NEW RUBIES FROM THE MOROGORO AREA, TANZANIA

By H. A. Hänni and K. Schmetzer

The authors present the mineralogical and gemological properties of rubies found recently in the Morogoro area of Tanzania that have many features in common with rubies from Myanmar (Burma) and other comparable marble-type deposits. Specifically, microscopic investigations of these Morogoro stones revealed some internal characteristics that are also seen in Burmese rubies—such as angular growth zoning, curved growth zoning ("swirls"), negative crystals, spinel crystals, rutile needles, and clouds of minute particles in areas defined by both types of growth zones, which may also be related to color zoning. However, the Morogoro material appears to have (1) lower amounts of V and Ga than Burmese rubies, and (2) a characteristic angular growth with r, a, *and* r' *faces. A gemological comparison of the recently produced Morogoro rubies with rubies found earlier in this area shows significant differences.*

ABOUT THE AUTHORS

Dr. Hänni is director of the Swiss Gemological Institute (SSEF), Zurich, and associate professor of gemmology at Basel University. Dr. Schmetzer is a research scientist residing in Petershausen, near Munich, Germany.

Acknowledgments: The authors are grateful to W. Spaltenstein, of Bangkok, Thailand, for providing the Morogoro specimens examined; to R. Guggenheim and M. Düggelin, of Basel University, Switzerland, for peforming the SEM-EDS analyses; and to H.-J. Bernhardt, of Ruhr-Universität Bochum, Germany, and H. Schwander, of Basel University, for the microprobe analyses.

Gems & Gemology, Vol. 27, No. 3, pp. 156–167.

In June 1987, one of the authors first received samples of gem-quality spinels from an apparently new source. The red, orange, reddish purple, purplish blue, and blue spinels reportedly originated from the Morogoro area in Tanzania. Physical, chemical, and spectral characteristics of the spinels were found to be within the range of natural gem spinels from classic localities such as Myanmar (Burma) and Sri Lanka (see, e.g., Schmetzer et al., 1989). Microscopic examination revealed the presence in about 70% of the samples of a characteristic feature that had not previously been noted in spinels: intersecting, doubly refractive, thin lamellae of what was later determined to be högbomite (Schmetzer and Berger, 1990), oriented parallel to the octahedral faces of the host spinel crystals.

Several parcels of rough and faceted stones subsequently examined were found to contain a high percentage of material with these högbomite lamellae, which suggested that the samples originated from a common source. All but one of the independent dealers who showed us these parcels cited the Morogoro area of Tanzania as the origin of the gem spinels (see also, Bank et al., 1989).

In the course of examining parcels of these spinels, the authors identified several samples of ruby; in fact, approximately 10% of the stones in these large "spinel" parcels were determined to be ruby or "light ruby."*

The two superficially similar minerals—rhombohedral ruby crystals and octahedral spinel crystals—were generally identified as two different materials before cutting. However, some dealers did not know that their spinel parcels contained facetable rubies, some of good to excellent quality (figure 1).

In recent months, significant quantities of Morogoro rubies of the type described here have been seen in the trade (E. Fritsch, pers. comm., 1991). According to C. Bridges (pers. comm., 1991), the principal ruby mines within the Morogoro area are the Epanko, Kitonga,

Figure 1. A new find of fine rubies has emerged from the Morogoro area of Tanzania. These cut stones range from 0.51 to 3.31 ct; the rough ranges from 5.65 to 8.55 ct. Photo by Shane F. McClure.

Lukande, Matombo, and Mayote. C. Forge, a French geologist who has visited the region, reports that Matombo is the locality where rubies occur together with spinels (pers. comm., 1991; figure 2).

Initial inspection of the samples using routine gemological methods revealed that they contained some types of inclusions that had long been regarded exclusively as characteristic of Burmese rubies. Because determination of the locality origin of rubies, sapphires, and emeralds is one of the most difficult tasks for gemological laboratories that provide this service, the authors attempted to ascertain definitive criteria that would allow these new Tanzanian rubies to be distinguished from those from Mogok and comparable marble or marble-related deposits.

We also noted that these new Morogoro rubies differ significantly from the largely cabochon-quality rubies that emerged earlier from this same area (Schmetzer, 1986b). Features that distinguish these two types of Tanzanian rubies are also presented in this article.

MATERIALS AND METHODS

More than 60 samples of new material from Morogoro were examined, including approximately 50 rough crystals, 10 faceted stones, and three cabochons. All were taken from the parcels of spinels with distinctive högbomite lamellae that were reported to be from the Morogoro area of Tanzania.

Refractive indices and densities were obtained by standard gemological methods. Seven samples (four rough and three cut), representing the range

* *Editor's note: "Light rubies" (lighter tones and/or lower saturations of red) would be called pink sapphires by the GIA Gem Trade Laboratory, Inc.*

