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OF GREAT BRITAIN
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CHARACTERIZATION OF TWO SAMPLES OF TAIWAN'S JADE

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SUMMARY

Two samples of Taiwan's jade, one of them with a clear cat's-eye effect, have been studied by optical, x-ray, thermal and electron microprobe analyses and SEM investigations. They showed that both samples are tremolitic members of the tremolite-actinolite-ferroactinolite series, with identical chemical and mineralogical composition. The diverse shades of green colour and cat's-eye effect are related to different arrangements of the fibres.

INTRODUCTION

Two samples of jade from Taiwan‡ were analysed by microscopy, x-ray diffraction, thermoanalytical, SEM and electron microprobe techniques to ascertain their nature. Both samples are cabochon cut, 15 × 10 × 5 mm in size and derive from the same

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‡The samples were supplied by Messrs Frank and Company, of Taipei, Republic of China (Taiwan), by kind recommendation of Dr E. Gübelin, of Lucerne, Switzerland.

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Fig. 1—Jade of Taiwan : Sample A. (1: 0.75)

Fig. 2—Jade of Taiwan : Sample B. Evident cat's-eye effect (1: 0.5)

deposit. One of them (sample A) has the typical colour of jade with rare and very slender veins of different shade, whereas the other (sample B) is lighter in colour and with an uncommon cat's-eye effect (Figures 1 and 2).

EXPERIMENTAL RESULTS

Optical investigations were carried out on fracture surfaces and on three polished oriented sections, one parallel to the cabochon basal ellipse and the other two orthogonal and containing respectively the major and minor axes of the basal ellipse. They showed that sample A is constituted by fibrous bunches without a clear preferential arrangement, whereas sample B is constituted by very thin parallel fibres.

The values of the birefringence, for sample B, measured by spinel refractometer, agree with those reported by E. Gübelin(3) for three samples of cat's-eye Taiwan jade. The values are:

$$n_x = 1.616 \qquad n_z = 1.632 \qquad = \quad 0.016$$

The values for sample A are very similar, even if they have a larger approximation due to the randomly arranged and distorted fibres. Also the densities of the two samples are similar: 3.01±0.005.

Morphological features of the two samples were investigated by SEM on sections parallel to the cabochon basal plane.

On sample A the fracture surfaces are constituted by bunches of fibres variously arranged and distorted (Figure 3). The polished surfaces generally show a marked compactness; but on them we can see some discontinuities, in which have been observed some fibres with a loose arrangement (Figures 4 and 5). From the investigations performed on fracture surfaces of sample B it appeared that the material is composed of fibres with a perfect parallel texture (Figure 6). This observation is confirmed by investigations carried out on polished surfaces, which also reveal that the material is highly compact and fit for polishing.

Chemical quantitative analyses were carried out by electron microprobe*. Two tremolite crystals, respectively from Malga Mont and Sas dell'Anel, analysed by R. Pirani(5, 6), were used as standards. All iron has been calculated as FeO_{tot}, H_2O^- and loss on ignition were determined by thermogravimetric analysis. Results

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*Electron microprobe : Jeol JXA50A. Operative conditions : Accelerating potential, 15 kV; Beam current, 5×10^{-8} A; Sample current, 3×10^{-8}A. Analytical conditions : Beam diameter, 20μm; Sodium volatilization test, <1%; Statistical error, <1%.

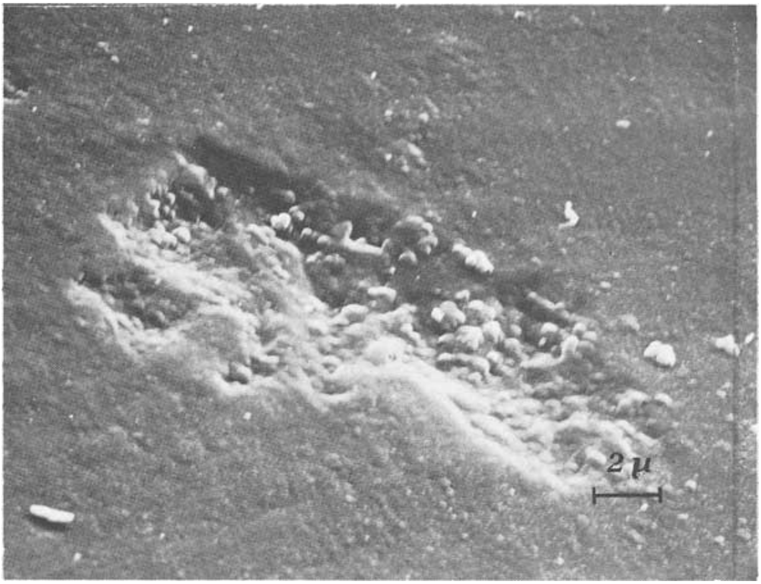

Fig. 3—Jade of Taiwan : Sample A. Randomly arranged tremolite fibrous crystals.

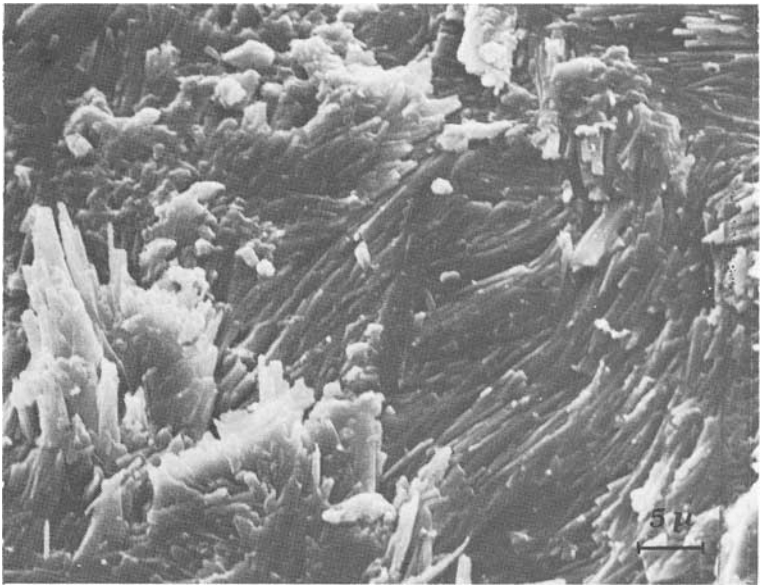

Fig. 4—Jade of Taiwan : Sample A. Example of superficial discontinuity.

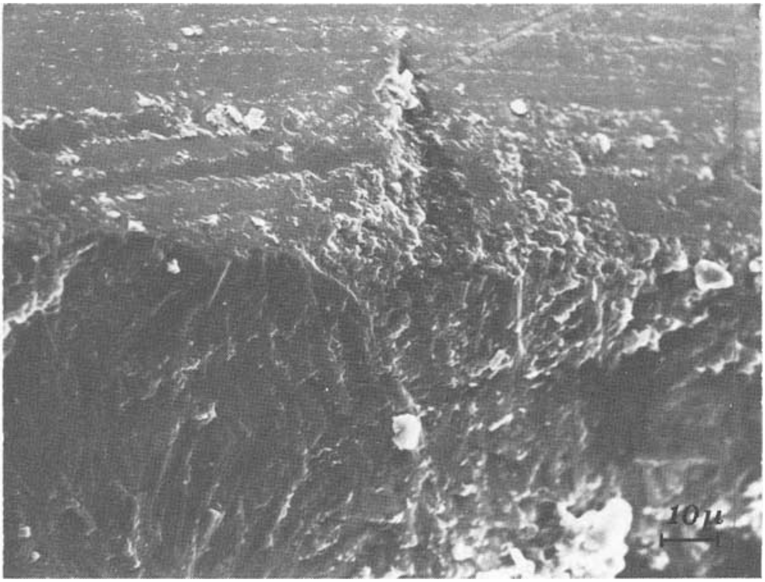

Fig. 5—Jade of Taiwan : Sample A. A discontinuity's image observed both on the polished plane (a) and on a fractured surface (b).

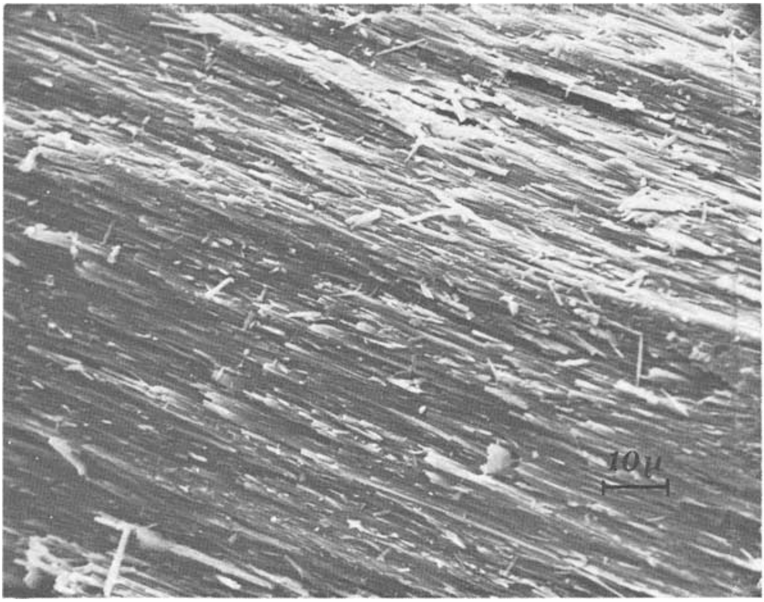

Fig. 6—Jade of Taiwan : Sample B. Fibrous crystals with a perfect parallel arrangement.

