NOTES
· AND ·
NEW TECHNIQUES

WELL-FORMED TSAVORITE GEM CRYSTALS FROM TANZANIA

By Robert E. Kane, Anthony R. Kampf, and Horst Krupp

Green grossular garnet crystals of fine form and clarity have been found recently in Tanzania, at the Karo pit of the tanzanite mining belt. Although the crystals tend to be relatively light in color, they are consistent in gemological properties and composition with the grossular variety popularly known as tsavorite. The very distinct and complex morphology of these crystals is remarkable. Eight different crystallographic forms have been identified, including one that has never before been recognized for any member of the garnet group.

Since early 1987, small amounts of gem-quality green grossular garnet (tsavorite) crystals (figure 1) have been recovered from pockets at the Karo tanzanite pit in the Merelani* Hills of Tanzania. The Merelani Hills are located south of Arusha and just west of Kimoingan Mountain. The area referred to locally and in the trade as the original tanzanite mine is actually a mining belt about 4 × 1 km which encompasses six major pits (figures 2 and 3). These pits are named after the men who originally filed mining claims on them (listed here in numerical order from one end of the belt to the other): 1 – De Souza pit no. 1, 2 – Ali Juuyawatu, 3 – Papanicolaou, 4 – Karo, 5 – Georgi, and 6 – De Souza pit no. 2. The complex tsavorite crystals discovered at the Karo pit are particularly noteworthy for the perfection of their external crystal form (again, see figure 1). Previously, tsavorite found here and elsewhere was almost exclusively massive (front portion of figure 4). Occasional incompletely developed crystals with extremely crude faces had also been recovered (back specimen in figure 4), but euhedral crystals were virtually unknown.

During a recent visit to Moshi, Tanzania (about 70 km east of the Merelani Hills), one of the authors (H. Krupp) obtained a number of well-formed tsavorite crystals. The largest of these (figure 1) weighs 14 grams and is only very slightly

*Merelani is an anglicized phonic spelling of the local Masai word for a tree common to the area. This spelling was employed by Bridges (1982), while Gübelin and Weibel (1975) used *Miralani*. A third spelling, *Mererani*, may in fact be more accurate. Nevertheless, *Merelani* is used here to avoid further confusion of the literature.

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Acknowledgments: The authors thank George R. Rossman, John Armstrong, and Arthur Chodos, of The California Institute of Technology, for providing the electron microprobe analyses; Campbell R. Bridges, of Bridges Exploration (Nairobi, Kenya), for helpful comments on the manuscript and for providing information on East African tsavorite localities; and Peter and Bobbi Flusser, of Overland Gems, Los Angeles, for making material available for examination.