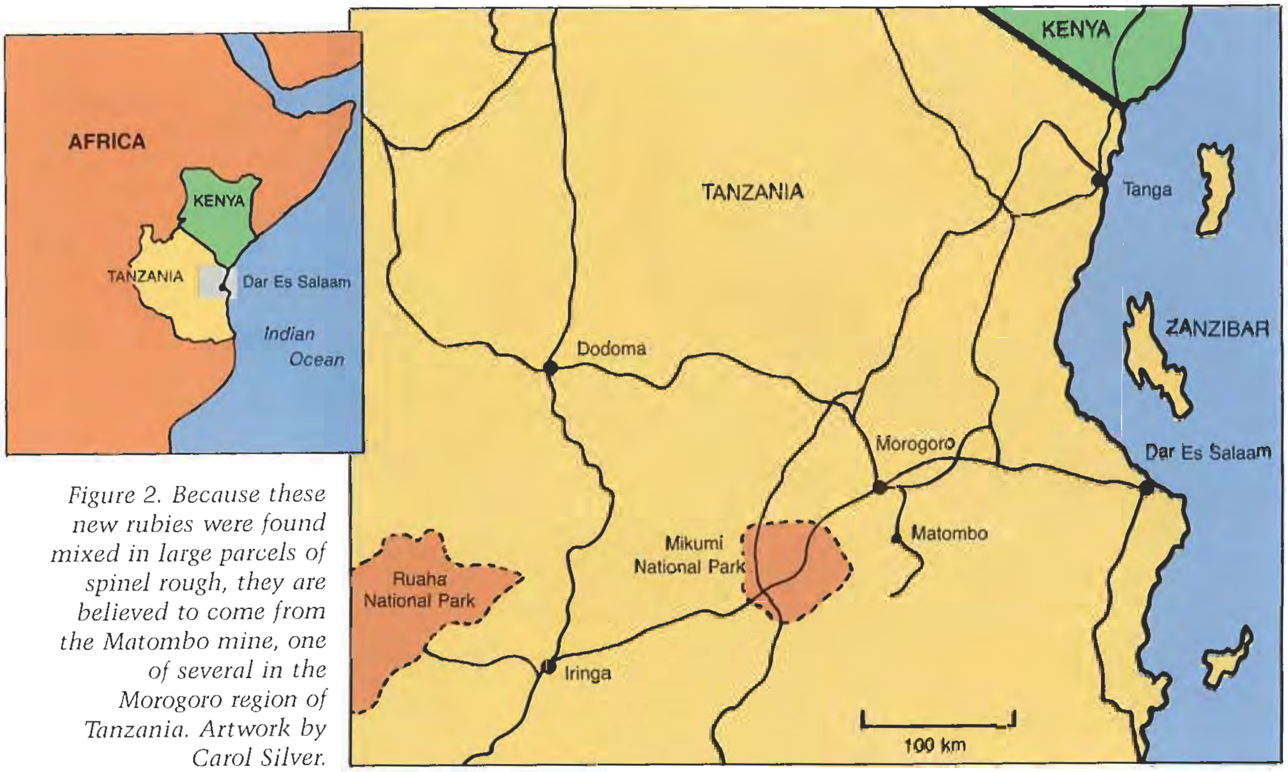


Figure 2. Because these new rubies were found mixed in large parcels of spinel rough, they are believed to come from the Matombo mine, one of several in the Morogoro region of Tanzania. Artwork by Carol Silver.

of typical appearances, were analyzed for trace-element contents by energy-dispersive X-ray fluorescence spectroscopy (Tracor X-ray instrument; operating conditions available on request to the authors). A total of 48 point analyses were performed on three faceted ruby samples with a Cameca Camebax microprobe operating at 15 kV and 15 nA, using wavelength-dispersive spectrometry. Two microprobe analyses of one spinel inclusion were performed with a JEOL JAX-8600 Superprobe with combined energy-dispersive/ wavelength-dispersive spectrometry under operating conditions of 15 kV and 15 nA. Zn was not quantified, but it was determined to be present. Zircon, apatite, and garnet inclusions were identified by qualitative analysis on a Philips SEM 515 with Tracor EDS system. Spectral data in the U.V.–visible range were obtained with Leitz-Unicam SP.800 and Pye-Unicam SP8-100 UV-Vis spectrophotometers, on approximately 20 representative samples.

Indexing of internal and external growth planes was performed on selected samples with a horizontal (immersion) microscope by the methods described in Schmetzer (1986a) and Kiefert and Schmetzer (1991). Photomicrographs were obtained with a Schneider immersion microscope with Zeiss optics and with a Wild-Leitz Stereomicroscope M8 with Fotoautomate MP S 55.

RESULTS

Visual Appearance. The rough samples examined varied from small, mostly elongated, flat to isometrically shaped crystals, and included irregularly terminated rough (figures 1 and 3) The largest piece of rough examined was 20 ct. Diaphaneity varied from translucent to transparent, depending on the relative content of inclusions. When rutile is

Figure 3. These ruby crystals were sorted from parcels of rough spinels that were reportedly from the relatively new find at Morogoro. The largest pieces are approximately 20 ct. Photo by H. Hänni.

Figure 4. Some of the Morogoro stones had sufficient rutile throughout to produce asterism when cabochon cut, as was the case with the approximately 4-ct stone in this ring. Photo by Shane F. McClure.

densely distributed throughout a crystal, asteriated stones may be cut (figure 4). The largest cut stone examined was approximately 4 ct.

Our samples varied from a red of medium saturation to a purplish red of medium to weak saturation. These colors compare favorably to those associated with medium-toned and "light" Burmese rubies.

Although we saw few fully transparent rubies, approximately one-fifth of the rough Morogoro stones we examined were sufficiently transparent for faceting. Most of the material was cabochon quality. However, such stones are commonly heat treated to improve clarity by burning off irregularly distributed rutile silk. Fractured rubies also may be subjected to a type of heat treatment—similar or identical to that used to produce glass-filled cavities in corundum—in which a borate melt fills the voids and, after prolonged heating, acts as a flux that causes a certain recrystallization of fracture planes (as described by Hänni, 1986a and b).

Physical and Optical Properties. We obtained refractive indices of n_o = 1.769 to 1.770 and n_e = 1.761 to 1.762, resulting in a birefringence of 0.008. Densities, determined hydrostatically, were found to vary between 3.99 and 4.01 g/cm^3. These values are typical for rubies from all localities. We observed a strong red fluorescence to long-wave ultraviolet radiation (365 nm), and a weaker red to short-wave U.V. (254 nm); these reactions are identical to those of Burmese rubies. Pleochroism of yellowish red parallel to the c-axis and reddish violet perpendicular to *c* was the same as that for rubies from similar marble-type deposits.

Chemical Properties. Energy-dispersive X-ray fluorescence (EDXRF) analyses (Stern and Hänni, 1982) of five samples revealed the presence of chromium and small concentrations of gallium, iron, and titanium. No vanadium was detected.

Three faceted samples were analyzed by electron microprobe to provide quantitative data on major and trace elements. The results are listed in table 1, along with optical data for the samples. Chromium is the only effective color-causing element observed and thus governs and correlates with the intensity (saturation) of red color. Titanium was present above, while iron and vanadium were found at or below, the limit of detection for the microprobe (approximately 0.02 wt.%). Because Fe and V are very low or absent, they provide no superimposed effect on color in this instance. The small variations in optical values and density

TABLE 1. Optical properties and chemical data for three rubies from the new deposit in the Morogoro area, Tanzania.