(Table I) were corrected, with an IBM 30/40 computer program, for background, electronic dead time, instrumental shift for small and long time, atomic number, absorption, continuous and characteristic fluorescence.

Chemical composition of the two samples is nearly identical.

TABLE I

	Sample A	Sample B
SiO_2	55.76	56.15
TiO_2	0.18	0.18
Al_2O_3	1.76	1.82
FeO_{tot}	2.71	2.71
Cr_2O_3	0.28	0.26
MnO	0.35	0.32
MgO	21.90	21.95
CaO	13.05	13.08
Na_2O	0.61	0.64
K_2O	0.28	0.26
L.O.I.	1.98	2.05
H_2O^-	0.28	0.35
F	—	—
	99.14	99.77

NUMBERS OF IONS ON THE BASIS OF 24 (O, OH, F)

	Sample A		Sample B	
Si	7.791	8.08	7.792	8.09
Al	0.290		0.298	
Ti	0.019	4.97	0.019	4.94
Fe_{tot}	0.317		0.314	
Cr	0.031		0.029	
Mg	4.558		4.537	
Mn	0.041		0.038	
Na	0.165	2.17	0.172	2.16
Ca	1.953		1.944	
K	0.050		0.046	
OH	1.845	1.84	1.897	1.90
F	—		—	
100Mg : (Mg + Fe_{tot} + Mn)	92.72		92.78	

TABLE II

Tremolite ASTM—13—437			Sample A		Sample B	
d Å	I/I_o	hkl	d Å	I/I_o	d Å	I/I_o
8.98	16	020	9.025	11	8.889	9
8.38	100	110	8.425	33	8.268	28
5.07	16	130,001	5.088	13	5.067	9
4.87	10	$\bar{1}11$	4.887	8	4.874	2
4.76	20	200	4.783	8	4.720	5
4.51	20	040	4.518	20	4.495	19
4.20	35	220	4.220	13	4.191	8
3.870	16	$\bar{1}31$	3.875	12	3.867	3
3.376	40	150,041	3.388	23	3.388	4
3.268	75	240	3.267	44	3.267	55
3.121	100	310	3.126	100	3.110	100
3.028	10	$31\bar{1},24\bar{1}$	3.043	8	2.988	3
2.938	40	$\bar{1}51$	2.945	33	2.935	6
			2.876	8		
2.805	45	330	2.814	31	2.805	13
2.730	16	$42\bar{1}$	2.738	23	2.722	12
2.705	90	151	2.710	75	2.702	12
2.592	30	$\bar{1}12,061$	2.596	30	2.589	5
2.529	40	$\bar{2}02,002$	2.540	30	2.535	5
2.407	8	$\bar{1}32$	2.414	8	2.404	3
2.380	30	350,400	2.386	13	2.380	11
2.335	30	$35\bar{1}$	2.341	31	2.338	6
2.321	40	$42\bar{1}$	2.320	22	2.315	5
2.298	12	420,071	2.300	29	2.295	5
2.273	16	112	2.276	13	2.276	2
2.206	6	$\bar{2}42,042$	2.212	6	2.243	2
2.181	6	$44\bar{1}$		34	2.161	7
2.163	35	171,261	2.166	14		
2.042	18	081,280	2.047	22	2.036	2
2.015	45	202	2.014	14	2.014	5
2.002	16	351,370	2.004	9	2.000	11
1.963	6	$28\bar{1},190$	1.967	5	1.961	7
1.929	6	152	1.924	17	1.939	2
1.892	50	510	1.891	14	1.890	15
1.864	16	$460,\bar{1}91$	1.864	8	1.861	5
			1.843			
1.814	16	530	1.817	8	1.848	2
1.746	6	$\bar{2}03$	1.751	5	1.814	9
1.686	10	$003,\bar{2}82$	1.886	10	1.748	2
1.649	40	$210\bar{1}$	1.651	33	1.686	3
1.639	10	$48\bar{0},\bar{5}11$	1.639	13	1.650	11

Also it has been noticed that inside the discontinuities on polished surface of sample A there is a slight increase of iron content.

X-ray powder patterns, obtained from the two samples, A and B, are nearly identical and are typical of tremolite (Table II).

Differential thermal analyses were carried out by a microthermodifferential apparatus (type BDL), working in a dry air stream (5 cc/min) and with a furnace gradient of 10 °C/min. The DTA curves also of the two samples are nearly identical. An endothermic effect at about 960 °C, due to recrystallization, is evident. The absence of the small exothermic effect at about 830 °C, reported for other tremolites (1, 2, 7), is probably due to the low iron content of samples A and B.

CONCLUSIONS

We may conclude that the two samples of jade, A and B, are tremolitic and mineralogically and chemically identical.

The values of birefringence and density are in agreement with the chemical composition of the two minerals, and using the diagram of Deer *et al.*,(1) where the refractive index and density are plotted against the chemical composition of the members of the tremolite-actinolite-ferroactinolite series, the two samples of jade appear to have a ferroactinolitic content of 10%.

The cat's-eye effect is confirmed to be mainly due to the perfect parallel arrangement of the fibres.

Regarding sample A, it has been observed that where the material is less compact there is a slight increase of iron content and the green shade becomes darker.

ACKNOWLEDGEMENT

The authors are indebted to Dr E. Gübelin for his valuable advice and criticism, Prof. R. Pirani for supply of the standards and G. Guidi and R. Tecchia for their collaboration in the analytical work.

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STUDIES OF A GEM GARNET SUITE FROM THE UMBA RIVER, TANZANIA*

By E. A. JOBBINS, J. M. SAUL, PATRICIA M. STATHAM and B. R. YOUNG

INTRODUCTION

A series of 204 variously coloured garnet pebbles was acquired by J. Saul during 1974 from the same alluvial area along the Umba River as the blue colour-change garnet described by Jobbins *et al.* 1975. The garnets were shown to us at the Institute and it was suggested that they would form an ideal subject for a detailed study of a large sample from a known and relatively restricted provenance.

A small polished flat was placed on each pebble to facilitate optical determinations. After cleaning in an ultrasonic cleaner the pebbles were sorted into thirteen groups on a colour basis by one author (P.M.S.) and a second author (E.A.J.) checked and agreed with this grouping, which greatly assisted the subsequent handling. At this stage it was noted that the stones in groups 12 and 13 showed marked colour changes (greys to pinks) from daylight to tungsten illumination, that those in group 11 appeared khaki by transmitted daylight but pale orange-brown by reflected daylight, and that there was more variation within the suite than had been apparent to any of us at first inspection.

PHYSICAL AND CHEMICAL PROPERTIES

The refractive index of each specimen was determined (±0.002) using sodium light and a standard Rayner refractometer.

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The specific gravities were determined by hydrostatic weighing in pure toluene. The plot of refractive indices against specific gravities is shown in Fig. 1, and it will be seen that the points form a broad straight band despite the wide range of constants and colours. Two

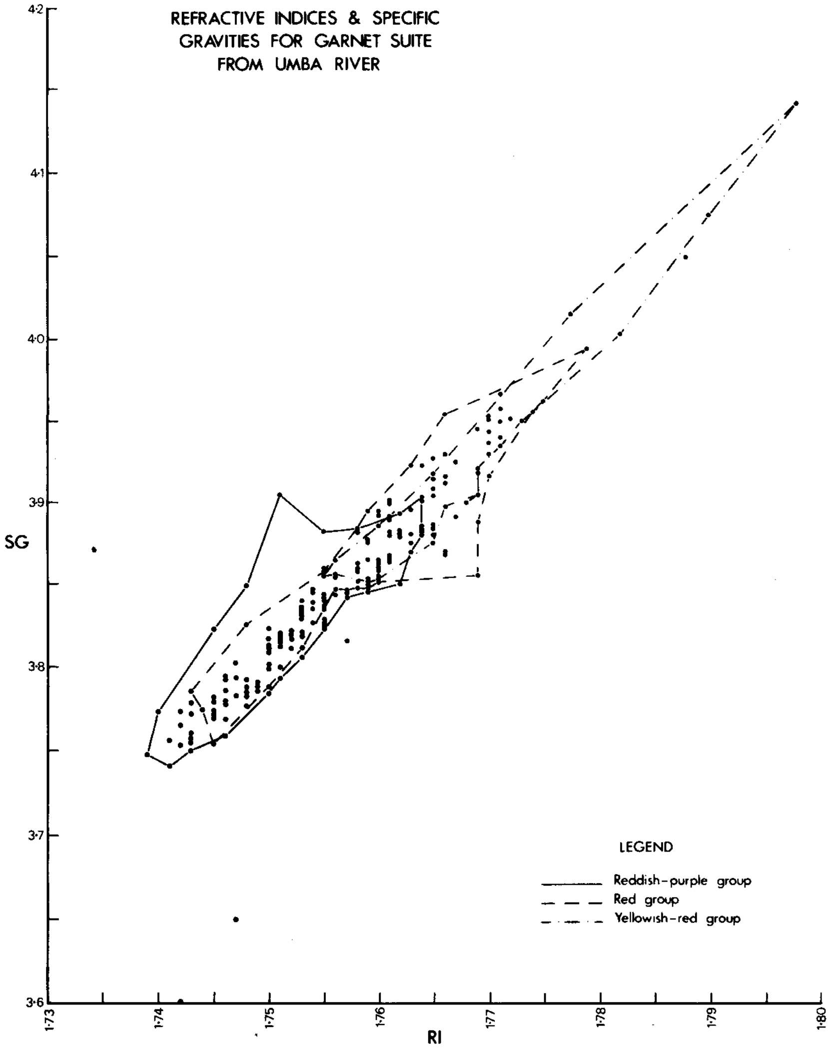


FIG. 1

stones 9/27 and 10/43 fall well below the main band and are rich in the grossular molecule (see Table I) with a low manganese content; they may originate from a different provenance.

