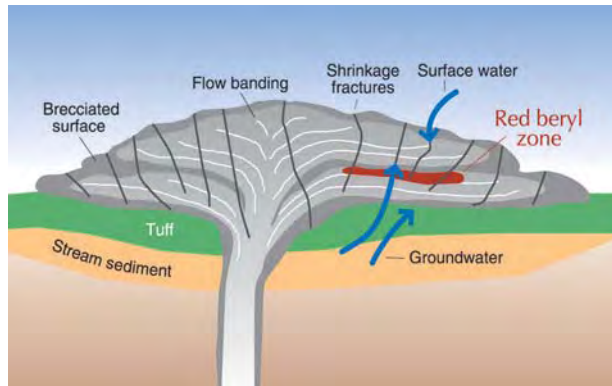


Figure 6. This cross section of the rhyolite lava flow is inferred from geologic field studies conducted at the Ruby Violet mine. The erupting lava flowed upward and outward from the vent of the volcano; as it cooled, conditions were achieved to allow for red beryl to form along fractures. Modified from Thompson (2002).

Figure 7. Typically, the red beryl crystals are locally concentrated along brown-stained, clay-filled fractures within the host rhyolite. Here, Rex Harris uses hand tools to carefully open up promising sections of the fractures. Photo courtesy of William Rohtert.



Keith et al. (1994) proposed that the beryllium necessary to form the red beryl was derived from the host rhyolite, from which it was mobilized as Be-F complexes within a favorable geochemical environment (see also Wood, 1992). Average whole-rock Be concentrations in the rhyolite range up to about 25 ppm—similar to Be values found in other topaz rhyolites (Christiansen et al., 1986). Even at only 25 ppm, there is sufficient Be in the rhyolite to crystallize the red beryl along fractures (for comparison, the organic black shales at Muzo Colombia, thought to be the source of beryllium for the emerald deposits, have an average Be concentration of only  $3 \pm 0.5$  ppm; Ottaway et al., 1994). Be mobilization was enhanced by the very low Ca contents of the host rhyolite (<0.01–0.18 wt.% CaO, compared to about 0.5–0.9 wt.% for other topaz rhyolites; see Keith et al., 1994). This would allow the fluorine released from the cooling rhyolite to bond with and transport beryllium, rather than being removed by the crystallization of fluorite.

According to Keith et al. (1994) and Christiansen et al. (1997), red beryl crystallized when high-temperature fluorine-rich gases (released from the cooling rhyolite) mixed with vapors from heated waters (derived from sediments trapped beneath the flow) to produce a low-density, supercritical fluid that reacted with the rhyolite along fractures (figure 9). At certain depths within the flow, red beryl formed where Be-F complexes in the supercritical fluid

Figure 8. This red beryl crystal (just above the index finger) was found partly embedded in the rhyolite, along a clay-filled fracture. Crystals can range up to about 5 cm long, but 90% of those suitable for faceting are less than 1 cm. Photo courtesy of Rex Harris.



