PERIDOT FROM TANZANIA

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Peridot from a new locality, Tanzania, is described and compared with 13 other peridots from various localities in terms of color and chemical composition. The Tanzanian specimen is lower in iron content than all but the Norwegian peridots and is very similar to material from Zabargad, Egypt. A gem-quality enstatite that came from the same area in East Africa and with which Tanzanian peridot has been confused is also described.

In September 1982, Dr. Horst Krupp, of Idar-Oberstein, sent GIA's Department of Research a sample of peridot for study. The stone was from a parcel that supposedly contained enstatite purchased from the Tanzanian State Gem Corporation, the source of a previous lot of enstatite that Dr. Krupp had already cut and marketed. Material from the second parcel, however, exhibited no cleavage ·and, during preshaping, displayed hardness characteristics different from those noted in the first parcel of enstatite. Closer examination revealed refractive indices that corresponded more closely to those of peridot than enstatite. These stones reportedly came from alluvial gem deposits in the vicinity of the Usambara Mountains in the Umba district near the Tanzania-Kenya border. While peridot from East Africa has been briefly reported (Bridges, 1982), there has as yet been no detailed documentation of the material in the gemological literature.

DESCRIPTION

The rough material examined by Dr. Manson consists of slightly worn-looking or partly corroded crystals. The crystal surfaces are characterized by varying degrees of frosting typical of alluvial transport. Still in evidence, however, are surficial solution and etch features, which suggest that the material was not carried far.

The 1.37-ct oval-cut stone now in GIA's permanent collection (GIA #13781) is exceptionally transparent and bright, with less yellow than is typical of most peridots. The refractive indices, measured from the table of the stone with a GEM Duplex II refractometer and sodium light, approximate $\alpha = 1.650$, $\beta = 1.658$, and $\gamma = 1.684$, indicating a biaxial positive optic character. The specific gravity, measured hydrostatically, is approximately 3.25.

CHEMISTRY

The Tanzanian peridot was analyzed using a MAC electron microprobe at an operating voltage of 15 KeV and beam current of 0.05 μA. The standards used were periclase for MgO, kyanite for Al_2O_3, quartz for SiO_2, wollastonite for CaO, rutile for TiO_2, chromic oxide for Cr_2O_3, almandine-spessartine garnet for MnO, fayalite for FeO, and nickel oxide for NiO. The data were corrected using the Ultimate correction program (Chodos et al., 1973).

For purposes of comparison, we also selected and analyzed peridots from major known localities: Egypt (Zabargad), Burma, Arizona, Norway, and Mexico (figure 1). The chemical compositions of these stones and the Tanzanian material are listed in table 1. Recent gemological and mineralogical literature on peridots from various localities provides additional information on comparable material (e.g., Burns, 1970; Wilson, 1976; Dunn, 1978; Gübelin, 1981; Steele et al., 1981; and Koivula, 1981).

RELATIONSHIP OF COLOR TO CHEMISTRY

The colors of the Tanzanian and 13 other peridots were determined with the GEM ColorMaster
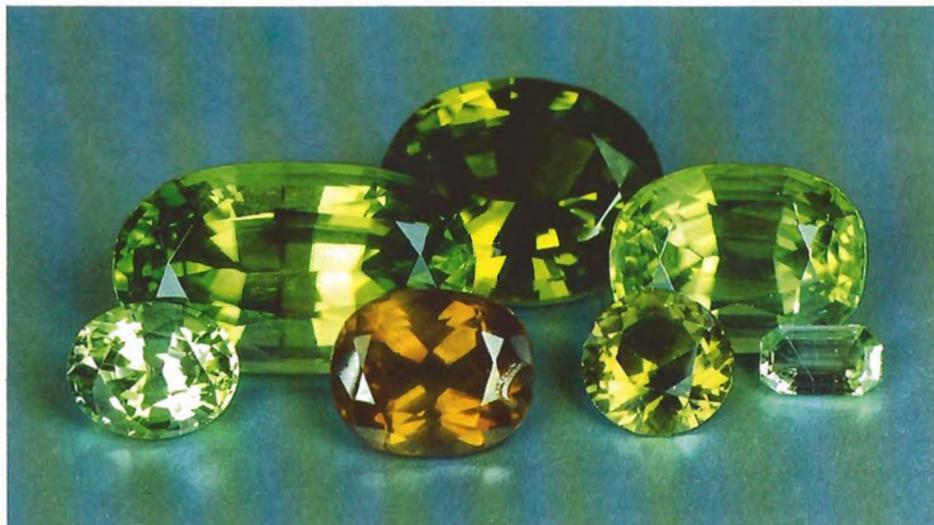