	Sample 1	Sample 2	Sample 3
Optical properties and color			
Color	Medium strong red	Medium red	Pink
Refractive indices			
n_o	1.770	1.770	1.769
n_e	1.762	1.762	1.761
Δ n	0.008	0.008	0.008
Electron microprobe analyses[a]			
No. of analyses	14	16	18
Al_2O_3	99.04 – 99.58	99.40 – 99.80	99.46 – 99.79
TiO_2	0.02 – 0.05	0.02 – 0.03	0.02 – 0.04
V_2O_3	$\leq$ 0.02	$\leq$ 0.02	$\leq$ 0.02
Cr_2O_3	0.29 – 0.49	0.21 – 0.37	0.10 – 0.22
Fe_2O_3	$\leq$ 0.02	$\leq$ 0.02	$\leq$ 0.02

[a]*Ranges in wt.%. See text for details of analysis.*

noted above occur because of the minor substitution of aluminum by other elements, especially chromium.

For comparison with the chemistry of rubies from other localities, see Kuhlmann (1983), Schmetzer (1986b), Tang et al. (1988, 1989), and Muhlmeister and Devouard (1991).

Optical Spectroscopy. In the hand spectroscope, Morogoro rubies reveal the typical ruby spectrum without characteristic iron bands. The absorption spectrum as recorded by spectrophotometer (figure 5) is also without any peculiarities. Again, there are no signs of iron in either the visible or the ultraviolet range. The curve in the ultraviolet to blue portion of the spectrum exhibits broad absorption minima at 365 and 480 nm for the *o* vibration and at 350 and 484 nm for the *e* vibration. These spectra are nearly identical to those reported for most Burmese rubies (Bosshart, 1982; Schmetzer, 1985, 1986b). A shoulder near the absorption edge at 315 nm is not always as prominent in the spectra of Morogoro rubies as is shown in figure 5, and may actually be absent.

Microscopic Characteristics. *Growth Features.* Two types of growth zoning were observed in rubies from Morogoro: curved (swirl-like) and straight or angular. Irregular "swirls" that are quite similar to those long associated with Burmese rubies occasionally occur in the Morogoro material (figure 6) and, as discussed elsewhere in this issue (Kane et al., 1991), have recently been observed in Vietnamese rubies as well. These curved growth features, which commonly occur as swirled color zoning, too, are due to complex surfaces (e.g., stepped surface growth or etched, dissolved surfaces) that were subsequently overgrown during crystal formation by layers of corundum of different chemical composition (especially chromium) and/or inclusion content. Such optical inhomogeneities are well known in, and have been considered a typical feature of, Burmese rubies (e.g., Gübelin and Koivula, 1986; Schmetzer, 1986b). Although present in some of the Tanzanian stones, such swirled growth zoning was not observed in the majority of samples examined.

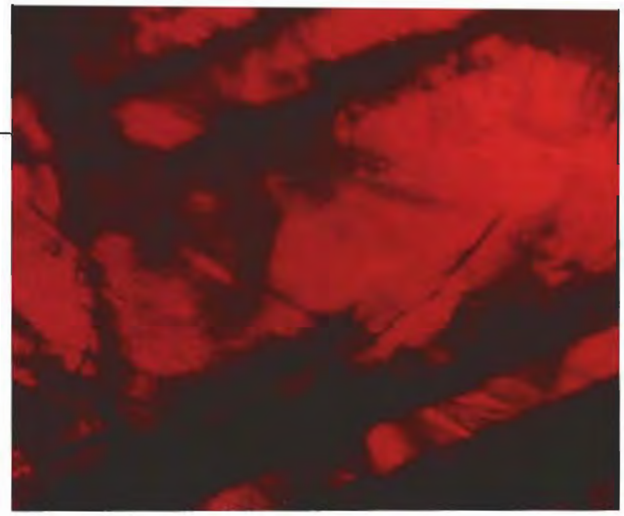
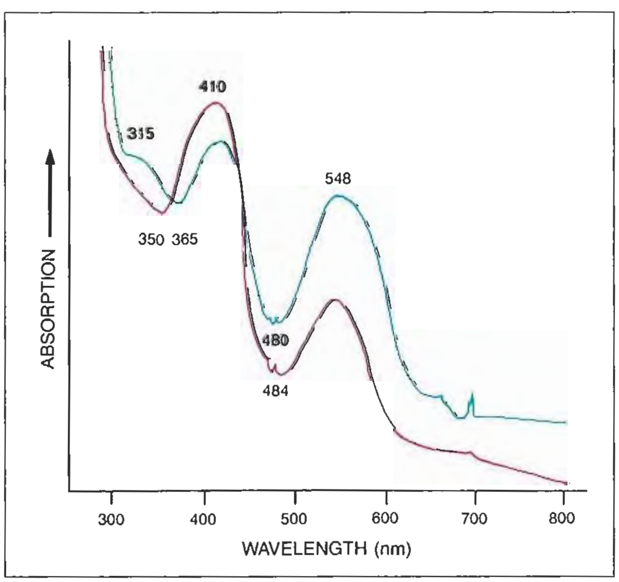


Figure 6. Some of the Morogoro stones revealed swirl-like growth features. Immersion, magnified 50×; photomicrograph by K. Schmetzer.

Figure 5. The absorption spectrum of a Morogoro ruby is typical of that commonly observed in rubies from different localities, especially Mogok or other marble-type deposits.



Most of the Morogoro rubies exhibited combinations of straight growth planes that were observed to lie parallel to the three major morphologic faces *c*, *r*, and *a* (figure 7). These straight or angular layers may differ from one another in chemical composition—and thus, for example, in transparency or color. In these rubies from Tanzania, inclusions are usually concentrated in specific zones defined by these straight or angular growth planes. In addition, most color zoning is related to these same growth features. In fact, we found that angular color zoning parallel to faces *r*, *a*, and *r'* (two rhombohedral and one prism) is characteristic of these Morogoro rubies (again, see figure 7). Less frequently, we observed color zoning parallel to a combination of the two rhombohedral faces *r* and *r'*.