Gems & Gemology, *Vol. 26, No. 2, pp. 142–148*

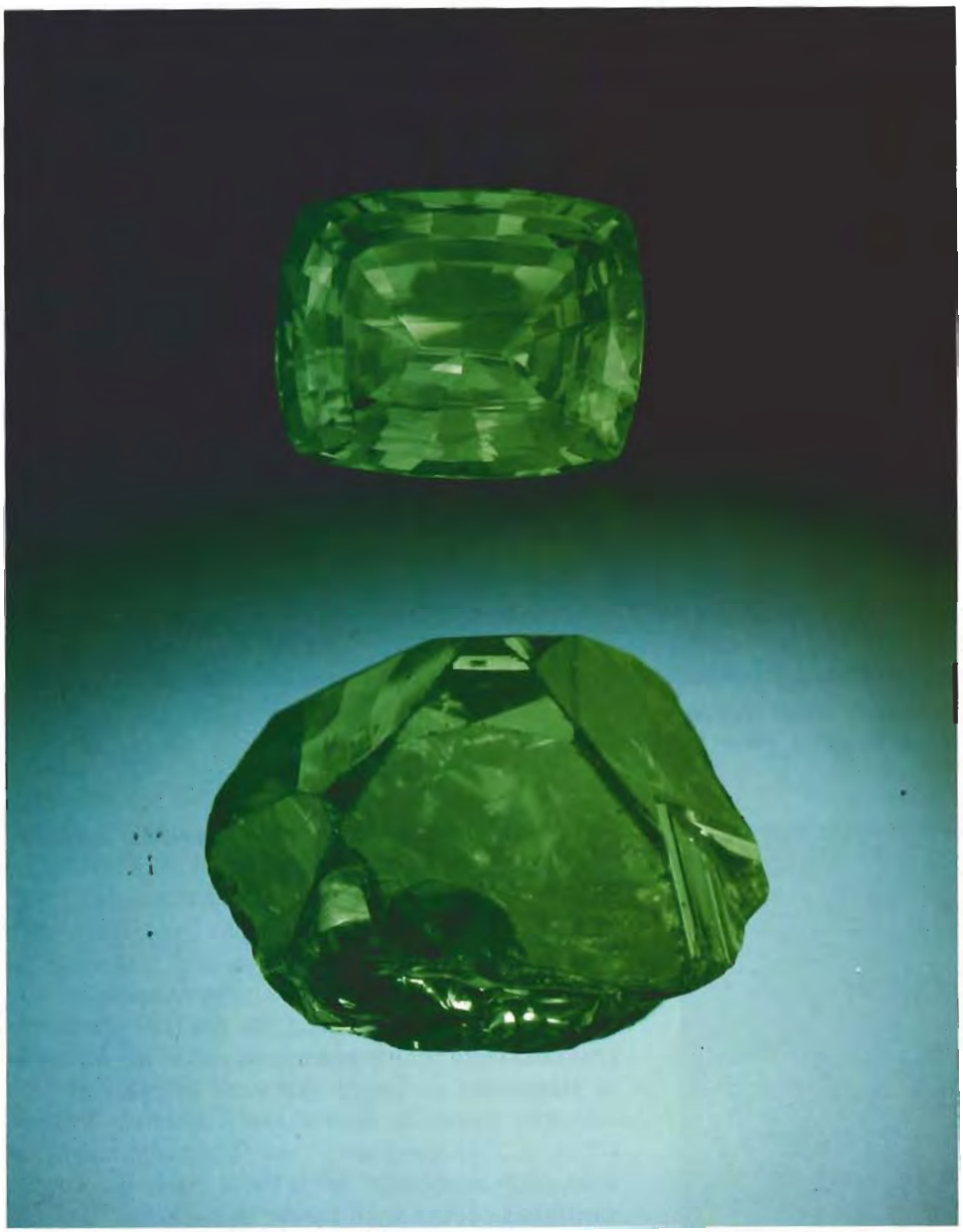


Figure 1. Well-formed tsavorite crystals are exceedingly rare. Recently, the Karo tanzanite pit in the Merelani Hills, Tanzania, yielded this 14-gram crystal and another from which the accompanying 14.84-ct gem was cut. Photo © Harold & Erica Van Pelt.

included. This crystal was used in this study together with a more complete, but also more included, 6-gram crystal and a 10.75-ct pear shape faceted from a Karo-pit crystal. This article describes the occurrence, gemological characteristics, composition, and morphology of the Karo-pit tsavorite crystals.

OCCURRENCE

The gem variety of green grossular garnet known as tsavorite (or, in some areas, tsavolite) was discovered in Tanzania in the late 1960s (Bridges, 1974). Since then, most commercial mining has been based in an area to the south of the Taita Hills in neighboring Kenya known as the Taita/Taveta district (figure 5). According to Gübelin and Weibel (1975), the tsavorite occurs in metamorphic rocks consisting primarily of graphite-bearing gneisses and marbles. It is generally found in rounded forms up to fist size (locally called "potatoes"), which have an interior of more or less fractured tsavorite surrounded by a shell consisting mainly of epidote and scapolite (again, see figure 4). Some of these masses exhibit crude crystal form, but generally they do not show distinct crystal faces.