Eight of the garnets (four chosen at roughly equal intervals on the main band on the RI/SG plot plus three garnets away from the band and one colour-change specimen from group 11) were analysed for the elements shown in Table I using a 'Geoscan' electron microprobe. Silicates and oxides of known composition and pure metals were used as standards. All elements were analysed using an accelerating voltage of 20 kV. The results have been corrected for absorption, atomic number effect and fluorescence using the Mark V version of the BM-IC-NPL computer program written by Mason, Frost and Reed.

With the electron microprobe it is not possible to distinguish the valency states of iron. For samples 1/3 and 1/26 it has been assumed that all the iron is in the divalent state. For the other samples the FeO and Fe_2O_3 contents have been calculated from the total Fe by assuming that the number of cations in the tetrahedral, octahedral and eight-fold co-ordination sites are in the ratio 3:2:3 as they would be in the theoretical garnet structure. Titanium is here considered as substituting as a trivalent cation in the octahedral sites and is grouped with the Al^{3+}, Fe^{3+}, Cr^{3+} and V^{3+}. However the position of titanium in the garnet structure is in doubt and it is likely that it can substitute in both the octahedral and tetrahedral sites (see Hartman 1969, Dowty 1971 and Huggins *et al.* 1977). Titanium has been ignored in calculating the molecular percentage of the end members.

Three x-ray powder films of each analysed garnet were taken in an 11.46 cm camera at room temperature (*c.*23 °C) using filtered copper ($\lambda K\alpha_1 = 1.54051$Å), cobalt ($\lambda K\alpha_1 = 1.78892$Å) and iron ($\lambda K\alpha_1 = 1.93597$Å) radiations, and the most suitable films were selected for measurement. The unit cell dimensions *a*(Å), which are accurate to ±0.001Å, were obtained by plotting the values obtained from the high angle lines against the Nelson and Riley function

$$\tfrac{1}{2}\left(\frac{\cos^2\theta}{\sin\theta} + \frac{\cos^2\theta}{\theta}\right)$$

and extrapolating to $\theta = 90°$.

The absorption spectra of the whole sample were determined using transmitted light through water-immersed specimens on a microscope stage and a Beck prism spectroscope. As expected we

TABLE I

ELECTRON MICROPROBE ANALYSES OF GEM GARNETS FROM UMBA RIVER AREA

Specimen No.	1/15	9/27	1/3	CCG	11/1	1/26	9/14	10/40	10/42
SiO_2	41.94	38.4	41.7	40.3	39.51	40.5	38.0	37.5	36.6
TiO_2	0.03	0.37	0.04	0.05	0.23	0.01	0.27	0.20	0.22
Al_2O_3	23.98	20.6	23.1	21.8	22.13	22.7	21.5	20.5	20.7
Fe_2O_3	0.59*	2.74*		1.16*			1.21*	1.25*	0.55*
FeO	7.40*	1.54*	16.5+	0.16*	3.27+	17.7+	4.41*	2.27*	2.01*
MnO	4.14	1.3	1.1	18.2	18.27	2.2	25.4	30.5	37.6
MgO	20.78	nt.fd.	16.6	12.9	9.31	13.5	6.3	2.7	1.2
CaO	1.62	34.0	1.2	5.3	6.85	2.7	3.6	5.2	1.5
Cr_2O_3	0.04	nt.fd.	0.01	nt.fd.	0.03	0.10	nt.fd.	nt.fd.	0.01
V_2O_3	nt.fd.	0.05	0.01	0.75	0.26	0.04	0.18	0.04	0.01
CoO	nt.fd.	0.12	0.18	0.03	nt.fd.	0.01	nt.fd.	0.04	nt.fd.
NiO	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.	0.06	nt.fd.
ZnO	0.04	0.04	0.01	0.03	nt.fd.	0.03	0.05	0.05	0.01
Na_2O	nt.fd.	0.04	nt.fd.	nt.fd.	nt.fd.	nt.fd.	0.12	0.11	nt.fd.
K_2O	nt.fd.	0.01	nt.fd.	nt.fd.	nt.fd.	nt.fd.	0.03	0.02	0.02
	100.56	99.21	100.45	100.68	99.86	99.49	101.07	100.44	100.43

Specimens 11/1 and 1/15, analyst P.H.A. Nancarrow, the remainder, Anne E. Tresham.

nt.fd. = not found. *FeO and Fe_2O_3 are calculated from total Fe by assuming that the number of cations in the tetravalent, trivalent and divalent positions are in the ratio 3: 2:3.

+Assuming that all the iron is in the divalent state. CCG = Blue colour-change garnet.

	1/15	9/27	1/3	CCG	11/1	1/26	9/14	10/40	10/42
n	1.739	1.747	1.753	1.757	1.760	1.761	1.779	1.788	1.798
D_{obs}	3.745	3.650	3.823	3.816	3.855	3.863	3.995	4.049	4.141
D_{calc}	3.735	3.663$_5$	3.836	3.837	3.863	3.872	4.016	4.059	4.157
a(Å)	11.502	11.848$_5$	11.493	11.578	11.609	11.519	11.595	11.633	11.614

NUMBERS OF IONS ON THE BASIS OF 24(O)§

	1/15	Σ	9/27	Σ	1/3	Σ	CCG	Σ	11/1	Σ	1/26	Σ	9/14	Σ	10/40	Σ	10/42	Σ
Si	5.940	6.01	5.911	6.01	6.057		5.973	6.00	5.992		6.036		5.898	6.02	5.977	6.01	5.947	6.00
Al	0.068		0.097		—		0.029		—		—		0.118		0.028		0.057	
Al	3.935		3.640		3.955		3.779		3.956		3.988		3.815		3.824		3.907	
Fe^{3+}	0.063		0.317		—		0.129		—		—		0.141		0.150		0.067	
Ti	0.003	4.01	0.042	4.01	0.004	3.96	0.005	4.00	0.026	4.02	0.001	4.01	0.032	4.01	0.024	4.00	0.027	4.00
Cr	0.004		—		0.001		—		0.004		0.012		—		—		0.001	
V^{3+}	—		0.006		0.001		0.089		0.032		0.005		0.022		0.006		0.001	
Fe^{2+}	0.876		0.198		2.004		0.020		0.415		2.206		0.573		0.302		0.273	
Mn	0.496		0.169		0.135		2.285		2.347		0.278		3.339		4.117		5.174	
Mg	4.386		—		3.593		2.849		2.104		2.998		1.457		0.642		0.291	
Ca	0.246		5.609		0.187		0.842		1.113		0.432		0.599		0.888		0.261	
Co	—	6.01	0.015	6.01	0.021	5.94	0.004	6.00	—	5.98	0.001	5.92	—	6.02	0.005	6.01	—	6.00
Ni	—		—		—		—		—		—		—		0.008		—	
Zn	0.004		0.005		0.001		0.004		—		0.004		0.006		0.006		0.001	
Na	—		0.011		—		—		—		—		0.037		0.034		—	
K	—		0.002		—		—		—		—		0.006		0.004		0.004	

§The numbers of ions have been calculated to three places of decimals to minimize rounding errors in the summations.

MOLECULAR PERCENTAGE OF END-MEMBERS

	1/15	9/27	1/3	CCG	11/1	1/26	9/14	10/40	10/42
Almandine	14.6	3.3	33.8	0.3	6.9	37.3	9.6	5.1	4.6
Andradite	1.6	8.0	—	3.2	—	—	3.5	3.8	1.7
Grossular	2.4	85.7	3.1	8.6	17.7	6.8	5.9	11.3	2.6
Pyrope	73.0	—	60.7	47.5	35.2	50.7	24.4	10.7	4.8
Spessartine	8.3	2.8	2.3	38.1	39.3	4.7	56.0	69.0	86.2
Uvarovite	0.1	—	0.02	—	0.1	0.3	—	—	0.03
Goldmanite	—	0.2	0.02	2.2	0.8	0.1	0.6	0.1	0.03

were dealing essentially with two reasonably distinct spectra—almandine and spessartine, the intensities of which are shown in Table II; the grossular molecule provided no spectrum. A number of stones with a very weak almandine spectrum showed additional absorption of the green and/or blue, but chromium lines in the red were not seen. In some cases chromium lines may have been inhibited by iron, but chromium is certainly present in analyses for specimens 1/3, 1/15, 1/27 and 10/42 shown in Table I. It would seem, for instance, that in specimen 1/26 the 0.1% Cr_2O_3 is being completely inhibited by the 0.04% V_2O_3. Vanadium, which showed in all the analyses except 1/15, may well account for some of this general absorption and masking of the chromium, but it was not possible to recognize any specific vanadium lines. This behaviour accords well with that of the blue colour-change garnet from the same area described earlier (Jobbins *et al.* 1975) and these stones also show no fluorescence when copper sulphate solution is used as a filter. In contrast the present stones are not fluorescent under long or short wave UV radiation or under the Chelsea filter, as was the blue garnet which showed red under the filter.