The angle between the faces *r* and *a* equals 137.0° (see Box A, figure A-2, and figure 7), and the

BOX A:
CRYSTAL MORPHOLOGY

We distinguished three predominant shapes of rough: (1) flattened to tabular pseudo-cubes (referred to here as "pseudo-squares"); (2) pseudo-cubes; and (3) corroded, irregularly terminated samples. In all samples examined, the basal plane *c* (0001) and the positive rhombohedron *r* $(10\bar{1}1)$ were observed to be dominant faces (figure A-1a). In some of the samples, six additional subordinate prism faces *a* $(11\bar{2}0)$ were found (figure A-1b); these were sometimes similar or equal in size to the positive rhombohedron *r* and the basal plane *c* (figure A-1c). The angles between rhombohedral faces *r* and *r'* of corundum are 86° and 94°, respectively – very close to a right angle. Rubies with dominant rhombohedral faces, therefore, form cube- to square-like shapes, according to the relative size of the six rhombohedral faces. On one crystal, a small hexagonal dipyramid *n* $(22\bar{4}3)$ was also observed.

In all of the crystals we examined, two of the eight corners of each "cube" are cut off by triangular faces (figure A-1a), the crystallographic basal planes *c*. If parts of the edges of the pseudo-cubes or pseudo-squares are also cut off, the faces of the hexagonal prism *a* are formed. These prism faces form right angles with the basal planes *c* and exhibit lath-like forms (figures A-1b,c).

When two of the eight corners of a pseudo-square or a pseudo-cube are replaced by triangular faces, habits that superficially resemble spinel octahedra are formed (figure A-1a). In other words, the six quadrilateral faces *r* of a corundum crystal without basal faces *c* are altered to pentagonal faces by the addition of two basal pinacoids *c*.

If the crystal faces are of a certain size, fine parallel striations can be seen with the unaided eye or a 10× loupe. These lines represent the traces of narrow twin lamellae of corundum that cut the crystal faces *c*, *r*, and *a*.

Normally, ruby and spinel are easily distinguished with a spectroscope or dichroscope, but this is not always possible. For example, in heavily twinned crystals, which have three sets of lamellae, the dichroic colors of the main crystal may be hidden by the many narrow twin lamellae, which are present in different orientations. Therefore, observation of the traces of protruding twin lamellae (which show up as sets of parallel lines on the crystal faces) or closer examination of the crystal morphology may be helpful in some situations to indicate that a crystal is corundum with rhombohedral habit rather than spinel. Note that the octahedral angle of spinel, at 109.5°, is distinctly different from the rhombohedral angle of corundum, which is 93.9° (figure A-2).

The morphologic characteristics observed in our Morogoro ruby samples have also been described for some Burmese rubies (Bauer, 1896; Melczer, 1902). Tanzanian crystals with rounded shapes and outlines that have a smooth but corroded surface also strongly resemble ruby crystals from Mogok. The only differences that can be cited at present are that the hexagonal dipyramid *n* seems to be more common and/or somewhat larger in Burmese rubies than in those from Morogoro, and that the prism faces *a* may be more dominant or larger in Burmese rubies.

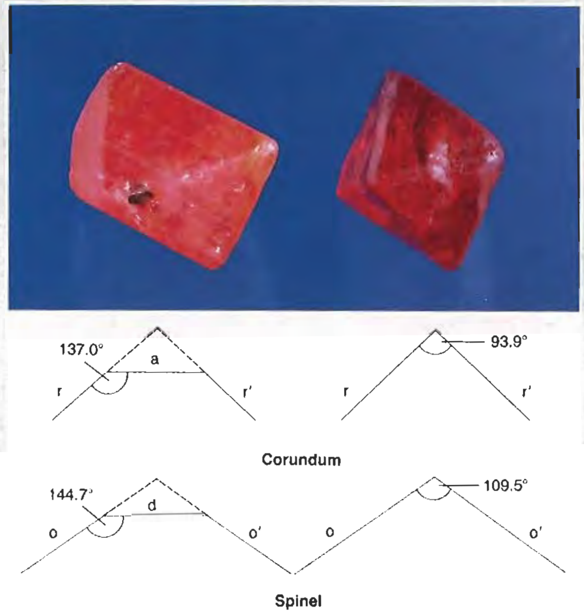
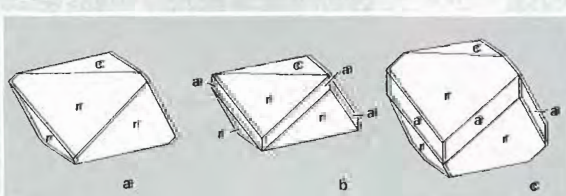


Figure A-2. The characteristic angles of corundum (left in photo), formed by rhombohedral and prism faces, are distinctly different from the characteristic angles of spinel (right in photo), formed by octahedral and dodecahedral faces. Photo by Shane F. McClure.

Figure A-1. The ruby crystals from Morogoro show the basal plane c (0001), the positive rhombohedron r $(10\bar{1}1)$, and the prism a $(11\bar{2}0)$ as dominant crystal faces.



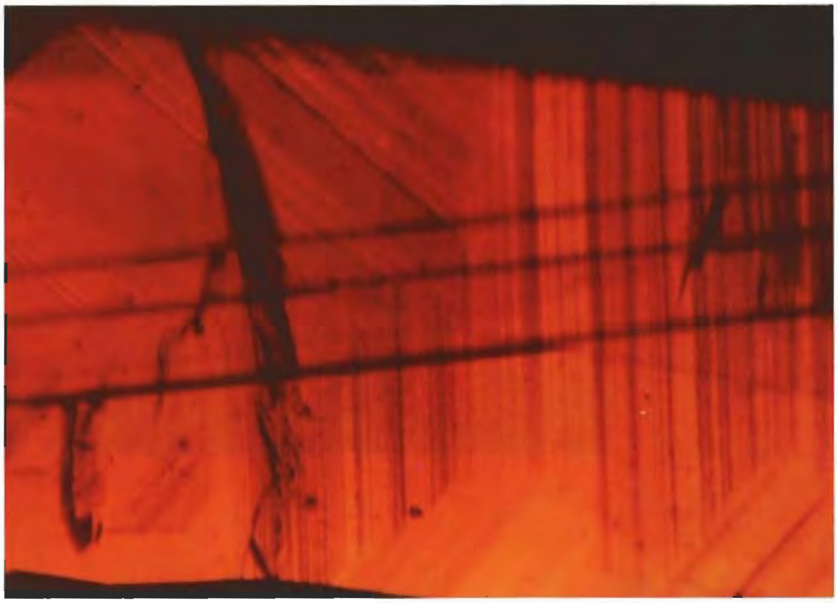


Figure 7. Growth planes parallel to two rhombohedral and one prism face, evident here as straight and angular layers of color, are characteristic of the Morogoro rubies examined. Note also the irregular distribution of what appears to be rutile dust in the growth zones. This growth structure is easily seen in faceted samples as well. Immersion, magnified 40×; photomicrograph by K. Schmetzer.