Tanzanite and tsavorite are found in very similar geologic environments; although tanzanite and tsavorite generally do not occur in commercial

Figure 2. This general overview shows a small section of the 4 × 1 km tanzanite mine belt in the Merelani Hills, south of Arusha in Tanzania. Photo by Horst Krupp.

quantity or quality at the same deposit, they are often found together. Gübelin and Weibel (1975, p. 402) note that green grossular garnets "varying in hue and shade between bright lime-green and dull dark green . . . are occasionally also seen as accessory minerals in the zoisite (tanzanite) mines in the Miralani Hills." And Bridges (1974) reports that tanzanite occurs as a minor accessory mineral in fragments or larger shattered crystals at the tsavorite mines in Kenya and Tanzania. Bridges (1982, p. 274) also states that "The same clay-like mineral is associated with these pockets [of tanzanite] as occurs with tsavorite pockets."

Bridges (pers. comm., 1989) provided the authors with details of the occurrence of tanzanite and tsavorite at his Scorpion mine in the Taita/Taveta district. In the no. 4 tsavorite ore shoot of this mine, what appears to be bluish zoisite (tanzanite) forms kelyphitic shells of about 1–2 mm thickness

Figure 3. Although some operations, such as this one at Karo, are open pit, 90% of the current mining in the Merelani Hills is underground and involves blasting with dynamite. The miners will continue through the hole shown in the central right portion of this photo until they reach the gem-bearing reef, where they will then begin horizontal tunneling. Photo by Horst Krupp.

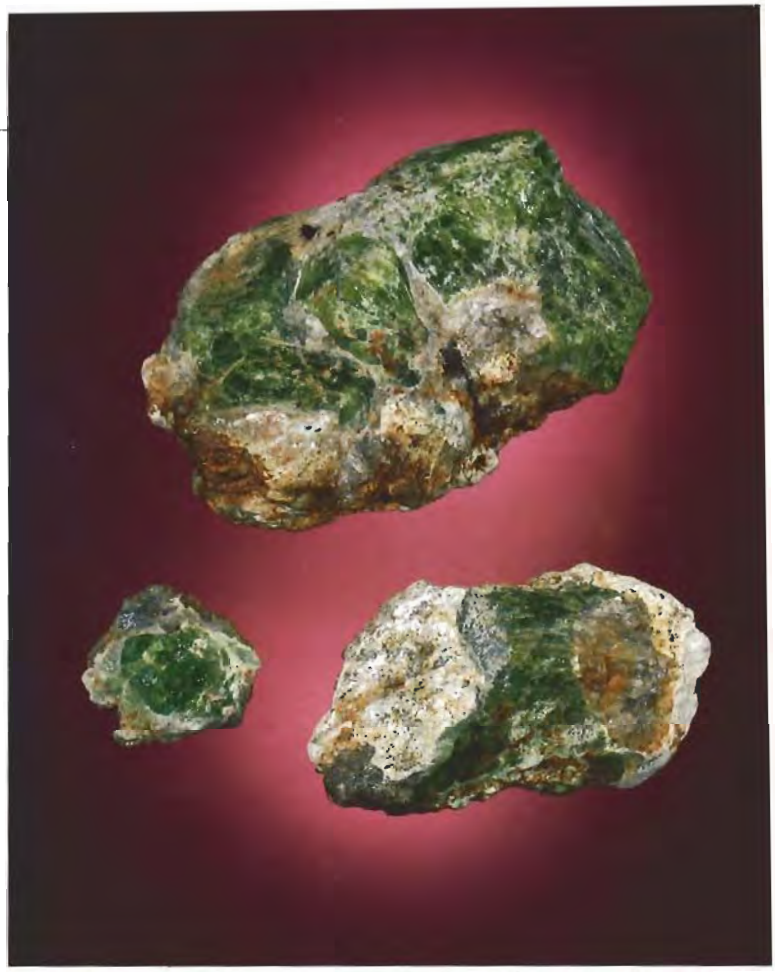


Figure 4. These tsavorite specimens from the Lualenyi mine, Taita/Taveta district, Kenya, are typical of the form in which most tsavorite is found. The specimen at the top (20 cm across) contains large, crudely formed crystals. The two smaller specimens are typical broken "potatoes." Photo by Shane McClure.

around green grossular (tsavorite) nodules. Bridges interprets the tanzanite shell as being the result of retrograde metamorphism. In this ore shoot, compacted crystal groups and individual crystals with a few distinct faces were encountered. Rare examples of crystals with all faces present, but possessing the kelyphitic tanzanite shell, have been found. A parallel ore shoot in this mine contains beautifully colored but badly shattered tanzanite, sometimes in the form of crystals.