Figure 1. Seven of the peridots studied, representing the range of colors from various localities. These stones are (left to right) from: Tanzania, Burma, Burma, Arizona, Mexico, Egypt, and Norway.

(again, see table 1) and converted to CIE color coordinates. Figure 2 shows the positions of the stones on the relevant portion of the CIE diagram, from which it is evident that the hue of the Tanzanian peridot is closer to that of the Norwegian and Zabargad material than to the hues of the other peridots. Since the stones from Tanzania, Norway, and Zabargad all contained less iron than the other peridots analyzed (see table 1), our first assumption was that the color would correlate simply with the amount of iron present. However, an examination of the stones when arranged according to Fe content (figure 3) indicates no such orderly relationship.

TABLE 1. Chemical composition (in weight %) and color of peridot specimens from various localities.[a]

Chemical composition and color	Tanzania	Egypt (Zabargad)	Burma				Arizona		
	(13781)	(15)	(16)	(13034)	(13035)	(11447)	(12430A)	(12430B)	(12430C)
Composition[b]									
MgO	51.26	50.95	50.44	48.90	50.71	49.51	50.28	48.89	48.22
SiO_2	40.62	41.03	41.07	40.25	40.75	40.81	40.80	40.55	40.77
CaO	*[c]	0.03	0.04	*	*	*	0.09	0.11	0.06
TiO_2	*	*	*	*	*	*	*	*	*
Cr_2O_3	*	*	*	*	*	*	*	*	*
MnO	0.12	0.13	0.11	0.15	0.07	0.09	0.10	0.12	0.17
FeO	7.74	7.95	8.14	10.16	8.58	10.06	8.25	9.73	9.68
NiO	0.39	0.41	0.38	0.31	0.39	0.33	0.35	0.37	0.39
Total	100.13	100.50	100.18	99.77	100.50	100.80	99.87	99.77	99.29
Ratio Mg/Mg+Fe	0.922	0.920	0.917	0.896	0.913	0.898	0.916	0.900	0.899
ColorMaster coordinates	A-29/80/04	A-21/57/02	B-36/100/01	B-29/36/01	B-48/46/01	A-26/63/03	—[c]	B-27/44/01	A-18/40/02
CIE x and y coordinates	0.399/0.501	0.406/0.515	0.422/0.540	0.505/0.451	0.542/0.427	0.414/0.494	—[c]	0.475/0.480	0.421/0.487

[a]*The GIA catalog number for each stone is indicated in parentheses.*
[b]*Error is less than ±2 weight %.*
[c]*Asterisk indicates less than 0.02 weight % throughout table.*
[d]*Color coordinates for heat treated peridot:*

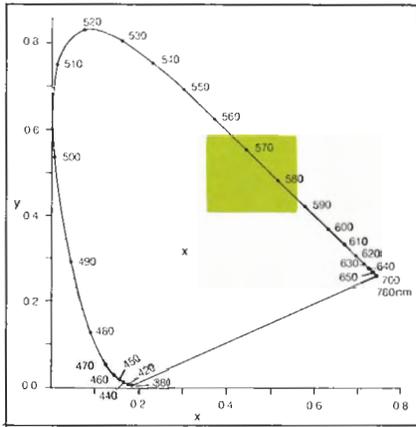|	ColorMaster	CIE
Before heat treatment	*A-27/63/03*	*0.418/0.491*
After 12 hours at 700°C	*B-54/99/04*	*0.458/0.474*
After additional 12 hours at 750°C	*D-18/83/04*	*0.506/0.469*