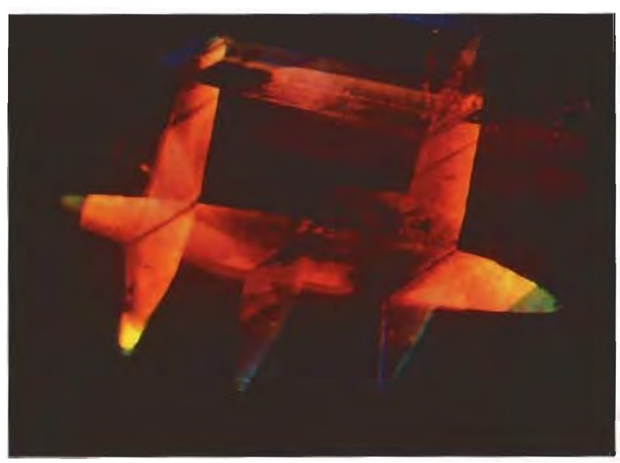
angle between faces *r* and *r′* is 93.9°. In one cut stone, growth structures parallel to *n*, *r*, and *n′*—i.e., with two angles of 154.0°—were observed. Growth planes parallel to two rhombohedral faces and one prism face that form two angles of 137.0° have been, until now, observed only rarely in rubies from other localities, including those from Mogok. Consequently, since this structural feature is encountered very frequently in the type of Tanzanian ruby described here, it can be regarded as characteristic of this locality. It is useful for purposes of identification as well, since it has never been observed in synthetic rubies. These structural differences are useful for distinguishing rough, faceted, or even cabochon-cut samples (Schmetzer, 1986a).

The Morogoro rubies also frequently exhibit narrow twin lamellae oriented parallel to one or, commonly, two or three rhombohedral faces. When these sets of thin lamellae occur parallel to only one rhombohedral face, the interference figure of the ruby commonly looks somewhat distorted, but it is still visible. When there are two intersecting systems of lamellae, the intersection forms a set of relatively coarse, parallel straight lines that can easily be seen with a microscope (figure 8). With twin lamellae present parallel to three rhombohedral faces, there will be three sets of these straight lines intersecting one another at angles of 94° and forming a nearly rectangular, three-dimensional framework.

Since the twin lamellae possess a certain thickness, the portions of corundum that lie in straight lines within the intersections (figure 9) appear as rods with square or rectangular cross-sections. Eppler (1974) referred to these as "inclusions of corundum needles." Schmetzer (1986b) noted that the side walls of these rods are often covered with polycrystalline boehmite (again, see figure 9). Such features are common in rubies and sapphires from several localities that show repeated twinning parallel to more than one rhombohedral face (Hänni, 1987), and provide a quick, conclusive method of separating natural from synthetic stones.

Occasionally, small fissures are confined to

Figure 8. The Morogoro rubies frequently exhibited narrow twin lamellae oriented parallel to one or more rhombohedral faces. Here, two systems of lamellae intersect. Immersion, crossed polarizers, magnified 25×; photomicrograph by K. Schmetzer.



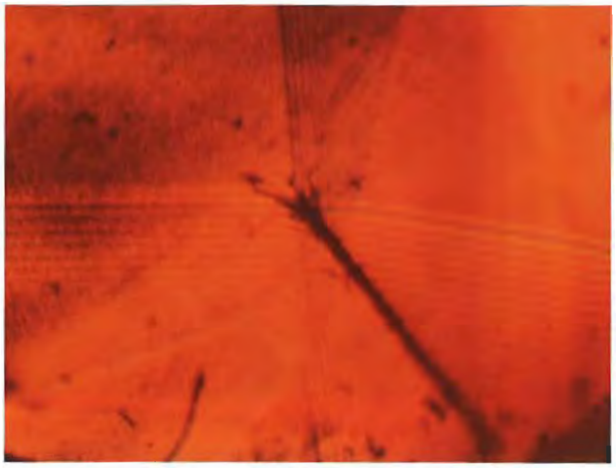


Figure 9. When the stones are viewed with immersion at high magnification (80×), the intersecting lamellae are apparent as coarse, parallel straight lines. In this stone, small boehmite particles can be seen confined to the intersection line of the lamellae. Photomicrograph by K. Schmetzer.

these intersection lines from which they hang like flags on a rope (figure 10). While it is not currently known what causes these fissures, they may arise from stress and strain due to deformation forces applied to the parent rock.

Negative Crystals. Also well known in Burmese rubies is the presence of negative crystals that repeat, in the case of our Tanzanian rubies (figure 11), the externally dominant faces *c*, *r*, and *a*, and thus resemble small octahedral crystals. These inclusions were recognized in Burmese rubies by Eppler (1976) as negative crystals, although they had frequently been mentioned earlier as spinels (e.g., Eppler, 1974).

When examined with the microscope, these inclusions showed a very strong Becke line and, where they were exposed at the surface, were determined to be cavities.

Figure 10. Small fissures were occasionally seen confined to the intersection lines of the twin lamellae, hanging from them like flags. Magnified 20×; photomicrograph by H. Hänni.

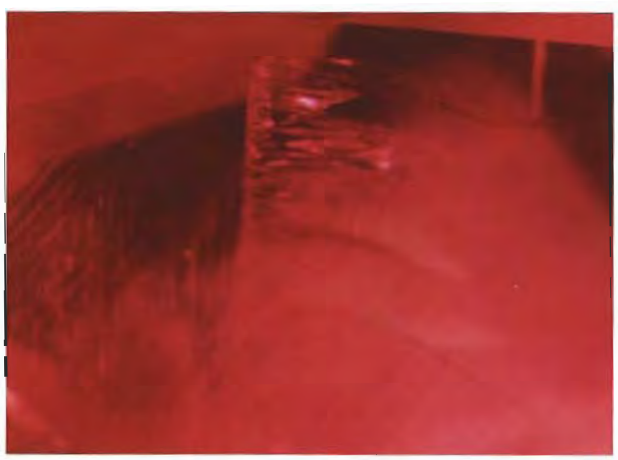


Figure 11. Negative crystals with a rhombohedral habit were observed in many of the Morogoro rubies. Immersion, magnified 80×; photomicrograph by K. Schmetzer.