One of the authors (H. Krupp) spoke with miners who have worked the tanzanite mine belt in the Merelani Hills. They confirmed that tsavorite has been found there, but usually in small fractured masses, with only a few pockets yielding tsavorite

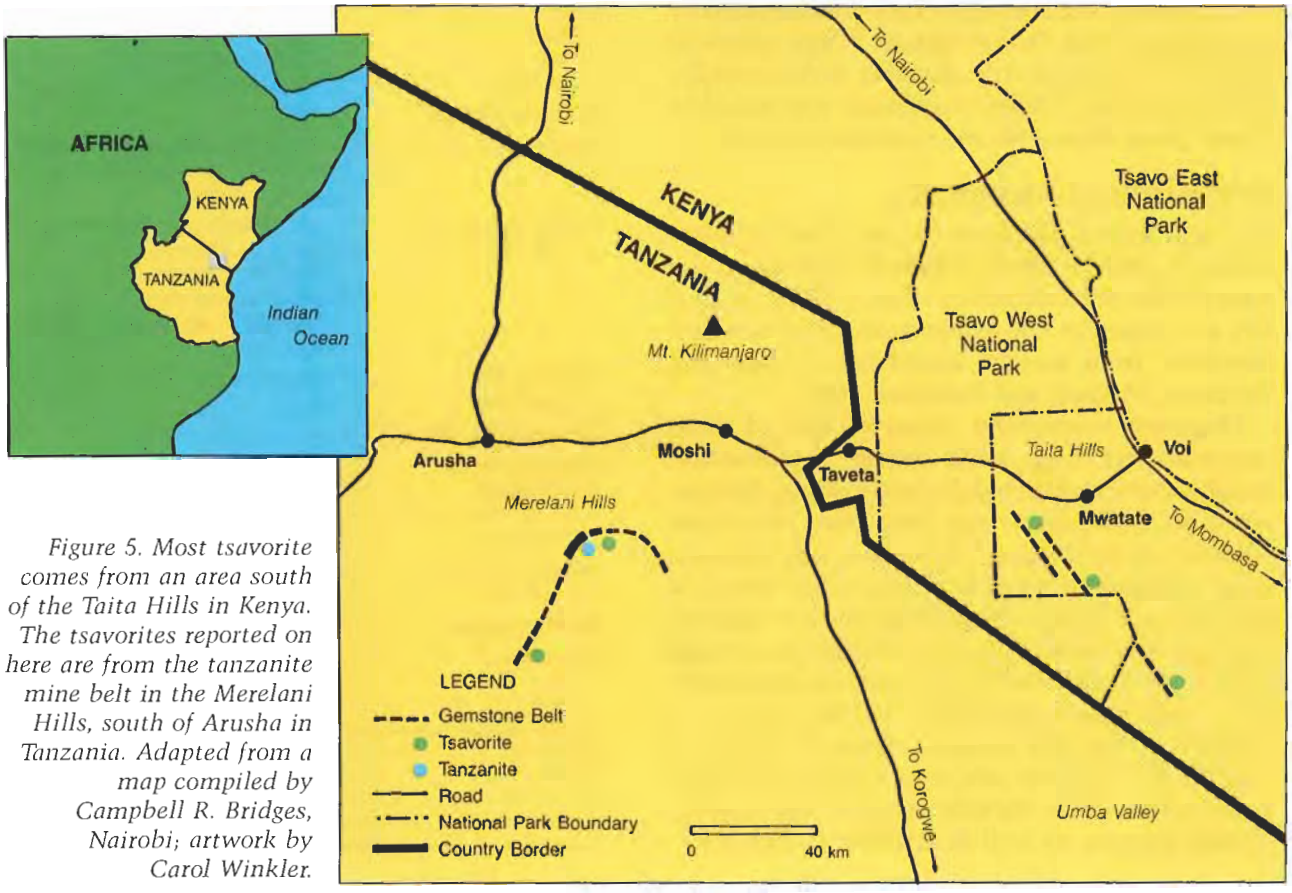


Figure 5. Most tsavorite comes from an area south of the Taita Hills in Kenya. The tsavorites reported on here are from the tanzanite mine belt in the Merelani Hills, south of Arusha in Tanzania. Adapted from a map compiled by Campbell R. Bridges, Nairobi; artwork by Carol Winkler.

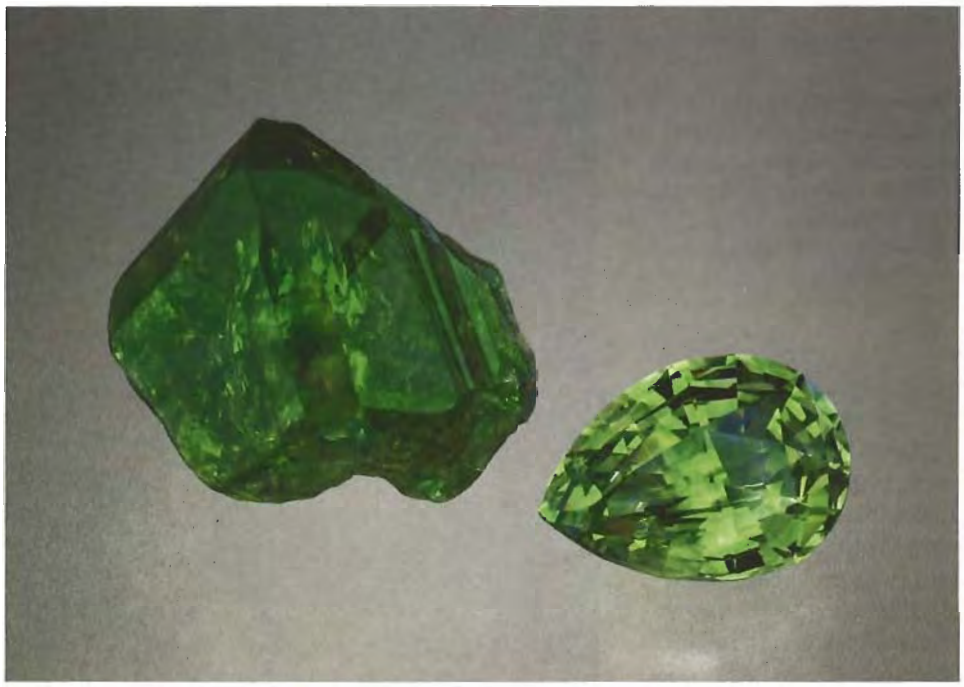


Figure 6. This 5.42-ct faceted tsavorite from the Karo pit was cut from a crystal fragment recovered along with well-formed crystals such as the 6-gram one shown here. Photo © Harold & Erica Van Pelt.

crystals. They did not provide information regarding the quantity or quality of these crystals. Yet no other mining area has produced well-formed, gem-quality crystals of tsavorite.

The well-formed tsavorite crystals examined by the authors were free of matrix. Only traces of graphite were noted still adhering to the crystals; it is not known whether tanzanite was found in direct association with the tsavorite crystals.

GEMOLOGICAL PROPERTIES

The gemological properties of the 6-gram crystal (figure 6) and the 10.75-ct faceted stone from the Karo pit are summarized in table 1. These properties are generally consistent with those of other tsavorites from various localities in Kenya and Tanzania (Manson and Stockton, 1982).

The most noteworthy characteristics of these tsavorites are their weak orange transmission luminescence and their dull chalky orange fluorescence to both short- and long-wave ultraviolet radiation. In the authors' experience, this behavior is not often observed in tsavorite; when it is, it is generally restricted to material with a light to medium-light tone similar to the Karo-pit crystals.