Groups 12 and 4 which exhibit less colourful pinkish-greys and greyish-purples respectively show notable colour changes to deep pinks by tungsten lighting. Both groups are characterized by strong spessartine and weaker almandine spectra. In group 11 there is a marked increase in redness by tungsten lighting (an alexandrite type effect), and the same stones also appear different colours by transmitted and reflected daylight, khaki and orange-brown respectively. This latter colour change was similar to that shown by didymium glass (MI 33205) in the IGS collections and raised the possibility that rare-earth elements might be the cause. To investigate this behaviour specimen 11/1 was analysed, but rare earths were not found by the microprobe, although they may be present in concentrations below detection limits of the instrument. Gallium, which is known to be present in some unusually coloured corundums from the Umba River area and Australia, was not detected in any of the analysed specimens.

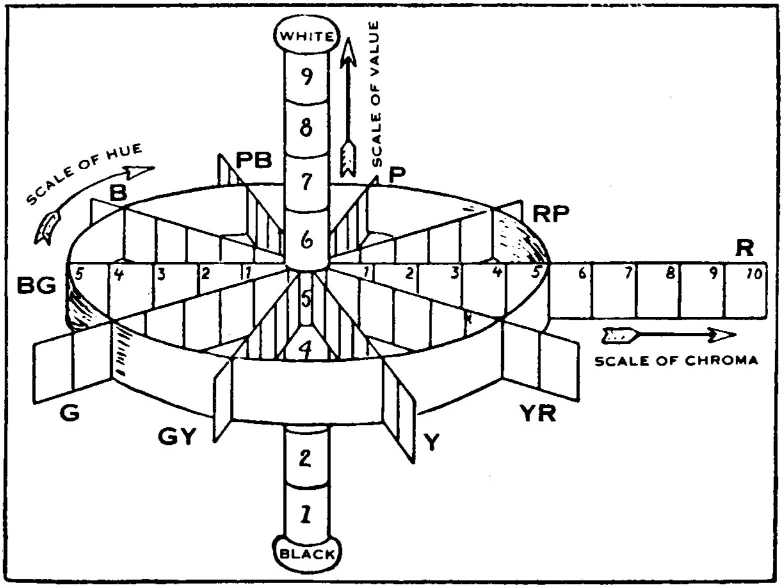
COLOUR GRADING

At a later stage in the study it was decided to colour-grade the series using one of the standard systems of colour charts, and the American Munsell system, which has previously been used for colour-grading of rocks, was selected. A broad correlation between this system and the Methuen Book of Colour, a British system, is possible.

The *Munsell Book of Color* provides an orderly arrangement of standard paper charts which serve as guides for the measurement and notation of all colours. These standards represent equally spaced divisions of the three attributes of colour defined in the Munsell system as *hue, value* and *chroma* (see Figure 2). The *hue* notation of a colour indicates its relation to red, yellow, green, blue and purple; the *value* notation indicates its lightness; and the *chroma* notation indicates its strength (or departure from neutral).

In recording a colour by Munsell notation the symbol for *hue* is written first and is followed by a symbol written in fraction form, the numerator indicating the *value* and the denominator indicating the *chroma* (H V/C). For instance, a sample which is 2.5 Red in hue, 5 in value and 8 in chroma is written 2.5R 5/8. A colour having neither hue nor chroma is known as a neutral.

Our reasons for this exercise were: (1) to try to provide colour



from the Munsell Book of Color

FIG. 2. HUE, VALUE and CHROMA in their relation to one another. The circular band represents the HUES in their proper sequences. The upright centre axis is the scale of VALUE. The paths pointing outward from the centre show the steps of CHROMA, increasing in strength as indicated by the numerals.

descriptions on a scientific basis which could easily be recalled and compared by workers elsewhere and which were not dependent upon subjective colour descriptions based on flowers, fruit and other variable objects; (2) to see if there was any correlation between colour and other physical properties, and (3) to see how practicable such a grading exercise would be on a sample of this size. More complicated grading systems dependent upon spectrophotometry were not considered in this study.

There were many problems in the colour grading among which were (a) the fact that the gemstones were transparent and the colour matching charts opaque; (b) some gems appeared as different colours in transmitted and reflected light despite the fact that, as garnets, they are essentially isotropic and daylight was the only illumination. We determined the colour gradings by transmitted light. The colour gradings for the series are shown in Table II and can be compared there with the absorption spectra intensities, refractive indices and specific gravities. In Figure 1 the outlines formed by areas of reddish-purple (RP), red (R) and yellowish-red (YR) Munsell hue notations respectively are plotted on the refractive index/specific gravity graph of the series and the gradation from reddish-purple to yellowish-red (equivalent to brown in the lower *values*) is seen to correspond broadly with increase in the content of the spessartine molecule.

GEOLOGY

The garnet suite consists of stones found during prospecting in the Umba River Valley area of north-eastern Tanzania. Although the stones probably came from the same group of secondary deposits, it is certain that they did not originate in one primary deposit. This is reflected in the range of colours and in the various external morphologies exhibited by the garnets. In order of frequency these are:

(1) stream-rounded pebbles,

(2) naturally sub-rounded grains which appear to be the fresh cores of larger grains that underwent conchoidal fracturing upon weathering,

(3) sub-rounded grains showing bright surfaces possibly due to resorption,

(4) sharp sub-rectangular fragments, usually with two dimensions substantially greater than the third,

TABLE II. OPTICAL AND PHYSICAL PROPERTIES OF GARNET SUITE, UMBA RIVER, TANZANIA

GROUP 1 PURPLE

No.	Colour Grade			A/S Al	A/S Sp	R I	S G
1	2.5	RP	5/8	5	4	1.743	3.772
2	5	RP	5/10	5	2	1.743	3.750
3	2.5	RP	5/10	5	1	1.753	3.822
4	5	RP	5/10	5	1	1.746	3.795
5	7.5	RP	5/10	4	1	1.748	3.783
6	5	RP	5/10	5	1	1.753	3.833
8	5	RP	6/10	4	0	1.751	3.794
9	5	RP	5/10	6	0	1.760	3.861
10	2.5	RP	5/10	3	3	1.742	3.753
11	5	RP	6/10	3	0	1.750	3.809
12	7.5	RP	5/10	3	0	1.755	3.860
13	2.5	RP	5/10	4	0	1.753	3.806
14	5	RP	6/10	4	0	1.745	3.772
15	7.5	RP	6/8	2	0	1.739	3.748
16	5	RP	5/10	2	0	1.762	3.884
17	2.5	RP	7/6	3	0	1.741	3.741
18	5	RP	5/10	3	0	1.747	3.783
19	5	RP	6/10	3	0	1.750	3.812
20	5	RP	6/10	3	0	1.747	3.794
21	5	RP	5/10	3	0	1.752	3.822
22	5	RP	6/10	3	0	1.745	3.771
23	5	RP	5/10	3	0	1.758	3.857
24	7.5	RP	5/10	3	0	1.748	3.793
25	7.5	RP	6/10	3	0	1.757	3.842
26	7.5	RP	5/10	3	0	1.761	3.880
27	2.5	RP	5/10	3	0	1.746	3.759

GROUP 2 REDDISH PURPLE

No.	Colour Grade			A/S Al	A/S Sp	R I	S G
1	10	RP	6/10	4	5	1.743	3.761
2	5	RP	6/10	4	4	1.741	3.757
3	7.5	RP	7/8	3	3	1.742	3.766
4	7.5	RP	7/8	1	4	1.746	3.786
5	10	RP	7/8	2	4	1.744	3.774
6	7.5	RP	7/8	3	4	1.750	3.784
7	5	RP	6/8	4	4	1.753	3.841
8	7.5	RP	6/8	4	4	1.753	3.823
9	10	RP	8/6	1	5	1.755	3.827
10	5	RP	7/8	4	4	1.740	3.773
11	5	RP	8/6	1	4	1.743	3.755
12	5	RP	8/4	1	4	1.743	3.779
13	5	RP	8/4	1	4	1.745	3.823
14	5	RP	8/6	2	4	1.742	3.773
15	5	RP	7/6	2	3	1.745	3.779
16	5	RP	7/6	2	4	1.754	3.835
17	7.5	RP	7/8	4	5	1.745	3.773
18	7.5	RP	7/8	4	3	1.748	3.783

KEY

ABSORPTION SPECTRA (A/S)