Rutile. Rutile occurs in various forms in rubies from the Morogoro area. The rutile precipitations appeared near-colorless, probably due to the absence of iron. Typically, fine needles and lancet-like rutile twins were observed (figure 12) and may cause asterism in cabochon-cut stones (figure 13).

In addition, dusty to flaky disseminations, often referred to as clouds, of very fine particles caused turbidity in many of the stones; these may consist of rutile as well (figure 14). These fine inclusions of rutile and/or other particles were concentrated in varying densities and were often seen in growth zones bound by planes parallel to *c*, *r*, or *a* (figures 7, 14). They also occurred in irregularly defined areas, apparently related to a process of alternating growth and dissolution.

Other Mineral Inclusions. Four additional mineral species have, to date, been recognized in the subject gem-quality rubies from the Morogoro area.

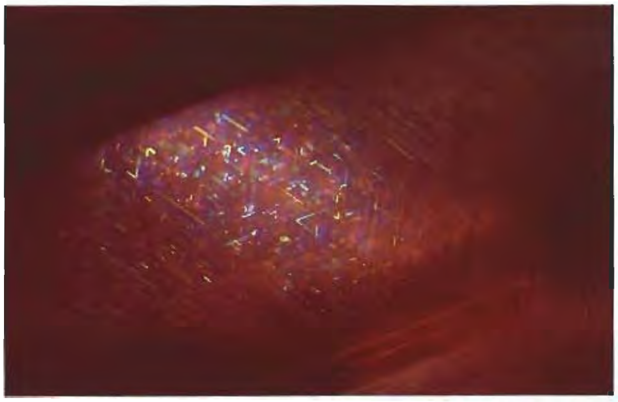


Figure 12. Rutile was commonly present as needles and lancet-like twins in the Morogoro rubies examined. Magnified 20×; photomicrograph by H. Hänni.

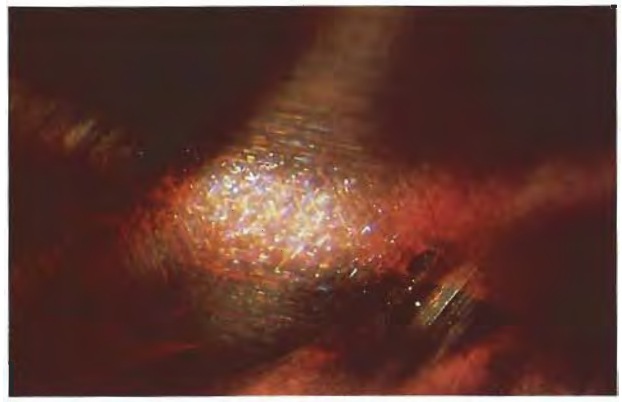


Figure 13. Dense concentrations of rutile inclusions produced asterism in some of the Morogoro stones. Magnified 10×; photomicrograph by H. Hänni.

Spinel crystals were seen that are similar to negative crystals both in octahedral habit and in lack of birefringence. Thus, these small octahedra cannot always be differentiated from negative crystals with a microscope. One of these spinel inclusions was exposed at the surface of a faceted sample and so was examined by electron microprobe (see table 2). Analysis revealed small amounts of Ti, Cr, V, and Fe, in addition to the major elements Mg and Al.

Small prismatic to rounded crystals with tension cracks (figure 15) were identified as zircon by SEM-EDS on the basis of Zr and Si present as the major elements.

Apatite was observed as small prismatic crystals (figure 16) and was identified by the presence of Ca and P as determined by SEM-EDS.

Pyrope inclusions were also identified by SEM-EDS, which detected major components of Si, Al,

Figure 14. Extremely fine inclusions of rutile and/or other particles were concentrated in varying densities and were often, as here, confined to growth zones in the ruby. Immersion, magnified 65×; photomicrograph by K. Schmetzer.

TABLE 2. Electron microprobe analyses of one spinel inclusion in a ruby from the new deposit in the Morogoro area, Tanzania.[a]

Oxide (wt.%)	Analysis 1	Analysis 2	Cations (calculated to O = 4)	Analysis 1	Analysis 2
Al_2O_3	70.46	69.90	Al	2.002	2.000
V_2O_3	0.02	0.02	V	0.000	0.000
Cr_2O_3	0.47	0.36	Cr	0.009	0.007
FeO	0.47	0.54	Fe	0.009	0.011
MgO	27.09	27.00	Mg	0.973	0.977
Total	98.51	97.82		2.993	2.995

[a]See text for details of analysis. Note that Zn was identified as present and estimated in the range of 1–5 wt.% ZnO.

and Mg. In the Morogoro stones examined, pyrope appeared as irregularly shaped to rounded pink grains.

Fluid inclusions were seen in the microscope as primary voids and pseudo-secondary healing feathers. The voids predominantly contain a monophase filling, but two-phase (liquid/gas) fillings, although rare, were also observed.

Unhealed open fissures, usually filled with secondary FeOOH phases that had stained the fissures brownish red, were occasionally observed during microscopic examination.

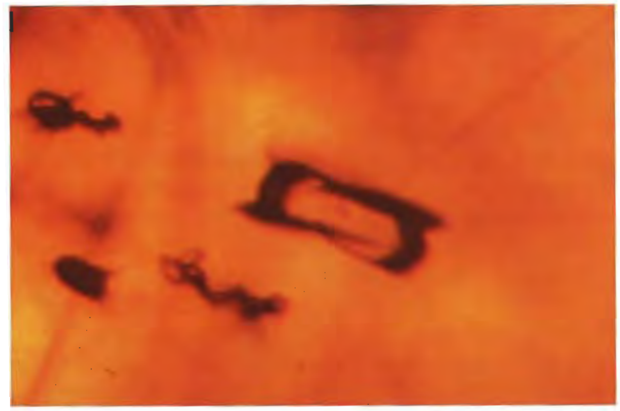


Figure 15. Small prismatic crystals such as this, with tension cracks, were identified as zircon. Immersion, magnified 100×; photomicrograph by K. Schmetzer.