Although these tsavorite crystals are notable for their high degree of clarity, we did observe a number of internal features, none of which is unusual for tsavorite (see, e.g., Gübelin and Koivula, 1986). These include straight and angular growth features, as well as graphite inclusions.

TABLE 1. Gemological properties of tsavorite found as well-formed crystals at the Karo pit, Merelani Hills, Tanzania.[a]

Color	
Hue	Slightly yellowish green
Tone	Light to medium light
Saturation	Moderately strong
Refractive index	1.737
Polariscope reaction	Single refraction, with a weak to moderate anomalous-double-refraction effect
Optical absorption spectrum[b]	Broad absorption blocking out all of the violet and most of the blue portions of the spectrum and a broad diffuse band of weak intensity at approximately 580–610 nm
Transmission luminescence	Weak orange
Chelsea color filter	No reaction
Fluorescence to U.V. radiation	
Long-wave	Moderate dull chalky orange
Short-wave	Very weak dull chalky orange
Phosphorescence to U.V. radiation	None
Specific gravity[c]	Approximately 3.58
Microscopy	Straight and angular growth features; graphite inclusions

[a]Properties listed were obtained from one rough crystal weighing 6 grams and one faceted mixed-cut pear shape weighing 10.75 ct.
[b]As observed through a GIA GEM Instruments fiber-optic spectroscope unit with a Beck prism spectroscope.
[c]Determined by the hydrostatic weighing technique.

CHEMICAL COMPOSITION

The composition of tsavorite from Kenya and Tanzania has been studied by many workers (Switzer, 1974; Gübelin and Weibel, 1975; Amthauer, 1975; Schmetzer, 1978; Bank et al., 1979; Manson and Stockton, 1982; Schmetzer and Bank, 1982). All have reported a composition close to that of pure grossular, but with significant quantities of V_2O_3 and, usually, lesser quantities of Cr_2O_3. The green color has been attributed to V^{3+} and/or Cr^{3+}, and it has been observed to vary in intensity with the amounts of these chromophores present.

Analysis of the 6-gram crystal on an electron microprobe yielded the chemical composition shown in table 2. This is similar to those determined for tsavorites by the other researchers cited above. The amounts of Cr_2O_3 and V_2O_3 determined, 0.05 and 0.19 wt.%, respectively, are toward the low end of the ranges reported in the other studies. This is consistent with the relatively light tone exhibited by the cut stone and crystals examined.

TABLE 2. Chemical composition[a] of a 6-gram tsavorite crystal from the Karo pit, Merelani Hills, Tanzania.

Oxide	Weight %[b]
SiO_2	40.33
TiO_2	0.28
Al_2O_3	22.49
V_2O_3	0.19
Fe_2O_3	0.26
Cr_2O_3	0.05
MgO	0.02
CaO	37.16
MnO	0.27
TOTAL	101.05