Al Almandine
Sp Spessartine

INTENSITIES

1. Very faint
2. Faint
3. Weak
4. Medium
5. Strong
6. Very strong

COLOUR GRADING

RP Reddish-purple
R Red
YR Yellowish-red
Y Yellow

GROUP 3 BROWNISH PURPLE

No.	Colour Grade			A/S Al	A/S Sp	R I	S G
1	7.5	RP	5/10	5	4	1.750	3.813
2	7.5	RP	6/10	4	3	1.751	3.813
3	10	RP	4/8	5	3	1.764	3.903
4	7.5	RP	6/10	4	3	1.755	3.829
5	7.5	RP	6/10	4	2	1.755	3.843
6	10	RP	6/10	4	2	1.762	3.882
7	7.5	RP	6/8	4	4	1.749	3.791
8	5	RP	6/10	4	3	1.755	3.825
9	10	RP	6/8	4	4	1.760	3.865
10	7.5	RP	5/8	4	3	1.759	3.852
11	10	RP	5/6	3	5	1.755	3.882
12	7.5	RP	5/8	4	2	1.763	3.880
13	7.5	RP	5/10	4	2	1.759	3.847
14	7.5	RP	6/8	4	3	1.758	3.852
15	7.5	RP	6/8	2	2	1.757	3.845
16	7.5	RP	5/8	2	0	1.761	3.867
17	7.5	RP	6/8	2	2	1.747	3.802
18	7.5	RP	5/8	2	3	1.764	3.881
19	7.5	RP	6/10	4	4	1.755	3.836
20	10	RP	6/8	3	5	1.751	3.905
21	10	RP	4/8	5	3	1.748	3.849
22	10	RP	5/8	4	3	1.756	3.857
23	10	RP	4/8	4	3	1.760	3.860
24	7.5	RP	5/8	4	3	1.764	3.885
25	7.5	RP	5/8	4	3	1.752	3.817
26	7.5	RP	7/8	4	4	1.751	3.817
27	7.5	RP	5/8	4	3	1.761	3.867
28	7.5	RP	6/8	4	3	1.746	3.793
29	5	RP	6/8	2	5	1.758	3.883
30	7.5	RP	7/8	4	4	1.750	3.799
31	7.5	RP	7/6	3	3	1.753	3.840
32	5	RP	6/8	4	4	1.748	3.783
33	10	RP	6/8	3	3	1.743	3.757
34	10	RP	6/8	3	3	1.758	3.881

GROUP 4 GREYISH PURPLE

No.	Colour Grade			A/S Al	A/S Sp	R I	S G
1	10	RP	7/6	2	6	1.753	3.839
2	7.5	RP	7/6	1	5	1.740	3.749
3	10	RP	7/8	1	6	1.758	3.860
4	7.5	RP	7/6	1	6	1.753	3.833
5	10	RP	8/4	2	6	1.754	3.847
6	10	RP	6/8	3	5	1.763	3.869

GROUP 5 BROWNISH PINK

No.	Colour Grade			A/S Al	A/S Sp	R I	S G
1	2.5	R	5/10	6	6	1.752	3.811
2	7.5	RP	6/10	4	6	1.762	3.893
3	7.5	RP	6/10	4	6	1.746	3.778
4	10	RP	5/10	4	6	1.762	3.850
5	2.5	R	5/10	5	3	1.753	3.812
6	2.5	R	5/10	4	4	1.749	3.789
7	2.5	R	5/10	4	3	1.753	3.818
8	2.5	R	5/8	3	5	1.771	3.934
9	10	RP	6/10	3	4	1.753	3.833
10	2.5	R	6/10	4	4	1.750	3.801
11	7.5	RP	6/10	4	0	1.751	3.800
12	7.5	RP	6/10	4	4	1.754	3.848
13	10	RP	7/8	3	3	1.749	3.787
14	7.5	RP	6/10	5	2	1.763	3.875
15	10	RP	7/8	4	4	1.751	3.816
16	10	RP	5/10	5	3	1.756	3.843
17	2.5	R	5/10	3	4	1.766	3.868

GROUP 6 PALE BROWNISH RED

No.	Colour Grade			A/S Al	A/S Sp	R I	S G
1	10	R	8/4	1	6	1.748	3.788
2	5	R	7/8	4	6	1.750	3.918
3	10	R	8/4	2	6	1.769	3.948
4	5	R	8/4	1	6	1.757	3.846
5	5	R	6/8	2	6	1.760	3.892
6	7.5	R	5/10	4	4	1.752	3.820
7	5	R	7/6	4	6	1.751	3.820
8	7.5	R	7/8	4	6	1.753	3.835
9	2.5	R	7/8	3	6	1.751	3.817

GROUP 7 BROWNISH RED

No.	Colour Grade			A/S Al	A/S Sp	R I	S G
1	10	R	6/8	4	5	1.755	3.858
2	10	R	6/8	4	5	1.764	3.924
3	10	R	7/8	4	5	1.760	3.895
4	7.5	R	7/8	4	4	1.746	3.780
5	5	R	7/6	4	1	1.748	3.776
6	10	R	6/10	4	5	1.764	3.902
7	10	R	6/6	3	5	1.769	3.855
8	10	R	6/6	2	5	1.748	3.826
9	5	R	6/8	4	6	1.759	3.894
10	10	R	7/6	3	6	1.761	3.901
11	10	R	7/8	3	5	1.755	3.827
12	10	R	5/8	4	5	1.759	3.848
13	10	R	6/8	3	5	1.760	3.851
14	5	R	6/8	4	3	1.746	3.769
15	5	R	5/10	2	5	1.774	3.958
16	7.5	R	7/8	2	5	1.743	3.786
17	5	R	5/12	4	4	1.761	3.866
18	7.5	R	6/10	4	2	1.745	3.782
19	5	R	6/10	4	5	1.772	3.952
20	10	R	5/8	3	4	1.758	3.848
21	7.5	R	6/10	1	5	1.770	3.930
22	10	R	7/6	2	5	1.759	3.873

GROUP 8 PINKISH ORANGE

No.	Colour Grade			A/S Al	A/S Sp	R I	S G
1	10	R	7/8	1	6	1.761	3.901
2	10	R	7/8	2	5	1.762	3.879
3	10	R	6/8	2	6	1.770	3.937
4	10	R	6/10	2	6	1.766	3.930
5	10	R	7/8	2	5	1.750	3.813
6	10	R	7/8	2	6	1.755	3.844
7	10	R	7/8	1	6	1.753	3.835
8	10	R	6/10	2	6	1.771	3.958
9	10	R	6/10	1	5	1.763	3.924
10	2.5	YR	8/4	1	6	1.756	3.868

KEY

ABSORPTION SPECTRA (A/S)

Al Almandine
Sp Spessartine

INTENSITIES

1. Very faint
2. Faint
3. Weak
4. Medium
5. Strong
6. Very strong

COLOUR GRADING

RP Reddish-purple
R Red
YR Yellowish-red
Y Yellow

GROUP 9 REDDISH BROWN

No.	Colour Grade			A/S Al	A/S Sp	R I	S G
1	10	R	4/10	5	5	1.765	3.928
2	10	R	4/10	3	5	1.754	3.827
3	10	R	4/10	3	5	1.761	3.891
4	10	R	4/10	2	4	1.770	3.917
5	10	R	4/10	3	5	1.770	3.951
7	10	R	4/10	1	5	1.775	3.963
8	10	R	5/10	2	5	1.770	3.953
10	10	R	4/10	3	4	1.764	3.882
11	10	R	4/10	2	5	1.766	3.913
13	10	R	4/10	1	5	1.771	3.940
14	10	R	5/10	1	4	1.779	3.995
15	10	R	5/10	4	3	1.750	3.786
17	10	R	5/10	3	6	1.756	3.847
18	10	R	4/10	3	5	1.764	3.881
20	10	R	4/10	4	6	1.769	3.888
21	10	R	4/10	4	6	1.765	3.886
25	7.5	R	5/12	4	3	1.745	3.754
27	10	R	4/10	0	1	1.747	3.650
28	10	R	5/10	2	4	1.759	3.866
29	10	R	6/10	2	6	1.771	3.967
30	7.5	R	4/12	5	3	1.749	3.791
32	10	R	5/10	2	6	1.764	3.885
34	10	R	5/10	2	6	1.768	3.900
35	10	R	5/10	2	5	1.766	3.954
36	10	R	5/10	2	6	1.766	3.869
37	10	R	5/10	4	6	1.767	3.891
39	10	R	5/10	2	6	1.763	3.896

GROUP 10 REDDISH BROWN

No.	Colour Grade			A/S Al	A/S Sp	R I	S G
6	2.5	YR	6/10	2	6	1.765	3.915
9	2.5	YR	5/10	2	6	1.766	3.917
12	2.5	YR	6/10	2	6	1.773	3.950
16	2.5	YR	6/10	2	6	1.758	3.863
19	2.5	YR	6/12	1	6	1.790	4.074
22	2.5	YR	6/12	4	6	1.769	3.921
23	2.5	YR	6/10	2	6	1.765	3.905
24	2.5	YR	6/10	3	6	1.771	3.950
26	2.5	YR	6/12	2	6	1.782	4.003
31	2.5	YR	6/10	2	6	1.778	4.015
33	2.5	YR	6/12	1	6	1.767	3.926
38	5	YR	6/10	1	6	1.765	3.884
40	2.5	YR	5/10	1	5	1.788	4.049
41	5	YR	7/10	0	5	1.761	3.882
42	2.5	YR	6/10	1	5	1.798	4.141
43	2.5	YR	6/12	0	0	1.742	3.601
44	5	YR	7/8	0	6	1.765	3.909

GROUP 11 GREENISH/ORANGE BROWN

No.	Colour Grade			A/S Al	A/S Sp	R I	S G
1	2.5	Y	7/6	1	5	1.760	3.855
2	2.5	Y	6/8	2	5	1.769	3.905
3	10	YR	7/4	2	5	1.760	3.854
4	5	Y	7/4	1	6	1.770	3.943
5	5	YR	7/6	2	5	1.759	3.851
6	10	YR	7/4	2	6	1.766	3.894
7	5	Y	7/4	3	5	1.765	3.875
8	5	YR	7/6	2	6	1.764	3.885
9	7.5	YR	8/2	1	6	1.759	3.877

GROUP 12 PINKISH GREY

No.	Colour Grade			A/S Al	A/S Sp	R I	S G
1	10	YR	7/2	1	5	1.761	3.889
2	10	YR	7/2	1	5	1.765	3.918
3	10	YR	8/2	1	5	1.750	3.824
4	10	YR	7/2	2	5	1.755	3.855
5	2.5	Y	8/2	2	5	1.765	3.915
6	2.5	Y	7/2	2	6	1.760	3.886

GROUP 13

No.	Colour Grade	A/S Al	A/S Sp	R I	S G
1	Colour grading not feasible	3	5	1.755	3.838
2		3	4	1.756	3.856
3		2	5	1.769	3.919

(5) irregular forms.