Figure 2. (A) CIE color graph; the shaded area is the region reproduced at right (B), on which coordinate points are plotted for the 14 peridots examined. (Note the GIA catalog numbers for cross-referencing with table 1.) Points x and o represent, respectively, the coordinates for stone 12430A before heat treatment and after 12 hours at 700°C. Enstatite 96B is also included on the diagram.
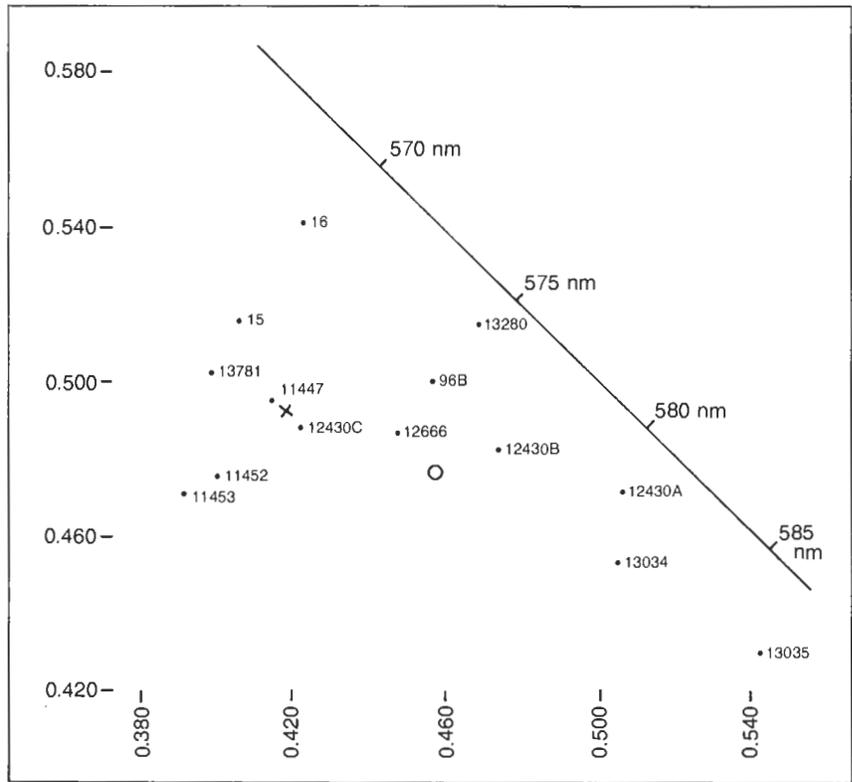
	Norway		Mexico
(13280)	(11452)	(11453)	(12666)
48.25	51.76	51.63	49.24
40.56	41.18	41.19	40.79
0.07	*	*	0.07
*	*	*	*
*	*	*	*
0.17	0.08	0.06	0.11
11.18	6.95	6.94	9.22
0.36	0.43	0.29	0.40
100.59	100.40	100.11	99.83
0.885	0.930	0.930	0.905
C-28/100/00	A-38/96/07	A-37/97/08	B-26/50/02
0.469/0.513	0.400/0.474	0.391/0.469	0.447/0.483

Next, we questioned whether the oxidation state of the iron present was affecting color. A study of diamond inclusions (Prinz et al., 1975) revealed that nearly colorless olivine inclusions oxidized to pale brown to red at the temperatures and times required to burn away the surrounding diamond (about 800°C for 6 to 24 hours). In order to confirm this effect, we selected for heat treatment one of the Arizona peridots already analyzed (GIA #12430A; see table 1). Exposure to 600°C for 4 hours yielded no visible effect, but after the stone had been subjected to a temperature of approximately 700°C for 12 hours, it turned noticeably darker and browner. An additional 12 hours of heating at 750°C produced the present color of the stone (figure 4). This suggests that the oxidation state of iron in peridot has a marked influence on the color. Further study of valence states and site locations of iron by means such as Mössbauer spectroscopy will provide a better understanding of the causes of color in peridots, but is beyond the scope of this article. It should be noted, though, that the times (several hours) and temperatures (over 500°C) required to oxidize peridot sufficiently to cause a change in color do not represent a risk for the jeweler/gemologist in terms of the color stability of a stone during repairs, in