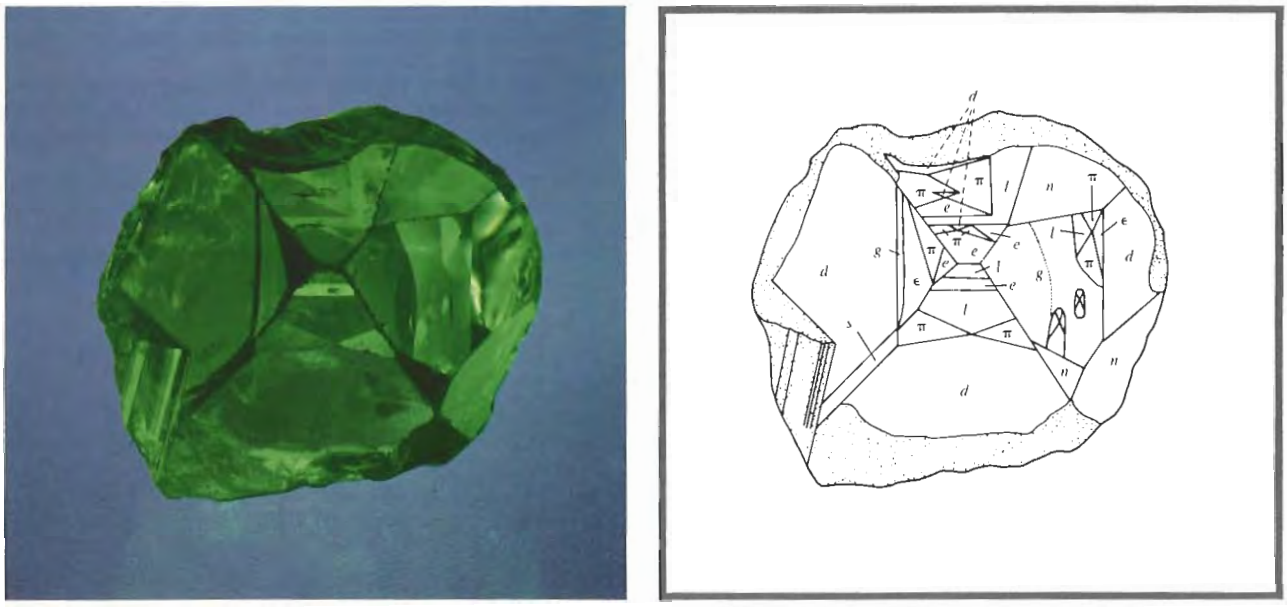
[a] *Analyses were performed on a JEOL 733 microprobe operating at a beam accelerating potential of 15 kV, a current of 35 nA, and spot size between 10 and 25 μm. The data were corrected using the program CITZAF (Armstrong, 1988), employing the absorption corrections of Armstrong (1982), the atomic number corrections of Love et al. (1978), and the fluorescence corrections of Reed (1965), as modified by Armstrong (1988). Paul Carpenter, California Institute of Technology, analyst.*

[b] *Average of five point analyses.*

CRYSTAL MORPHOLOGY

The most remarkable aspect of the tsavorite crystals described here is the perfection of their faces (figure 7). Heretofore, even a crude face on a tsavorite fragment was considered unusual. The distinctness and high luster of the faces on these crystals enabled us to measure precisely their

Figure 7. In this top view of the 14-gram tsavorite crystal shown in figure 1, all 39 of the faces measured on this crystal—and labeled in the accompanying crystal drawing—can be seen. The crystal forms noted are: d *{011}*, e *{012}*, g *{023}*, l *{035}*, ϵ *{045}*, n *{112}*, s *{123}*, *and* π *{1·10·16}*. *Photo © Harold & Erica Van Pelt.*



complex morphology with a Huber two-circle optical goniometer.

Both the 6- and 14-gram crystals were found to exhibit the same crystallographic forms (sets of equivalent faces), although the relative development of these forms differed somewhat between the two crystals. A total of eight forms were found. The labels and Miller indices of these forms are as follows: *d* {011}, *e* {012}, *g* {023}, *l* {035}, ϵ {045}, *n* {112}, *s* {123}, and π {1·10·16}.

The eight crystallographic forms have been noted on the appropriate faces in the drawing of the 14-gram crystal that appears in figure 7. The three growth hillocks on the large *g* face are composed of the same group of faces, which is labeled only on the largest of the hillocks. A total of 39 faces were measured on this crystal, and the crystal is less than half complete.

Of special note is the presence of faces corresponding to the π {1·10·16} form. To our knowledge, this crystallographic form has never before been reported for any member of the garnet group.

CONCLUSION

Unlike most other facetable gem minerals, tsavorite generally does not occur in well-formed crystals. The tsavorites documented here from the Karo pit of the tanzanite mine belt, Merelani Hills, Tanzania, are extraordinary for the perfection of their faces. From a crystallographic point of view, these samples are even more remarkable for prominently exhibiting the π {1·10·16} crystal form, which has never before been reported for any member of the garnet group.

Although stones faceted from the green grossular crystals described here are generally less intense in color than is considered optimal for tsavorite, their chemical composition and gemological properties are consistent with those of previously studied tsavorites.

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