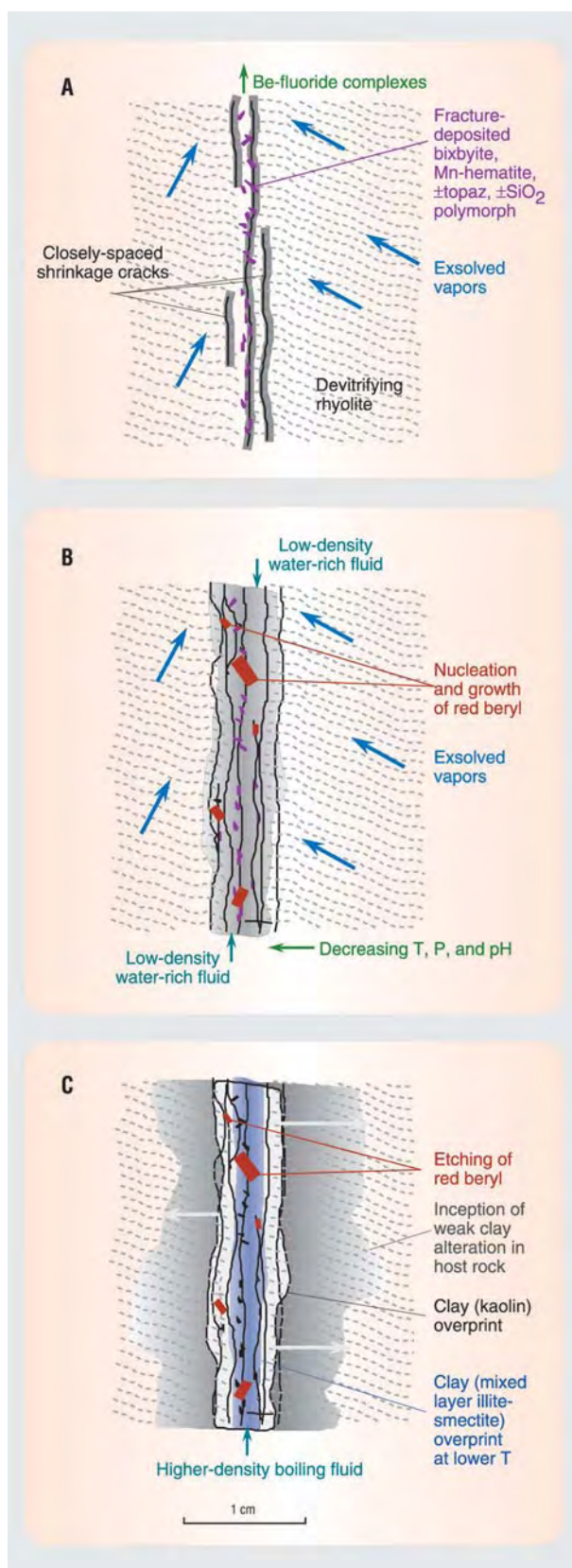
chemically reacted with rhyolitic glass, alkali feldspar, and Fe-Mn oxide minerals (bixbyite) along the fractures, primarily as a replacement of alkali feldspar (see also Aurisicchio et al., 1990; Barton and Young, 2002).<sup>\*</sup> As temperatures continued to drop, subsequent reactions produced an acidic aqueous fluid that caused clay alteration along the fractures and within portions of the rhyolite. The absence of clay minerals as inclusions within the red beryl supports the theory that beryl formation occurred before the clay alteration. Therefore, the beryl formed at temperatures below the crystallization of rhyolite magma (i.e., <650°C), but above those of clay alteration (200–300°C).

## HISTORY AND MINING

Lamar Hodges discovered red beryl in the Wah Wah Mountains in 1958, while prospecting (unsuccessfully) for uranium; his family worked the deposit, then known as the Violet Claims 1–8, as a hobby for the next 18 years (Barlow, 1979; Christensen and Austin, 1999; Garber, 2003). In 1976, the Harris family of Delta, Utah, purchased mining rights to the property. Over the next 18 years, the Rex and Ed Harris families and their partners worked the deposit on a more regular basis, usually for about 60 days per year, mainly in the spring and fall. Most of the mining then (as in recent years) took place in three open pits (lower, middle, and upper), with removal of ore

<sup>\*</sup> According to Keith et al. (1994) and Christiansen et al. (1997), the nearly anhydrous red beryl crystallized from supercritical fluid that contained some water, but the activity of water in the fluid is thought to have been very low (i.e., only slightly higher than its activity in the rhyolite). Where water was absent in the flow, red beryl formation did not occur. The chemical reaction that formed red beryl consumed water and produced hydrofluoric acid, the principal agent of the clay alteration, as well as soluble fluorides.