It is likely that a number of primary deposits of gem garnet were formed simultaneously under similar but not identical conditions, and that the gems thus formed were and are being concentrated in the valley of the Umba.

The regional geology is complicated and has not been mapped on a scale useful to the gem prospector. Metamorphosed sedimentary rocks predominate in the area and are intruded by numerous pegmatites and ultrabasic bodies. The metasediments themselves give ages of around 550 million years (Ma), the age of the Pan-African Event. By analogy with other areas within the same belt of rocks, the Mozambique Mobile Belt, the pegmatites and ultrabasics may also be of similar age.

The 550 Ma event appears to have been of an unusual nature and determined the physical conditions necessary for the gemmy crystallization of the garnets. The unusual range of chemistries probably resulted from the different lithologies (and therefore chemical environments) provided within the metasediments themselves and in the contact zones between metasediments, pegmatites and ultrabasics. Some of the African prospectors prefer to explore areas in which ultrabasics are in contact with particular beds within the metasedimentary sequence. The metasediments are themselves complex with a repetition of lithologies due to cyclic sedimentation within the original depositional basin. There is also later structural repetition of the beds.

Gem almandine (frequently the rhodolite variety) and spessartine have been reported to exist in primary deposits in the valley, but these deposits were not particularly valuable because of the generally poor quality of the crystallization and the high degree of breakage during extraction. On the other hand, the great majority of garnets found in the secondary environments were of gem quality although many of them were small, spotted or of non-commercial shades. The Umba River area thus provides one more demonstration of the general superiority of weathered rough.

It is possible that some of the garnets were recovered from very deeply weathered primary deposits, 'rotten rock', but that the prospectors thought they were digging in a gravelly soil. Some rhodolites from the area have also been recovered from hard secondary deposits, either silcrete or calcrete, but we do not believe that any of these were in our sample of 204 stones.

Other gems found in the valley include pale and subtle coloured sapphires as well as those of the more usual shades (primary deposit known), brown zircon (primary deposit known), kornerupine (primary deposit known) and pebbles of sillimanite (fibrolite), scapolite, actinolite, tourmaline (several varieties including chromian and vanadian), smoky quartz, sphene (?) and both clino- and ortho-pyroxenes.

CONCLUSIONS

We must emphasize the wide range of composition, colour and colour-change seen in this sample from a limited provenance. Vanadium and chromium appear to be involved in these colour-change effects, but we cannot discount the possibility that cobalt or zinc (both of which we have found in Sri Lanka blue colour-change spinels) have some effect. Rare-earth elements, which are known to cause colour-change in other materials, were not detected, but they may be present at concentrations below the detection limit of the microprobe.

The colour-grading presented many problems and in any similar exercise with pleochroic gem minerals, especially those cut and set in jewellery, there would be considerable difficulties.

It is a pleasure to acknowledge ready assistance from our colleagues in the Institute and discussions with them and with other good friends.

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LIDDICOATITE, A NEW GEM TOURMALINE SPECIES FROM MADAGASCAR

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INTRODUCTION

Tourmaline is a group name for six individual species. The general formula can be written as:

$$(X)_1(Y)_3Al_6B_3Si_6O_{27}\,(O,OH)_3\,(OH,F)$$

wherein sodium, Na^{1+}, usually occupies the 'X' position in the formula.

Four of the six species are defined on the basis of the dominant cation in the 'Y' position of the formula. For example, if the 'Y' position is occupied by ferric iron, Fe^{3+}, the species is buergerite which has little gem significance. If the 'Y' position is occupied by ferrous iron, Fe^{2+}, the species is schorl, which is of little gem use but is rarely encountered as mourning jewellery. If the 'Y' position is occupied by aluminium and lithium (Al,Li), the species is elbaite, and this is the gem tourmaline most often encountered as green and pink gems. If magnesium, Mg^{2+}, occupies the 'Y' position, two species are possible: dravite in which sodium, Na^{1+}, occupies the 'X' position, and uvite, in which Ca^{2+} occupies the 'X' position

The discovery of the substitution of calcium for sodium in the magnesium tourmalines led logically to a systematic search for calcium analogues of the other tourmaline species. The calcium analogue of schorl was sought for but not found (Dunn *et al.* 1977*a*.). The possibility for a calcium analogue of elbaite did still exist but was unlikely inasmuch as lithium/aluminium tourmalines are almost always found in sodium-rich pegmatites. This paper is written to report on the discovery of this sought-for calcium lithium/aluminium tourmaline. A more technical description of this new tourmaline is given by Dunn *et al.* (1977*b*).

LOCALITY

The new tourmaline is found in Madagascar. The exact locality cannot be stated with precision since the material did not

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come from a particular mine or deposit but was found as detritus in the soils near Antsirabe, in Madagascar. For detailed descriptions of the pegmatites of the area and the tourmaline crystals, the reader is referred to the work of Lacroix (1893, 1922) and Duparc *et al.* (1910).

We have named this new tourmaline liddicoatite in honour of Richard T. Liddicoat, the President of the Gemological Institute of America. Mr Liddicoat's contributions to gem knowledge and gemmological education have been enormous, and we are most happy to take this humble step and name this new tourmaline in his honour.

CHEMISTRY

Liddicoatite is ideally

$$Ca(Li,Al)_3Al_6B_3Si_6O_{27}(O,OH)_3(OH,F),$$

being the calcium analogue of elbaite,

$$Na(Al,Li)_3Al_6B_3Si_6O_{27}(O,OH)_3(OH,F).$$

Calcium, Ca^{2+}, substitutes for sodium, Na^{1+}, in this mineral and the charge balance is accomplished through adjustment in the lithium/aluminium ratio. Wet chemical analyses of gem liddicoatite and gem elbaite from Madagascar are given in Table 1. Sample #135815 is the purest liddicoatite found in this study and is the type specimen which is in the collection of the Smithsonian Institution. The other samples are of gemmy crystals intermediate in composition between liddicoatite and elbaite, as is readily seen by comparison of their calcium/sodium content.

PHYSICAL AND OPTICAL PROPERTIES

The density of liddicoatite varies from 3.00 to 3.07 g/cm³. The density of the type specimen, #135815, is 3.02 g/cm³. Liddicoatite, like elbaite, is uniaxial (—). The refractive indices, determined in sodium light are $\varepsilon = 1.621$, $\omega = 1.637 \pm 0.003$, with a birefringence of 0.019. The mineral has strong pleochroism with $\omega > \varepsilon$. Liddicoatite specimens examined to date do not exhibit any response to ultra-violet or x-radiation. The hardness of liddicoatite is 7-7½ (Mohs). The above refractive indices apply only to the type specimen. The refractive indices of tourmalines depend on the amount of iron, manganese and chromium in the crystal (Deer *et al.* 1962) and thus are of little use in determining the composition of gem tourmalines. In summary, liddicoatite, like uvite, cannot be

Table 1

Wet Chemical Analyses of Liddicoatite and Elbaite from Madagascar

	#135815 Brown	#136517 Pink	#136518 Green
SiO_2	37.7	37.0	37.9
Al_2O_3	37.9	37.3	39.5
TiO_2	0.38	0.01	0.05
FeO	0.83	0.05	2.25
MnO	0.27	4.58	0.67
MgO	0.11	0.02	0.03
CaO	4.21	2.15	0.45
Na_2O	0.88	1.44	2.02
Li_2O	2.48	1.82	1.83
F	1.72	1.47	1.34
B_2O_3	10.89	10.69	10.38
H_2O+	2.69	2.54	2.46
Total	100.06	99.07	98.88
O=F	0.72	0.62	0.56
Total	99.34	98.45	98.32

J. Nelen
Chemist

determined on the basis of physical or optical properties. This is somewhat frustrating inasmuch as both gem elbaite and gem liddicoatite come from Madagascar. It is with some regret that the authors must present a new gem species which cannot be differentiated from elbaite using standard gemmological techniques. At the present time, only chemical analytical methods suffice for characterization of the species. It is hoped that in the future there will be other techniques which will be available to the gemmologist for differentiation between the species.

