NOTES
· AND ·
NEW TECHNIQUES

BERYL GEM NODULES FROM THE BANANAL MINE, MINAS GERAIS, BRAZIL

By Anthony R. Kampf and Carl A. Francis

Bicolored (aquamarine-morganite) beryl from a 1986 discovery at the Bananal mine is described. Most of the cutting material was of carving grade, but a small percentage of the crystals contained faceting-quality morganite gem nodules. This is the first published report of gem nodules of a species outside the tourmaline group. Much of the Bananal morganite is of a pleasing orange to pink-orange color that changes to pink on extended exposure to heat or sunlight. The inclusions in the nodules appear to be limited to muscovite crystals, while the rest of the material (both aquamarine and morganite) contains two- and three-phase inclusions, but little or no muscovite. The cause of the gem nodules is not established, but it may relate to the presence of the same type of variation in mosaic texture observed in some color-zoned tourmaline crystals.

The term *gem nodule* is well known among tourmaline miners and cutters. It refers to a small, typically 2 to 30 mm in diameter, rounded mass of water-clear gem material that occurs in the central portion of an otherwise flawed crystal. In the case of the very gemmy pencil-like crystals of tourmaline, "nodules" may actually be prism sections up to several centimeters long with crudely hemispherical ends. Nodules of both types may be opaque, but interest is focused on transparent nodules which are highly prized as cutting material. Occasional references to gem nodules have been made in the gemological and mineralogical literature (e.g., Shepard, 1830; Sinkankas, 1955, 1959; Dietrich, 1985; Proctor, 1985; and Francis, 1985), but gem nodules have heretofore not been reported outside of the tourmaline group. Recently, however, a new find of gem-quality beryl in Minas Gerais, Brazil, has yielded a number of fine gem nodules.

OCCURRENCE

In January 1986, a group of miners made a significant discovery at the Bananal mine, near Salinas, Minas Gerais, Brazil. From a single pocket they recovered about 500 kg of bicolored (aquamarine-morganite) beryl crystals and crystal fragments. Because the pegmatite had been thoroughly altered to kaolinite, the material was recovered by wet sieving (C. Barbosa, pers. comm., 1988). Most of the crystals were moderately to heavily included; yet, according to Michael Ridding (pers. comm., 1989), about 100 kg were excellent carving rough (see figure 1). More importantly, a number of gem nodules of faceting quality were recovered. A

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Figure 1. This Bananal morganite carving depicts four faces of the Egyptian queen Nefertiti. The carving, designed and executed by the firm F. A. Becker, Idar-Oberstein, Germany, weighs 610 ct and is 5 cm tall. Courtesy of Ramsey Gem Imports, Inc.; photo by Shane McClure.

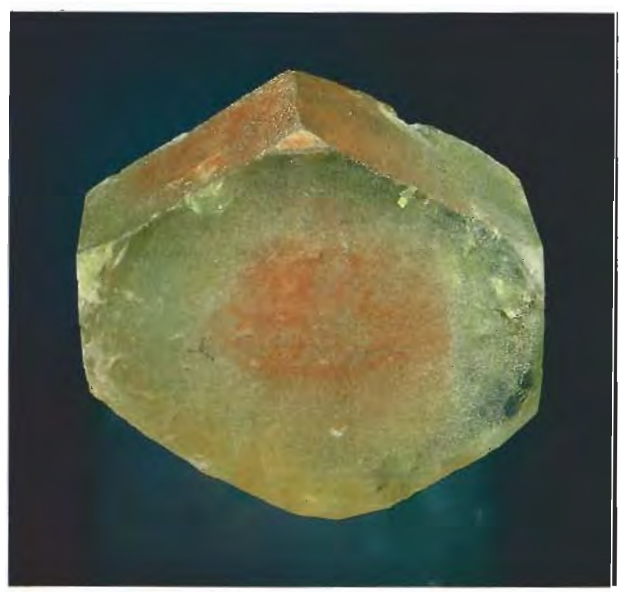
discovery of about 400 kg of similar bicolored beryl was reportedly made at this mine in the early 1960s (Koivula and Misiorowski, 1986). This material apparently corresponds to the orange beryl that Sinkankas (1981) mentioned. It is not clear whether gem nodules were found at that time, but at least some of the material from the earlier discovery was of faceting quality.

DESCRIPTION

The Bananal mine beryl gem nodules occur at the centers of tabular, bicolored crystals. The rims of the crystals are a pale to medium green to blue-green aquamarine, while the cores are morganite commonly of a distinctly orange hue. A few crystals with a complete set of hexagonal prism faces and a basal termination were found (figure 2), but most of the material recovered was in the form of partial crystals and irregular fragments. The relatively complete crystals have diameter-to-thickness ratios of about 2 to 1 and rim-to-core radius ratios between 1 to 2 and 1 to 4. The largest crystal observed by the authors (figure 3) is 18.5 cm across, but most are fist size or smaller. The morphology is simple, with the basal pinacoid {001} and prism {100} predominating, and the dipyramid {112} sometimes also present. Surface etching is quite common, giving the crystals a frosted appearance. A few crystals, including the large one noted above, have lustrous faces. The external features of the crystals are consistent with crystallization in a pegmatite pocket.