Figure 3. A selection from the peridots studied that clearly refutes the idea that the amount of iron alone accounts for the variety of color observed among peridots. These stones are arranged (left to right) from lowest to highest proportion Mg/Mg+Fe (i.e., from most to least FeO present).

Figure 4. The stone on the left is Arizona peridot GIA #12430A after heat treatment. Its original color was the same as that of the peridot shown on the right in this photo.

Figure 5. The stone on the left is an enstatite from East Africa (GIA #96B); the stone on the right is a peridot from Mexico (GIA #12666).


the cutting process, or during any kind of normal wear.

GEMOLOGICAL SEPARATION OF PERIDOT FROM ENSTATITE

We also examined an East African enstatite (GIA #96B) that we believe to be similar to the ones confused with the Tanzanian peridot. This stone at first appears to be quite like peridot (figure 5), and the refractive indices measured from the table of the stone—approximately $\alpha = 1.669$, $\beta = 1.672$, and $\gamma = 1.679$ (biaxial positive)—lie in the ranges of those for peridot, although the birefringence of enstatite is considerably lower than that of peridot (approximately 0.010 as compared to 0.036). The spectra of peridot and enstatite, however, provide an easy means of distinguishing

Figure 6. Optical absorption spectra of (A) enstatite from East Africa (GIA #96B), and (B) peridot from Mexico (GIA #12666).
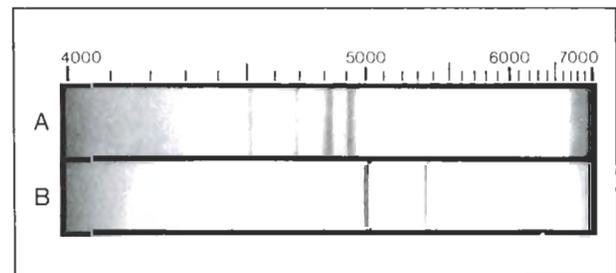
the two stones. Although both have been thoroughly documented (Liddicoat, 1980), the spectra for the enstatite and peridot shown in figure 5 are reproduced here (figure 6) for immediate reference.

Chemical analysis of this same enstatite (see table 2; performed at the same time as the peridot analyses) revealed an MgO:FeO ratio similar to that of the Tanzanian peridot as well as a somewhat high aluminum content for enstatite (Dunn, 1975/76 and 1978; Schmetzer and Krupp, 1982). These compositional features are characteristic of enstatite formed in a high-temperature, high-pressure geologic environment in which peridot can also form (Deer et al., 1978).

SUMMARY

The dozen or so samples of cut peridot from Tanzania that we have seen are all exceptionally attractive gems with transparency and color comparable to that of material typical of Norway and to some of the stones from Zabargad. Although these East African peridots have been confused at times with enstatite, the characteristic spectra of the two materials provide an easy means of separation. The quantity of peridot available from Tanzania is as yet unknown and will determine the significance of this material to the gem market.

TABLE 2. Chemical composition and color of the enstatite specimen from East Africa.

Composition[a]	Weight %
MgO	32.71
Al$_2$O$_3$	7.10
SiO$_2$	53.93
CaO	0.14
TiO$_2$	0.09
Cr$_2$O$_3$	0.09
MnO	1.12
FeO	4.49
Total	99.67
ColorMaster coordinates	B-26/50/01
CIE x and y coordinates	0.457/0.498

[a]*Error is less than ±2 weight %.*

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