COMPARISON WITH BURMESE RUBY

The rubies from the new deposit at Morogoro are significantly different from the rubies that were found earlier in this general area (Box B). However, a number of key features are common to rubies from Mogok and this new deposit at Morogoro. These include:

- A characteristic color.
- Inhomogeneities in growth zoning parallel to distinct faces, as well as irregular "swirls," both often observed in conjunction with irregular color distribution.
- Sets of thin twin lamellae parallel to one, two, or three rhombohedral faces.
- "Clouds" of rutile needles and/or other disseminated particles.
- Coarse rutile.
- Octahedral inclusions of slightly rounded solid material (spinel) or similar-appearing negative crystals.

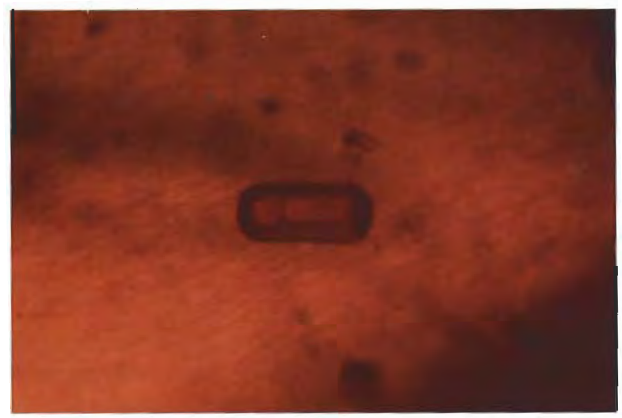


Figure 16. A second type of small prismatic crystal observed in the Morogoro rubies was determined to be apatite. Magnified 50×; photomicrograph by H. Hänni.

These similarities between the rubies from Morogoro and those from the Mogok district are probably due to a similarity in the geologic settings of the two occurrences. The Mogok rubies derive from a dolomitic marble in which red spinels are even more abundant than ruby (Keller, 1983). Tanzanian rubies from the new source in the Morogoro area are also found with an abundance of red and purple spinels. Therefore, it may be conjectured that these Tanzanian rubies also originate from a marble or marble-related parent rock. Other comparable occurrences of rubies and spinels situated in marble include Hunza, Pakistan (Bank and Okrusch, 1976; Gübelin, 1982); and Luc Yen, Vietnam (Weldon, 1991; Kane et al., 1991); gem-quality ruby with similar properties is also known from Nepal (Harding and Scarratt, 1986; Bank et al., 1988).

Characteristics that, to a certain extent, may be used to distinguish the new Morogoro rubies from those of Mogok are summarized as follows:

- Swirl-like growth structures are more frequently observed and more pronounced in Burmese rubies.
- Straight or angular color zoning may be more distinct in Burmese rubies.
- Angular color zoning parallel to the *r*, *a*, and *r'* faces has thus far been seen only in these rubies from Morogoro.

BOX B: COMPARISON OF NEW AND OLDER TYPES OF RUBIES FROM THE MOROGORO AREA

Rubies and pink sapphires from the Morogoro area of Tanzania have been known in the gem trade since the mid-1980s, or even earlier, as reported to us by a number of dealers (Schmetzer, 1986b). The first gemological description of material from this area involved stones that are somewhat different from those described in the present article; descriptions were provided by Schmetzer (1986b), with additional information in papers by Barot (1989) and Bank and Henn (1989). The "earlier" rubies from the Morogoro area are generally of cabochon quality, and most are translucent at best; only a very small percentage are facet grade. The following summary of diagnostic features of this earlier material from Morogoro may be useful:

- The color is usually medium to light red to "pink" with brownish tints.
- The material reveals high iron contents, as evidenced by the iron-related absorption bands at 450, 388, and 376 nm in the visible spectrum.
- Rutile inclusions are absent, although stones in one parcel examined revealed transparent colorless needles, which microprobe analysis proved to be sillimanite or kyanite.
- Neither color zoning parallel to growth planes nor irregular color distribution ("swirls") has been observed.
- Narrow twin lamellae are frequently found, mostly in three directions; these form dense, three-dimensional frameworks of intersecting straight lines.
- Intersecting lamellar straight lines are often confined to boehmite particles, so that the intersecting lines have a lath-like framework.
- Twin lamellae are frequently confined to parallel planes of polycrystalline boehmite.

Consequently, no difficulties arise in distinguishing samples of the older material from those stones discovered more recently at the Morogoro area. Nor does material from the earlier mining operations share any distinctive characteristics with Burma-type stones.

- Growth planes parallel to two rhombohedral faces and one prism face that form two angles of 137.0° are common in Morogoro rubies and rare in those from other localities, including Mogok.
- The presence of two or three systems of twin lamellae is less common in Burmese rubies, which usually have only one such system, as are intersecting straight, parallel lines, or even a three-dimensional framework of lines, which are related to the twin lamellae.
- Vanadium and gallium contents are generally higher in Burmese rubies, as measured by EDXRF (Stern and Hänni, 1982; Hänni and Stern, 1982).

Consequently, it seems evident that an unequivocal determination of origin of rubies from marble deposits can be ascertained only under favorable conditions and may be possible only for certain stones, even by the best-equipped gemological laboratory. Thus, the distinction between Burmese and Tanzanian marble-related rubies will be very difficult for the practicing gemologist.

CONCLUSION

Appreciable amounts of good-color, translucent to transparent rubies have recently emerged from the Morogoro area of Tanzania, possibly the Matombo mine. These rubies share many distinctive features with rubies from the historic locality at Mogok, in Myanmar (Burma). This is an important consideration to certain segments of the trade for whom origin is of critical concern. However, our examination of several Morogoro rubies and innumerable Burmese stones suggests that swirl-like growth features are more frequent, and straight or angular color zoning more prominent, in Burmese stones, while the presence of two or three systems of twin lamellae is more common in the Morogoro material. However, only the Morogoro rubies very frequently show growth features and color zoning parallel to the *r*, *a*, and *r'* faces, forming two angles of 137°. EDXRF analyses of seven samples of the Morogoro material indicate that there are lower amounts of the trace elements vanadium and gallium in the Morogoro stones than in their Burmese counterparts.