ZONED MADAGASCAR LIDDICOATITE

The Madagascar tourmalines have long been noted for their beautiful colour zoning. This zoning (Figure 1) is further notable in that it is parallel to a pyramid of the crystal instead of the more common colour zoning in tourmalines, which is parallel to the pedion or prism. One drawback of this type of zoning is that zone

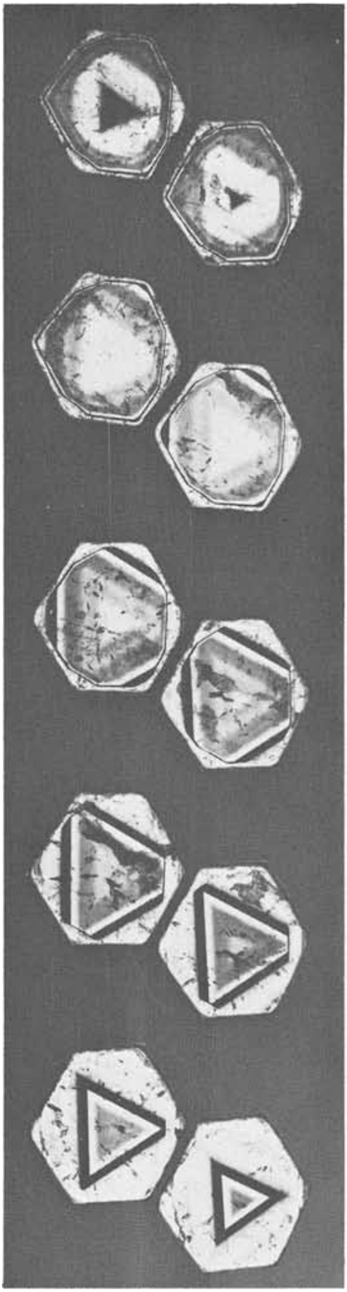

Fig. 1. Zoned Madagascar Liddicoatite sections cut parallel to the basal pinacoid.

margins appear fuzzy when a cross-section normal to the *c* axis is viewed parallel to the *c* axis. Nonetheless, the effect is quite striking and the specimens are very beautiful. A large number of such zoned sections were analysed using an electron microprobe and wet chemically analysed tourmalines as standards. The results of this analytical study indicate two points of interest.

Firstly, the sodium/calcium ratio, or one might as well state the elbaite/liddicoatite ratio, does not vary appreciably from colour zone to colour zone. Hence the crystals are usually one species throughout.

Secondly, the colour zoning is related to the amounts of iron and manganese in the respective zones. Hence, the species cannot be determined on the basis of colour. The preponderance of the analytical data suggests that most of these zoned Madagascar tourmalines are liddicoatite. Hence, it is best to call all these zoned crystals liddicoatite.

Further research on these crystals is now under way and may result in more knowledge about the nature of this beautiful tourmaline.

ACKNOWLEDGEMENT

Special thanks are due Mr Richard T. Liddicoat for permitting us to name this species in his honour and for his outstanding contributions to the great store of gem knowledge.

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NOTES ON THE OCCURRENCE AND MINERALOGY OF EMERALDS IN RHODESIA

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I INTRODUCTION

Emeralds were first discovered in Rhodesia in October, 1956, in the southern part of the Archaean Craton on the south side of the Mweza Greenstone Belt, Belingwe District, 5.2 km west-south-west of the confluence of the Nuanetsi and Sungai Rivers (Martin 1963). This material, marketed under the name 'Sandawana', is from the Zeus Claims now owned and operated by Rio Tinto (Rhodesia) Ltd. The emeralds tend to be small but have earned a world-wide reputation for their superior colour and quality. In 1958 emeralds were discovered in the Filabusi Greenstone Belt, and in 1960 emeralds were found associated with chrysoberyl in an extension of the Greenstone Belt north-west of Fort Victoria. These three greenstone belts have produced the only stones of marketable quality, and numerous claims are held in each area. Emerald occurs in other parts of the country, but the stones are of poor quality and at present are only of academic interest.

Many claims that produced emeralds are now only of historical interest whereas others are being currently investigated, but from geological evidence there is every reason to anticipate further significant discoveries. None of the abandoned or current claims have produced stones of the quality of the Zeus material.

II GENERAL GEOLOGY

Emerald, a chromiferous variety of beryl, is found in a restricted geological environment where beryllium-bearing pegmatites intrude rocks of ultramafic composition. It occurs as euhedral, pale green, hexagonal prisms in pegmatites, aplites, quartz stringers, quartz-feldspar and feldspar veins and as deep green porphyroblasts in the altered ultramafic rocks surrounding the veins. The ultramafic rocks are serpentinites or schists consisting predominantly of tremolite-actinolite, chlorite or talc derived by regional metamorphism from peridotitic intrusions and lavas believed to belong to the lower part of the Archaean Bulawayan Group.

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The beryllium-bearing pegmatites in the emerald localities are derived from the 'younger', intrusive granites dated at 2 650 m.y. (Phaup 1973). They are the Chilimanzi and Chibi adamellites in the Victoria and Belingwe Districts respectively and a small porphyritic adamellite which intrudes the southern margin of the Filabusi Greenstone Belt. The fluids produced during the pneumatolitic phase of pegmatite formation are predicted to have had temperatures of between 750 and 580°C and were intruded under pressure into the ultramafic schists causing local metasomatism.

The incorporation of chromic oxide from the ultramafic host rock into the crystallizing beryl resulted in the deep green emerald colour. Tremolite may have recrystallized during the injection phase but the most common metasomatic effect is an alteration of the ultramafic schists to phlogopite-biotite schists.

From the limited amount of observation on the emerald matrix material it can be determined that a sequence of alteration events affecting the host rock is dependent upon the chemistry of the invading fluid. If it is potassium rich the tremolite-actinolite rocks in the vicinity of the resulting veins are altered to phlogopite-biotite schists. The deposit then consists of thin pegmatite or quartz veins and lenses surrounded by black micaceous schist which grades outwards into less altered greenish-coloured ultramafic schists.

At Coen's Luck Claims (Filabusi) the potassic phase was followed by the introduction of boron, which led to the formation of zoned tourmaline prisms which grew across the foliation of the mica schists. The final phase was the introduction of beryllium-bearing fluids and the ultimate crystallization of beryl in both pegmatite and the surrounding schist. During this process the first-formed and pre-existing (protogenetic) minerals are usually included syngenetically in the beryl crystals.

Potassium metasomatism of the host rocks is well-developed in all three districts but in the Belingwe District emeralds are not confined to the phlogopite zones. Tremolite and tremolite-chlorite schists are reported to be the host rocks at the Zeus Claims (Phaup 1959, unpublished report) and at the Kanya Hlaza Claims emerald occurs in a tremolite-plagioclase rock. Potassium metasomatism was therefore not a controlling factor in the location of emeralds in these deposits although many other deposits in the district are characterized by phlogopite schist. It is possible that the fluids were soda-rich and as such have no marked metasomatic effect on the ultramafic rocks. In the emeralds from the Belingwe District inclusions of phlogopite are rare or absent, whereas in the stones from Filabusi they are more common and from the Victoria District are abundant.

The crystallization of beryl in the schists away from the pegmatites implies that beryllium fluids were mobile and the degree of molecular migration from the fluid channels was considerable. The beryl which formed within the pegmatite or quartz veins may be a very pale emerald green and only the porphyroblasts enclosed by the phlogopite schist (or tremolite schist in the case of the Zeus Claims) have the deep green emerald colour and are potentially of gem quality.

III INCLUSIONS

The study of emerald inclusions is in its infancy, but it can be demonstrated that every stone is unique in the form and content of its inclusions. Mineral inclusions are similar in emeralds originating from the same geological province but are different from those in deposits from other areas. The identification of mineral inclusions, their form and abundance, considered in conjunction with optical constants, which vary from area to area, forms the basis for the distinction of one emerald province from another.

The most important occurrences of emerald in Rhodesia originate from the Mweza, Victoria and Filabusi Greenstone Belts and material examined from these areas is listed as follows:-

Mweza Greenstone Belt (Belingwe District)—Zeus (Sandawana); Kanya Hlaza and Athens; Maharani and Vidan Claims.

Victoria Greenstone Belt—Novello; Twin Star; Chikwanda; Popoteke; Mayfield and Renders Claims.

Filabusi Greenstone Belt—Flame Lily; Mustard and Coen's Luck Claims.

For comparative purposes the properties of emerald beryl of academic interest only from the I Wonder Claims (Karoi), Makanga Claims (Salisbury), Sabtri Claims (Buhera) and Mush Claims (Soti Source) are included.

The classification of the inclusions in emeralds is a genetic one and is based on that used by Gübelin (1974). Three classes of inclusions are recognized: protogenetic, syngenetic and epigenetic. Protogenetic inclusions are all pre-existing minerals that were included in the emerald during crystallization. Syngenetic inclusions are predominantly liquid which is contained in cavities (vacuoles) that form during, or after, the growth of the emerald. Other syngenetic features are colour zoning and the crystallographic control of the inclusions of protogenetic minerals. Epigenetic features, which include twinning and exsolution phenomena, are of no significance in Rhodesian emeralds.

PROTOGENETIC INCLUSIONS

These are all mineral inclusions and they may be further subdivided into (a) minerals formed by earlier regional metamorphism unrelated to the introduction of beryllium fluids, (b) minerals formed during metasomatism immediately prior to the crystallization of beryl.