*Figure 9. These diagrams depict the inferred sequence of events leading to the crystallization of red beryl and alteration of the host rhyolite. Shrinkage fractures in the cooling rhyolite provided channels for the upward release of supercritical fluids containing beryllium-fluoride complexes (A). These fluids interacted with pre-existing minerals and rhyolitic glass, resulting in the formation of red beryl crystals along the fractures (B). Subsequently, acidic aqueous fluids caused clay alteration in the rhyolite and etched some of the beryl crystals (C). Modified from Keith et al. (1994).*



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ultimately reaching depths of about 20 m below the surface. Most of the gem-quality red beryl recovered to date has come from the lower pit, where red beryl-containing fractures occur every few meters (Keith et al., 1994). Mining has involved limited blasting to break up the host rock, the use of earth-moving equipment (backhoe and bulldozer) to clear access to productive areas, and digging with hand tools to locate and remove the beryl crystals from the fractures. According to Rex Harris (pers. comm., 2003), from 1976 to 1994 the deposit yielded about 0.5 carat of facetable red beryl per ton of ore, with at least 2,000 tons of ore extracted each year. Until 1994, the Harris family remained the single primary source of red beryl that could be marketed for faceting purposes or as mineral specimens.

On the basis of the recognized gem value of red beryl, and the geologic potential of the deposit identified through reconnaissance geologic mapping, in March 1994 Kennecott Exploration Co. (KEC) entered into a three-year lease with the Harris family, with the option to purchase the mine and surrounding claims as well as exploration rights (Verbin, 1994). Their intention was to determine whether sufficient red beryl reserves existed in the deposit and, if improved gem recovery was feasible, to allow the mine to be worked economically on a larger scale. KEC planned to quarry the mineralized rhyolite, crush the rock to a minimum size, and then chemically dissolve it to recover the red beryl crystals. Over the next three years, Kennecott conducted an extensive program of geologic mapping, core drilling, and bulk sampling.

According to an unpublished 1996 report by KEC project leader William Rohtert, nearly 3,962 m (13,000 feet) of core was recovered from 56 drill holes to investigate the subsurface geology of the deposit. In November 1995, KEC began an underground bulk-sampling program to confirm the extent of the deposit identified by core drilling, calculate the potential ore grade, and test the effectiveness of mechanized mining. In all, they removed nearly 11,000 tonnes of rock from almost 600 m of tunnels. This work resulted in a more complete understanding of the distribution and geologic controls of the red beryl mineralization. Proven and probable reserves were subsequently estimated to be over 1,000,000 tons of ore with a rough gem grade of 0.25 gram (1.25 ct) of beryl per ton (and locally up to 5 grams per ton). At a faceting yield of 10% (W. Rohtert, pers. comm.,

2003), this would equate to 0.125 ct of faceted red beryl per ton of ore. Geologic and geophysical surveys suggested at least five additional exploration targets in the immediate area.

A proprietary method ("caustic fusion") to chemically dissolve the rhyolite and liberate the red beryl crystals was developed for KEC by the technical staff of Lakefield Research in Lakefield, Ontario, Canada, but it proved uneconomic compared to hand-picking crystals from the crushed ore. KEC also built a preliminary crushing plant capable of processing 10 tons of ore per hour near Cedar City (40 km from the site). Ore was crushed to two different feed sizes, and then passed by conveyor belt through a recovery room where it was hand-picked for red beryl crystals. The material was then hand-sorted into three categories: non-gem, near-gem (with less than 50% of a crystal being facet quality), and gem (with more than 50% facet quality). The beryl concentrate was cleaned and then re-sorted by professional gemologists to more accurately categorize facetable crystals by size, color, and quality. The rough was faceted in Thailand (and in Bogotá, Colombia, for some melee-size material), and then the polished goods were sorted by size, color, and clarity by gemologists at KEC's Salt Lake City offices. Unfortunately, production figures for this period remain proprietary.

Despite the technical successes of KEC's Ruby Violet exploration program, internal corporate politics and downsizing at RTZ (the parent company) led to the disbanding of Kennecott's colored gemstone initiative at the end of 1996, and the company decided to divest the property.

In March 1997, Utah-based Gemstone Mining Inc. (GMI)—the U.S. subsidiary of Gibraltar-based Amelia Investments Ltd.—purchased from the Harris family a one-year extension of the lease option, also to evaluate the feasibility of mining red beryl on a large scale (Lurie, 1997; Genis, 2000; Austin, 2002). In addition, GMI acquired all cut and uncut gem material that Kennecott had produced; their scientific, production, and marketing data; and the processing plant. Gem material from this stockpile and from further mining was then sold by GMI to a Gibraltar-based company, Red Emerald Ltd. (REL), for faceting, marketing, and sales. A third company, Canada-based Red Emerald Resources (formerly Neary Resources), provided investment funds for both companies in exchange for a portion of the profits. Later, additional funding was provided by another investor.