The nodules are limited to the morganite portion of the crystals; the nodule surface coincides with the aquamarine-morganite color boundary. As has been generally noted for tourmaline nodules (e.g., Proctor, 1985, p. 97), the more flawed outer portions of these crystals can often be readily broken away to expose the nodules. The crystal in figure 3 possesses an extremely large gem nodule, 12.5 cm in diameter, that is quite clear except for inclusions of muscovite with occasional trails of minute bubbles. Muscovite inclusions are characteristically present in most of the faceted stones and facetable rough from this occurrence, and the only facetable material was in the gem nodules (J. Ramsey, pers. comm., 1988). The largest

Figure 2. This beryl crystal from the Bananal mine exhibits the basal pinacoid {001}, prism {100}, and dipyramid {112} forms. Note the frosted faces which have resulted from surface etching. The crystal is 11 cm across. Courtesy of Hyman and Beverly Savinar; photo © Harold & Erica Van Pelt.



fine faceted stone from this discovery, 461 ct, contains the muscovite inclusion in figure 4.

The aquamarine rind of the large crystal is much more heavily flawed than the nodule. Many two- and three-phase (liquid-gas and solid-liquid-gas) inclusions and internal basal cleavage fractures were observed. These cleavage fractures appear to radiate away from the central nodule, giving the impression of a radiating lamellar texture. This is further reflected by a somewhat lamellar texture on the external cleavage and fracture surfaces. No muscovite inclusions were observed in the rind portion of this crystal.

The vast majority of the crystals recovered did not contain gem nodules (M. Ridding, pers. comm., 1988). The crystal pictured in figure 2, for example, is moderately included throughout, with two- and three-phase inclusions in both the morganite core and the aquamarine rind. Internal basal cleavage fractures were not prominently developed in this crystal, and no muscovite inclusions were observed. It has also been reported that some of the morganite carving material from this occurrence exhibited cloudy or hazy areas, apparently the result of numerous minute inclusions of unknown identity (M. Ridding, pers. comm., 1988).

It is not uncommon for the larger faceted morganites to exhibit an intense, bright orange color in daylight or fluorescent light and a pink-orange ("padparadscha") color in incandescent light. John Ramsey (pers. comm., 1988) notes that the orange color in the morganite from this occurrence changes to pink of a similar color saturation when the material is exposed to sunlight for an extended period or when it is heated (figure 5). Sinkankas (1981) reported the same behavior in the orange morganite from the earlier production. According to George Rossman (pers. comm., 1988), this is a common phenomenon in morganite: "Millions of years of exposure to the low levels of radioactive potassium in the feldspars and micas of the host pegmatite displaces electrons in the atomic structure of the beryl. The displacement of electrons results in color centers which impart a brown color. The brown color combines with the pink color caused by trace amounts of divalent manganese in the structure, resulting in an overall orange hue. Exposure to sunlight for a few hours is usually sufficient to return the electrons to their original sites, thus eliminating the brown component and revealing the pink color. The pink color will then remain stable under normal conditions."

Figure 3. A morganite nodule is evident in this beryl crystal from the Bananal mine. The entire crystal is 18.5 cm across; the nodule is 12.5 cm in diameter. Courtesy of Hyman and Beverly Savinar; photo © Harold & Erica Van Pelt.

DISCUSSION

In reference to tourmaline nodules, Francis (1985) wrote: "Neither quartz nor beryl, which occur with approximately the same frequency and abundance in the same geological environment, show

Figure 4. This muscovite inclusion was observed in a large fine morganite faceted from a Bananal mine nodule. Photomicrograph by John I. Koivula; magnified 40×.

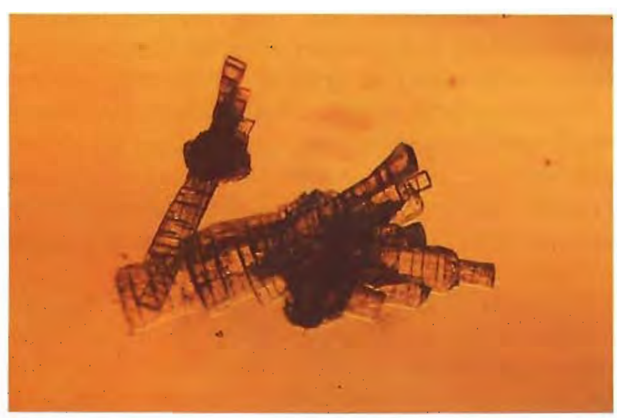


Figure 5. Both of these gems are from the 1986 discovery at the Bananal mine. The 131-ct pink morganite was the same color as the 235-ct pinkish orange stone before exposure to strong Southern California sunlight for approximately one month. Courtesy of Ramsey Gem Imports, Inc.; photo © Tino Hammid.

