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GOLDEN YELLOW TOURMALINE OF GEM QUALITY FROM KENYA

By HENRY A. HÄNNI, Ph.D., F.G.A.,* ERIK FRANK, Ph.D.,* and
GEORGE BOSSHART, Dip.Min., G.G.†

*Institute of Mineralogy and Petrography, Basel University, Switzerland.

†Swiss Foundation for the Research of Gemstones, Zurich, Switzerland.

Yellow and brown tourmalines are mainly reported from Sri Lanka, Burma and Brazil (Dunn, 1977), but are known from less important localities (Madagascar, Namibia, U.S.A., etc.) as well. Recently, tourmalines of very attractive golden yellow colour appeared in the trade, originating from Voi-Taveta area, Kenya. Although the rough material is found in rather small chips, it yields very pleasing gemstones after cutting. It is hoped that further findings will provide bigger fragments or whole crystals as well. On rough and cut specimens various mineralogical and gemmological investigations were performed. All results proved the tourmalines to be members of the dravite-uvite series with a ratio of 78:22.

TABLE 1

Representative list of partial microprobe analyses of yellow tourmalines from Kenya (Voi-Taveta)

	a			b			c			d				
SiO ₂	36.81	36.64	36.24	36.52	36.28	36.61	36.56	36.94	36.64	36.10	36.36	36.30	36.90	36.56
Al ₂ O ₃	35.27	35.38	35.06	35.12	34.77	35.06	34.86	35.35	34.95	34.96	34.88	35.04	35.23	34.94
TiO ₂	.74	.80	.21	.36	.61	.76	.66	.30	.31	.68	.80	.76	.80	.69
MnO	—	—	—	—	—	—	—	—	—	—	—	—	—	—
FeO ^{tot}	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MgO	9.61	9.30	9.28	9.15	8.95	9.26	9.40	9.51	9.42	9.45	9.60	9.52	9.61	9.64
CaO	1.20	1.05	1.07	1.12	.98	1.05	1.04	1.02	1.15	1.02	1.19	1.10	1.20	1.30
Na ₂ O	2.02	2.06	2.03	2.00	2.06	2.07	2.06	2.00	2.01	2.08	2.07	2.03	2.02	2.04
K ₂ O	.06	—	—	—	.08	.08	—	.05	—	—	—	—	.05	.07
V ₂ O ₅	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cr ₂ O ₃	—	—	—	—	—	—	—	—	—	—	—	—	—	—
anhydrous total	85.71	85.23	83.89	84.27	83.73	84.89	84.58	85.17	84.48	84.29	84.90	84.75	85.81	85.24

—Elements as Mn, Fe, V, Cr are below detection limit of 0.05 oxide wt%.

—a, b, c and d stand for four different samples, on which the point analyses were performed. This shows the variability within one crystal.

CHEMICAL COMPOSITION

Carbon-coated specimens were analysed by an ARL-SEMQ microprobe combined with an energy dispersive detector system (Tracor Northern), using an acceleration voltage of 15 kV and a sample current of 15 nA. For standardization natural and synthetic minerals were used. Data reduction was performed using a ZAF-type matrix correction program. More analytical details are described by Schwander and Gloor (1980).

A representative list of partial microprobe analyses, done on four specimens, is given on Table 1. The results show that the crystals from Voi-Taveta area are Mg-Al tourmalines of the dravite-uvite series, with Na/Ca ratios ranging from 3.1 to 3.8. Recalculating the analyses to the general formula of tourmaline (Table 2), assuming 3 B atoms per formula unit, we obtained compositions close to ideal formulae. However, there is some deficiency of Mg, (Na,Ca) and some corresponding excess in Al which may suggest a substitution as $Al \rightleftharpoons Na, Mg$.

No Mn, Fe, V or Cr could be detected by microprobe; these elements were checked too in the ppm-range by EDS-XRF-technique.* Only minor amounts of Fe (500-1000 ppm) were found. It is surprising that Ti is the dominant transition element in these crystals and that the saturation of yellow colour can be related with the Ti-content, ranging from 0.30 to 0.80 wt% of TiO₂. So far this is the first dravite-uvite tourmaline with such low Fe content.

On some rough crystal fragments there is sometimes a thin rim of green colour, this zone containing more Fe, as proved by XRF-analysis.