GMI performed further investigations of the geology and ore grade of the deposit, which included geologic mapping, core drilling, and bulk sampling. Favorable results prompted GMI to apply for a large-mine permit from state authorities. In December 1998, the option agreement was restructured, and GMI made a down payment to the Harris family to purchase the mine, agreeing to a payment schedule for the balance. At the same time, they began to work the deposit (which they referred to as the Red Emerald mine; Pesheck, 2000) using open-pit methods.

In June 2001, however, GMI did not make a scheduled payment to the Harris family, causing the mining contract to go into default. The U.S. Bureau of Land Management took control of the property on behalf of the Harrises, and GMI and REL ceased all mining and production activities. In August 2001, as required by state law as part of the large-mine permit, GMI began reclamation of the mine site. This action involved filling most of the open pits, hauling away waste rock, restoring much of the land surface to its original topography, covering the site with topsoil, seeding, and removing all structures. Efforts are underway to sell the remaining gem material obtained by GMI to pay investors and other costs (D. Merz, pers. comm., 2003).

The Harris family recently regained complete ownership of the mine, in accordance with the terms of the GMI purchase agreement, and they intend to resume small mining operations until a new purchaser is found for the property (R. Harris, pers. comm., 2003).

## PRODUCTION AND DISTRIBUTION

A recent assessment of the gem material in possession of the Harris family listed over 1,600 carats of faceted stones and 56,000 carats of mixed-grade crystals, of which about 10% were suitable for cutting. The quantity of material held at the time by GMI has not been made public.

Red beryl is sold as both mineral specimens and faceted gemstones, as well as set in jewelry. The average weight of cut stones has been about 0.20 ct, with approximately 10% of the gemstone production exceeding 1 ct. To date, the largest faceted red beryl weighs 4.5 ct.

For the most part, the material has been marketed in the U.S. and Japan. Small cut goods have been used primarily in custom jewelry, while larger



Figure 10. Red beryl crystals from the Ruby Violet mine display a simple prismatic morphology (dominated by basal pinacoid and prism faces) that is typical of most beryl. Shown here are two intergrown crystals (up to 2.1 cm long). Courtesy of Rex Harris; photo © Jeff Scovil.

faceted stones have been sold loose to collectors or incorporated into exquisite jewelry pieces (similar to those on the cover of this issue of *Gems & Gemology*).

## PHYSICAL AND GEMOLOGICAL PROPERTIES

Crystals of red beryl (figure 10) usually occur as simple hexagonal prisms that are well formed and are terminated by flat or, less commonly, stepped basal pinacoid faces (Foord, 1996). They range up to more than 2 cm wide and 5 cm long. However, 90% of the gem-quality crystals are less than 1 cm in length. They are elongated parallel to the *c*-axis, with length:width ratios of approximately 4:1 or greater. Some crystals exhibit evidence of breakage and rehealing. Doubly terminated and multiple crystals have also been encountered (see again figures 1 and 10).

Shigley and Foord (1984) summarized the gemological properties of red beryl. A literature review revealed similar, but slightly expanded ranges for refractive indices ( $n_e = 1.560\text{--}1.570$  and  $n_o = 1.567\text{--}1.572$ ) and specific gravity (2.65–2.72), but no other differences in gemological properties (see Nassau and Wood, 1968; Schmetzer et al., 1974; Miley, 1980–1981; Bank and Bank, 1982; Flamini et al., 1983; Hosaka et al., 1993; Harding, 1995). These include the pleochroism ( $\epsilon =$  purplish red,  $\omega$





Figure 11. Some crystals of red beryl from the Ruby Violet mine exhibit sector zoning, as shown here in these two samples. In the 0.23 ct polished crystal section on top, the zoning appears as a triangular orange red interior portion that is surrounded by purplish red. The 0.97 ct crystal on the bottom grew in opposite directions from a central starting point, so it displays this same color zoning as two triangular portions that form an hourglass pattern. Photos by James Shigley.