The examination of Morogoro rubies reinforces the observation that deposits of quite similar geologic conditions (in this case, marble or marble-related deposits) may be encountered in a variety of localities. The products of such deposits may also be quite similar, as appears to be the case for ruby from Myanmar, Pakistan, Vietnam, Nepal, and Tanzania.

REFERENCES

Bank H., Gübelin E., Harding R.R., Henn U., Scarratt K., Schmetzer K. (1988) An unusual ruby from Nepal. *Journal of Gemmology,* Vol. 21, No. 4, pp. 222–226.

Bank H., Henn U. (1989) Schleifwürdige Korunde von Ngoronghoro, Tansania. *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* Vol. 38, No. 1, pp. 44–46.

Bank H., Henn U., Petsch E. (1989) Spinelle aus dem Umba-Tal, Tansania. *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* Vol. 38, No. 4, pp. 166–168.

Bank H., Okrusch M. (1976) Über Rubin-Vorkommen in Marmoren von Hunza (Pakistan). *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* Vol. 25, No. 2, pp. 67–85.

Barot N.R. (1989) Outlook for world gem production is good. *ICA Gazette,* September, pp. 7–10.

Bauer M. (1896) Ueber das Vorkommen der Rubine in Birma. *Neues Jahrbuch für Mineralogie Vol. 1896, Band II,* pp. 197–238.

Bosshart G. (1982) Distinction of natural and synthetic rubies by ultraviolet spectrophotometry. *Journal of Gemmology,* Vol. 18, No. 2, pp. 145–160.

Eppler W.F. (1974) Über einige Einschlüsse in Birma-Rubin. *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* Vol. 23, No. 2, pp. 102–108.

Eppler W.F. (1976) Negative crystals in ruby from Burma. *Journal of Gemmology,* Vol. 15, No. 1, pp. 1–5.

Gübelin E.J. (1982) Gemstones of Pakistan: Emerald, ruby, and spinel. *Gems & Gemology,* Vol. 18, No. 3, pp. 123–139.

Gübelin E.J., Koivula J.I. (1986) *Photoatlas of Inclusions in Gemstones.* ABC Edition, Zurich.

Hänni H.A., Stern W.B. (1982) Über die Bedeutung des Gallium-Nachweises in Korunden. *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* Vol. 31, No. 4, pp. 255–260.

Hänni H.A. (1986a) Behandelte Korunde mit glasartigen Füllungen. *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* Vol. 35, No. 3/4, pp. 87–96.

Hänni H.A. (1986b) Glass-like fillings in rubies and sapphires. *Swiss Watch and Jewelry Journal,* No. 9, p. 779.

Hänni H.A. (1987) On corundums from Umba Valley, Tanzania. *Journal of Gemmology,* Vol. 20, No. 5, pp. 278–284.

Harding R.R., Scarratt K. (1986) A description of ruby from Nepal. *Journal of Gemmology,* Vol. 20, No. 1, pp. 3–10.

Kane R.E., McClure S.F., Kammerling R.C., Khoa N.D., Mora C., Repetto S., Khai N.D., Koivula J.I. (1991) Rubies and sapphires from Vietnam. *Gems & Gemology,* Vol. 27, No. 3, pp. 136–155.

Keller P.C. (1983) The rubies of Burma: A review of the Mogok stone tract. *Gems & Gemology,* Vol. 19, No. 4, pp. 209–219.

Kiefert L., Schmetzer K. (1991) The microscopic determination of structural properties for the characterization of optical uniaxial natural and synthetic gemstones. Part 1: General considerations and description of the method. *Journal of Gemmology,* Vol. 22, No. 6, pp. 344–354.

Kuhlmann H. (1983) Emmissionsspektralanalyse von natürlichen und synthetischen Rubinen, Sapphiren, Smaragden und Alexandriten. *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* Vol. 32, No. 4, pp. 179–195.

Melczer G. (1902) Ueber einige krystallographische Constanten des Korund. *Zeitschrift für Krystallographie und Mineralogie,* Vol. 35, pp. 561–581.

Muhlmeister S., Devouard B. (in press) Trace element chemistry of natural and synthetic rubies. In A. S. Keller, Ed., *Proceedings of the 1991 International Gemological Symposium,* Gemological Institute of America, Santa Monica, CA.

Schmetzer K. (1985) Distinction of natural and synthetic rubies by ultraviolet absorption spectroscopy – Possibilities and limitations of the method. *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* Vol. 34, No. 3/4, pp. 101–129.

Schmetzer K. (1986a) An improved sample holder and its use in the distinction of natural and synthetic ruby as well as natural and synthetic amethyst. *Journal of Gemmology,* Vol. 20, No. 1, pp. 20–33.

Schmetzer K. (1986b) *Natürliche und synthetische Rubine – Eigenschaften und Bestimmung.* Schweizerbart, Stuttgart, Germany.

Schmetzer K., Berger A. (1990) Lamellar iron-free högbomite-24R from Tanzania. *Neues Jahrbuch für Mineralogie Monatshefte,* No. 9, pp. 401–412.

Schmetzer K., Haxel C., Amthauer G. (1989) Colour of natural spinels, gahnospinels and gahnites. *Neues Jahrbuch für Mineralogie Abhandlungen,* Vol. 160, No. 2, pp. 159–180.

Stern W.B., Hänni H.A. (1982) Energy dispersive X-ray spectrometry: A non-destructive tool in gemmology. *Journal of Gemmology,* Vol. 18, No. 4, pp. 285–296.

Tang S.M., Tang S.H., Tay T.S., Retty A.T. (1988) Analysis of Burmese and Thai rubies by PIXE. *Applied Spectroscopy,* Vol. 42, No. 1, pp. 44–48.

Tang S.M., Tang S.H., Mok K.F., Retty A.T., Tay T.S. (1989) A study of natural and synthetic rubies by PIXE. *Applied Spectroscopy,* Vol. 43, No. 2, pp. 219–223.

Weldon R. (1991) Why the Vietnam reds are giving us the blues. *Jewelers' Circular-Keystone,* Vol. 162, No. 5, pp. 46–48.