such nodules nor does any other species known to the writer." In addition to the Bananal beryl nodules described here, several other examples of nontourmaline gem nodules have recently come to our attention. Elvis ("Buz") Gray provided an aquamarine crystal from Raffin Gabbas in the Dgemma region of Plateau State, Nigeria; this 3.5-cm-long crystal is terminated by a basal cleavage plane at the heavily included end and by a gemmy nodule at the opposite end. Mr. Gray also presented small gem nodules of two garnets, a rhodolite from Langusu, Tanzania, and a spessartine from the Little Three mine near Ramona, San Diego County, California. Mr. Gray further reported encountering gem nodules while cutting benitoite from the Benitoite Gem mine, San Benito County, California. Gem nodules are thus known to occur in at least five gem species, two of which (rhodolite and benitoite) formed in environments other than granitic pegmatites. The generality of the phenomenon is thus established, but the genesis of gem nodules has not been explained.

Wagner et al. (1971) studied sections through color-zoned tourmaline crystals by a special X-ray technique known as source-image distortion. This technique is capable of discriminating changes in the texture of the mosaic structure* in single crystals. They determined that "abrupt texture changes are always accompanied by color changes," but that there is "no strict correlation between a particular color and a particular texture." In all of the samples they studied, they discovered that "the core region had a macromosaic** texture containing some small cracks whereas the overgrowth region was composed of lamellar grains." They considered and dismissed several crystal-growth models as explanations for the texture changes. They conjectured that "the texture changes are indicative of some growth parameter such as temperature, pressure, or others."

*Mosaic structure *refers to the fact that all single crystals are actually composed of minute, slightly misaligned crystal "blocks." The misalignment is usually a small fraction of a degree. The fewer the mosaic blocks and the smaller the amount of their misalignment, the more perfect the crystal.* Texture *is used here to refer to the size, shape, and orientation of the minute crystal blocks within parts of the single crystal.*

**Macromosaic structure *refers to a mosaic structure with relatively few randomly oriented microcracks and relatively few only slightly misaligned mosaic grains.*

Although Wagner et al. did not specifically consider or even mention the gem-nodule effect, their study appears to relate directly to this phenomenon. In essence, they found that when a difference in mosaic texture exists between the color zones of a tourmaline crystal, the core of the crystal exhibits less mosaicity and therefore greater crystalline perfection than does the exterior. Their findings are consistent with the typical behavior observed for crystals containing gem nodules: That is, the crystal readily breaks along the boundary between the nodule and the rest of the crystal, and in many instances the outer portion of the crystal breaks away in small fragments to expose the perfectly solid gem nodule core.

The observations made by Wagner et al. appear to fit the gem nodule–containing beryl crystals from the Bananal mine quite well. It is likely that these beryl gem nodules are very similar in nature to tourmaline gem nodules and that their formation resulted from a similar crystal growth variable.

The inclusions contained in the beryl from this occurrence may provide a clue to the origin of the nodules. The muscovite inclusions appear to be limited to the gem-nodule portion of the crystals, while the two- and three-phase inclusions are limited to the non-nodule material. It is widely believed that complex pegmatite formation involves two immiscible fluids, one a silicate melt and the other an aqueous fluid. Growth from an aqueous fluid is likely to yield two- and three-phase primary inclusions, while growth from a silicate melt will generally yield only solid primary inclusions. It is, therefore, tempting to hypothesize that the beryl crystals containing gem nodules were in contact with the silicate melt during that stage of their growth, while the outer portions of the nodule-containing crystals and the crystals without nodules formed in contact with the aqueous phase.

This hypothesis is contrary to the commonly held belief that all well-formed gemmy crystals found in pegmatites have crystallized from an aqueous fluid; however, London (1986) comments that "It appears that pocket-zone aluminosilicate minerals crystallize from hydrous silicate-rich fluids that may be in contact with an exsolving aqueous phase. . . ." It must also be remembered, though, that two- and three-phase inclusions in beryl are commonly secondary, having originated from the intrusion of aqueous solutions along fractures in the crystals. The lack of these inclusions in the Bananal mine nodules could merely reflect the lack of fractures in the nodules.

Without further supportive evidence, the hypothesis above must be regarded merely as conjecture. At any rate, it does not seem to shed light on the formation of gem nodules of nonpegmatitic origin.

SUMMARY

A discovery of bicolored aquamarine-morganite beryl crystals at the Bananal mine in early 1986 yielded much good carving material. A small percentage of the crystals contained morganite gem nodules of faceting grade. This is the first report of gem nodules of a species outside the tourmaline group. Much of the morganite is of a pleasing orange to pink-orange color, reminiscent of material produced from the same mine in the early 1960s. The orange color changes to pink when the material is exposed to heat or sunlight. The inclusions in the nodules are limited for the most part to muscovite crystals, while the rest of the material (both aquamarine and morganite) contains two- and three-phase inclusions, but little or no muscovite. The cause of the gem nodules is not established, but the same type of variations in mosaic texture observed in some color-zoned tourmaline crystals may be responsible.

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