= orange-red to red), lack of ultraviolet fluorescence, inclusions (described below), and an absorption spectrum displaying a weak 430 nm band plus strong broad bands centered at 500 and 570 nm.

As documented by Shigley and Foord (1984) and shown in figure 11, some red beryl crystals are color zoned with a central cone- or hourglass-shaped area of orange-red surrounded by purplish-red material. The color of faceted stones may vary according to where they were cut in relation to these zones, and is also influenced by the mineral's dichroism (figure 12). As a result of both factors, gemstones cut with the table facet oriented parallel to the c-axis typically appear red or purplish red. Conversely, those cut with the table facet oriented perpendicular to the c-axis tend to appear more orangy red. For maximum yield, the former often are usually given a rectangular shape, while the latter are round or oval.

Almost all red beryl crystals contain fractures and solid, fluid, or fluid-and-gas inclusions, often in such abundance that portions of many crystals are translucent or even opaque. Secondary fluid inclusions occur in isolation or along partially healed fractures ("fingerprints"; figure 13). Fractures sometimes mark the boundaries of the internal color zoning. Hexagonal growth zoning can be seen in some cut stones viewed in a direction parallel to the c-axis (figure 14). Mineral inclusions consist of colorless to white quartz and feldspar, and black grains of hematite or bixbyite (Shigley and Foord, 1984; Aurisicchio et al., 1990). One stone revealed an unusual spray of needle-like tubes that were filled with what is probably goethite (figure 15).

Chemically, red beryl is characterized by relatively high levels of Fe and Mn (generally 1–2 and 0.1–0.3 wt. % oxides, respectively), low contents of alkali elements (<0.4 wt. % Na<sub>2</sub>O and <0.2 wt. % K<sub>2</sub>O), and the near-total absence of water (Nassau and Wood, 1968; Shigley and Foord, 1984; Hosaka et al., 1993). Platonov et al. (1989) attributed the colors of both red beryl and pink morganite to Mn<sup>3+</sup>, and suggested that this ion occupies different sites in the crystal structure of these two beryl varieties. Dr. G. Rossman (pers. comm., 2003) speculates that the Mn<sup>3+</sup> was incorporated into red beryl during crystallization, whereas in morganite and pezzottaite (Hänni and Krzemnicki, 2003; Simmons et al., 2003; Laurs et al., 2003) it was produced from the oxidation of Mn<sup>2+</sup> due to exposure to natural ionizing radiation after the minerals had crystallized in granitic pegmatites.

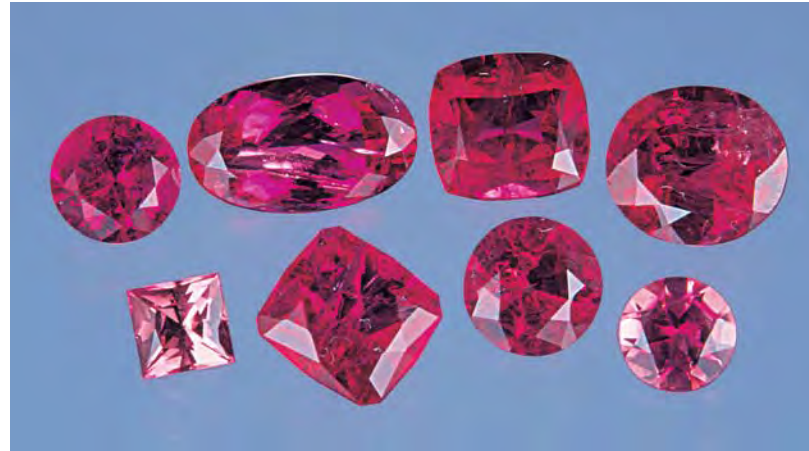


Figure 12. Faceted red beryl exhibits colors from orangy red to red to purplish red, as a result of color zoning present in many of the gem crystals and beryl's dichroism. The stones shown on the left (0.78–1.39 ct) are from a collection that was donated to GIA by Rex Harris and Michael and Tina Nielson of Red Beryl Inc., Delta, Utah. Those on the right weigh 0.22–1.09 ct, and are courtesy of Dominique Merz. Photos by Maha Tannous.