From the observed partial compositions and calculated atomic proportions we can exclude the presence of tsilaisite or elbaite components, although for that yellow colour one might have expected it. This confirms the assumption that no solid solution exists between dravite and elbaite as already reported in literature (Epprecht, 1953, Donnay and Barton, 1972, Sahama *et al.*, 1979).

X-RAY DATA

The lattice constants (Table 3) are calculated from x-ray powder diagrams (Bradley camera, Ni-filtered Fe K α radiation).

*energy-dispersive x-ray fluorescence

The strongest lines have the following d-values in Å: 2.573(100), 3.973(90), 2.955(80), 4.218(60), 3.475(50), the estimated intensities in brackets. It is not possible to determine the type of tourmaline by its lattice constants alone. Together with chemical information, the constants fit with the observations of Epprecht (1953) and the diagrams of Sahama *et al.* (1979).

TABLE 2
Chemical composition of Dravite-Uvite tourmalines

(Mg-Al-tourmalines)	
Dravite	$\text{NaMg}_3\text{Al}_6((\text{BO}_3)_3\text{Si}_6\text{O}_{18})(\text{OH})_4$
Uvite	$\text{CaMg}_3\text{Al}_5((\text{BO}_3)_3\text{Si}_6\text{O}_{18})(\text{OH})_4$

golden yellow tourmaline Kenya (partial microprobe analysis)*

wt%			
SiO ₂	36.64	Si	5.83
Al ₂ O ₃	35.38	Al	6.00
TiO ₂	.80	B	3.00
MnO	.00		
FeO	.00	Al	.63
MgO	9.30	Ti	.10
CaO	1.05	Mg	2.21
Na ₂ O	2.06	Ca	.18
K ₂ O	.00	Na	.64
B ₂ O ₃ †	10.90		
V ₂ O ₅	.00		3.76
Cr ₂ O ₃	.00		
anhydrous total	96.13	Number of ions on the basis of 29 O per formula unit	

*for technical reasons Boron and other very light elements are not able to be analysed by microprobe technique.

†B₂O₃ calculated on basis of ideal formula containing 3 B.

TABLE 3

Physical and optical properties of Dravite-Uvite tourmalines

	Dravite*	golden yellow tourmaline	Uvite
n_{ϵ}	1.617	1.619	1.619
n_{ω}	1.638	1.642	1.638
Δn	0.021	0.022	0.019
a_0	15.939Å	15.915	15.918
c_0	7.199Å	7.183	7.207
c/a	0.4517	0.4513	0.4509
SG	3.03	3.044	3.01
Dravite:Uvite ratio	80:20	78:22	4:96
Reference	Bridge <i>et al.</i> (1977)	this study	Dunn <i>et al.</i> (1977) NMNH #C5212

OPTICAL FEATURES

The refractive indices were obtained from oriented crystal sections on a Topcon refractometer, working with Na_D -light. The figures (Table 3) are consistent with the well known range of optical data for tourmaline. The axial image of a slice cut perpendicular to the c -axis, observed in a polarization microscope, is uniaxial negative, with a slight tendency to biaxial.

Inclusions are profiled negative crystals parallel to c -axis, curved growth tubes (trichites) and flat healing fissures consisting of long and short droplets of residual liquids.

Absorption spectra for both rays, registered on a Pye-Unicam SP8-100 spectrophotometer, show good transmission from red to yellow and a wide absorption band from blue to violet, followed by

*According to the analysis of Bridge *et al.* (1977) this sample does not represent a dravite end-member, but no other data were available

a minimum at 378 nm and an absorption edge around 320 nm for n_{ω} and 300 nm for n_{ϵ} . Dichroism is stronger than can be recognized by visual inspection, with absorption $n_{\omega} \gg n_{\epsilon}$. The strongly absorbing ray is responsible for the colour. The extraordinary ray is very pale yellow. For hue, saturation and degree of darkness the DIN 6164 indices are 3:5:1.5 (body colour) and 3:8:1 (internal reflexions).

Fluorescence is absent under long wave, and medium strong yellow under short wave violet radiation.

~~but~~ The absence of transition elements other than Ti and very little Fe, purity and small variation of the orange-yellow hue observed in these tourmalines are to be expected. The saturation of colour, as mentioned before, is governed by Ti content. A wide Absorption band centred around 440 nm appears to be caused by Ti alone.

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