Red beryl is not treated by heating or irradiation. Furthermore, because it is nearly anhydrous, it can be heated to temperatures that could damage emerald or other beryls, as might accidentally happen during jewelry repair (R. Harris, pers. comm., 2002). Since much of the material is naturally fractured, crystals and faceted stones are commonly treated with colorless substances such as paraffin wax, Opticon, cedarwood oil, and Canada balsam to improve their apparent clarity. However, most clarity treatment done today uses Arthur Groom's Gematrat epoxy resin filler (R. Harris, pers. comm., 2003; see also Weldon, 1998).

The gemological properties of red beryl distinguish it from other natural red gems such as ruby, garnet, spinel, zircon, and tourmaline, all of which have higher refractive indices and other significant differences. Beginning in the mid-1990s, a hydrothermal synthetic red beryl from Russia became commercially available. However, it can be readily separated from its natural counterpart on the basis of its crystal shape, inclusions and other internal features, absorption spectra, and chemical composition (Henn and Milisenda, 1999; Shigley et al., 2001; Fumagalli et al., 2003).

Figure 13. "Fingerprint" inclusions such as the one shown here are typical of red beryl. Photomicrograph by James Shigley; magnified 20 $\times$ .



Figure 14. This 1.02 ct orangy red round brilliant exhibited hexagonal growth zoning when viewed down the c-axis. Photomicrograph by James Shigley; magnified 10 $\times$ .



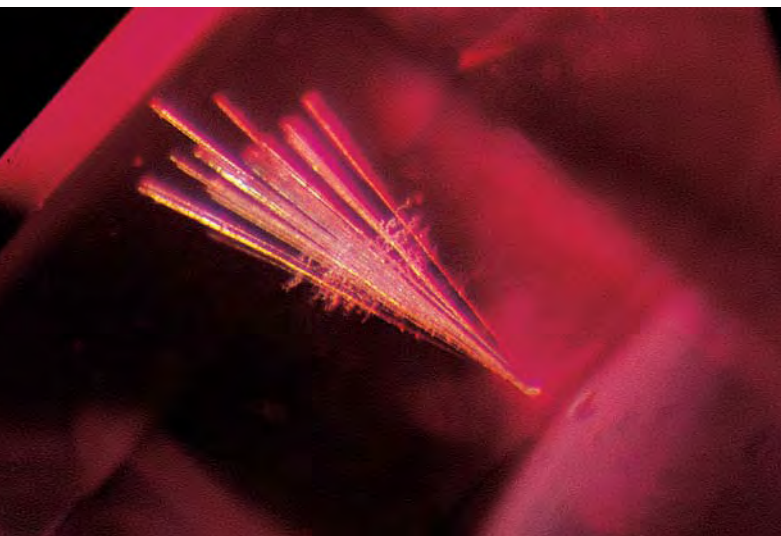


Figure 15. An unusual spray of needle-like tubes formed an interesting inclusion in this red beryl. These tubes are filled with an alteration mineral that is probably goethite, based on its Raman spectrum. Photomicrograph by John I. Koivula; magnified 40 $\times$ .

#### ABOUT THE AUTHORS

Dr. Shigley is director of GIA Research in Carlsbad, California. Mr. Thompson is a graduate gemologist and an engineering geologist with Intermountain GeoEnvironmental Services in Provo, Utah. Dr. Keith is professor of geology and chairman of the Brigham Young University Geology Department, in Provo, Utah.

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#### CONCLUSION

The formation of gem-quality red beryl at the Ruby Violet mine resulted from a unique set of geologic conditions that occurred within a cooling rhyolite flow due to the reaction along fractures of magma-derived gases, groundwater, and preexisting minerals and volcanic glass in the host rhyolite. Over the past decade, significant projects were undertaken by two mining companies to investigate the potential for large-scale production of red beryl. While this large-scale mining has not continued, these efforts contributed to an increased knowledge of the deposit and recognition of red beryl in the gem trade. At the present time, gem material and mineral specimens are being sold from the inventory of the Harris family, as well as from the GMI stockpile. With the potential of the deposit not fully exploited, further work at the Ruby Violet mine is expected to begin again in the near future.

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