Although some recrystallization of tremolite is postulated (Phaup 1959, unpublished report) the majority of the tremolite-actinolite was probably formed by regional metamorphism of the ultramafic rocks prior to the introduction of the beryl. These amphiboles are the most common protogenetic inclusion and exist as bundles of acicular and columnar crystals within the emerald porphyroblasts in all the material examined from the Belingwe and Filabusi provinces. It is therefore not a diagnostic mineral inclusion of Sandawana material as suggested in published reports of that material (Gübelin 1956). Colourless micas, chlorite and talc are also likely to belong to an earlier phase of regional metamorphism.

Phlogopite and biotite micas are the most common inclusions of minerals formed during the metasomatic alteration immediately before the introduction of beryl. They are therefore regarded as being related genetically to the same phase of events that introduced the beryl into the ultramafic rocks. The micas occur as ragged and corroded platelets and usually show a random distribution within the emerald. They are a common feature of Victoria emeralds, are less common in the Filabusi emeralds and occur only rarely in the Belingwe material (Kanya Hlaza and Vidan only). Rare euhedral booklets of mica occur in the emerald from Kanya Hlaza. Apart from the metasomatic development of the mica, the following minerals are considered to be related to this generation of protogenetic inclusions:- garnet (Zeus), haematite and other iron oxide minerals (Zeus, Mustard, Kanya Hlaza), plagioclase euhedra (Zeus, Vidan, Kanya Hlaza), tourmaline (Coen's Luck, Mustard), and rutile (Coen's Luck, Mustard, Zeus, and Kanya Hlaza).

SYNGENETIC INCLUSIONS

Syngenetic features are those that occurred during the crystallization of the beryl and are predominantly liquid in nature. The liquid is contained in vacuoles of varying shape and size that formed at different stages of the crystal's growth. The liquid inclusions may be further subdivided into primary and secondary inclusions depending upon the age of the containing cavity. The incorporation of protogenetic minerals into the crystal is a syngenetic feature and occasionally there is some crystallographic control, although more frequently the protogenetic minerals show a random habit within the host crystal. Colour zoning, a rare feature in Rhodesian emerald, was observed in the Mayfield, Zeus and Kanya Hlaza material. Pale and deep-green zones, forming alternating bands parallel to the hexagonal prism faces, imply fluctuations in the availability of the colouring pigment, chromic oxide.

Primary Syngenetic Cavities

'Fissuring' is the development of tubular cavities, also termed 'negative crystals', parallel to the principal crystallographic axis (C), giving the crystals a striated appearance. This feature is also common in the aquamarine variety of beryl. During the development of the crystals, there were fluctuations in the supply of the requisite molecules to the growing crystal faces, and in place of a planar surface being formed, a skeletal face with subtraction structure faults develops. These growth tubules remain as cavities and enclose a liquid (primary liquid inclusions) from which a gaseous phase may separate out and remain as a gas libella within the tubule, producing what is termed a two-phase inclusion. The tubules sometimes run the entire length of a crystal and may therefore be several millimetres long. They are of primary origin and are a feature of most Rhodesian emeralds particularly those from Mustard and Novello Claims.

Cavities with square or rectangular outline, are also a common feature in Rhodesian emeralds and are regarded as having the same origin as the tubules. They are crystallographically controlled and are smaller in dimensions than the tubules, being of the order of 20-30 μm in length. The longest cavity measured was 40 μm, containing a gas libella of 25 μm diameter.

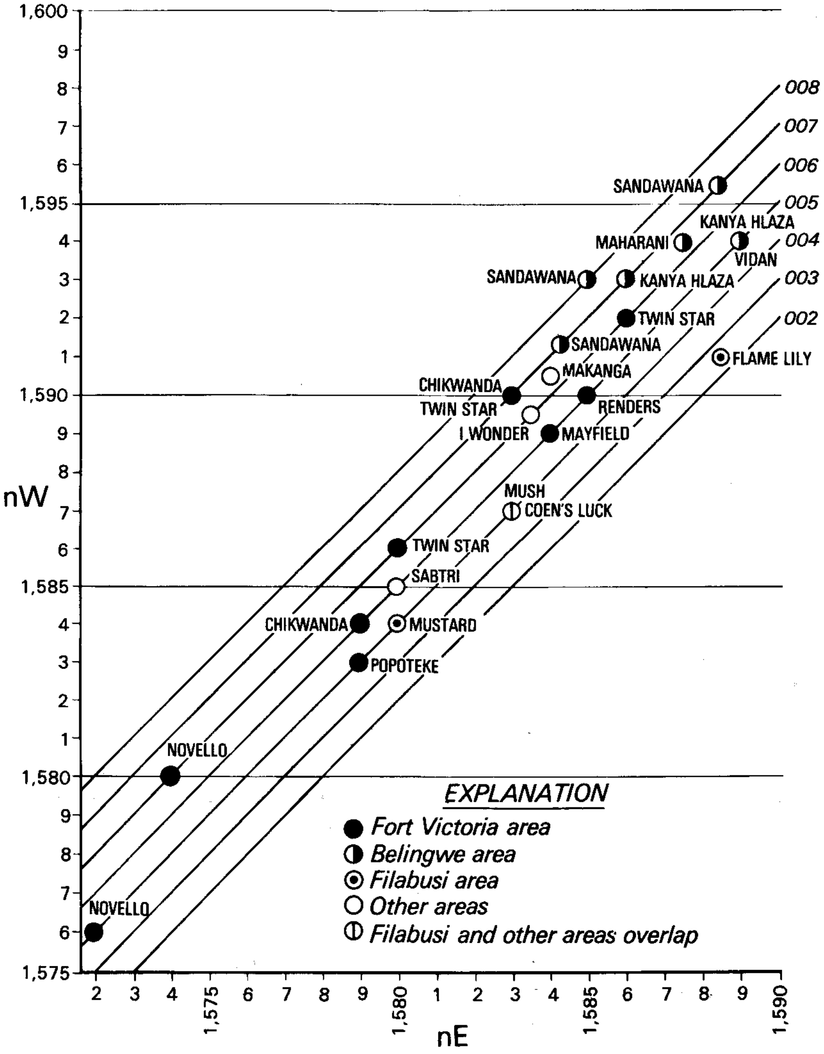

Fig. 1 *REFRACTIVE INDICES OF RHODESIAN EMERALDS*

Secondary Syngenetic Cavities

'Healing fissures', 'feathers' and 'peppering' are features usually showing little or no crystallographic control in their development. During the growth of the host crystal flaws develop where tensions exist: in some emeralds there is a tendency for these flaws to develop parallel to the basal plane (0001), but generally they exist as twisted and random planes. Coupled with the formation of the flaws is the healing process whereby the flaw is bathed in the mother-fluid by capillarity some time after its development. The flaw becomes partially healed, the crystal continues to grow, but some residual fluid remains trapped in the crack and manifests itself in a variety of forms producing (a) 'feathers'—fimbricated liquid droplets, (b) 'healed fissures'—lacey and fan-like liquid patterns, (c) 'peppering'—droplets of ultramicroscopic dimensions showing rounded or tadpole-like forms usually containing a gas libella. The size of the 'peppering' cavities is very small, 20μm and less, and in their aggregated habit they give an impression of dust. They are regarded as the most advanced state of the healing of the flaws whereby the smallest amount of residual liquid remains in the form of isolated droplets. All emeralds so far examined from Rhodesia contain liquid inclusions, and 'peppering' is common to all. The intermediate healing stage is represented by the feathers or fingerprint variety, and where minimum healing has occurred the healed fissure structure is formed. Healed fissures were observed in emeralds from Zeus, Kanya Hlaza, Chikwanda, Popoteke and Flame Lily Claims. 'Peppering' is observed around garnet inclusions in the Zeus emerald, and it is suggested that the inclusion resulted in crystal tension and the formation of a flaw, that was later partially healed.

IV OPTICAL PROPERTIES

Table 1 shows the optical constants of the emeralds examined and a description of their inclusions. The refractive indices were determined by oil immersion techniques, utilizing sodium light and the readings were made on a Leitz-Jelley refractometer.

The optical constants are plotted graphically in Fig. 1, and it may be seen that material originating from the Belingwe province has the highest optical constants of all the emeralds examined.

TABLE 1

REFRACTIVE INDICES AND CHARACTERISTICS OF RHODESIAN EMERALDS

Province	Claim	nE	nW	DR	Inclusions
Victoria	**Novello**	1.572	1.576	0.004	'Peppering'—dense aggregations of minute cavities (5-8μm), some of which contain a gas libella. Brown mica platelets. Polygonal, square and rectangular cavities with two-phase inclusions arranged in trails. Fine negative crystals (tubules). SG 2.71-2.74 (Martin 1963).
Victoria	**Novello**	1.574	1.580	0.006	As above.
Filabusi	**Mustard**	1.580	1.584	0.004	Mineral inclusions:- muscovite and phlogopite platelets plentiful. Rutile and profuse peppering of an opaque, euhedral mineral. Rare acicular mineral—possibly amphibole, appears to be hollow, unlike the amphibole from Belingwe material. Tourmaline occurs very rarely. Ilmenite platelets.
Victoria	**Popoteke**	1.579	1.583	0.004	Typical Fort Victoria material—'peppering'—profuse in planes and trails. Parallel 'fissuring' and at right angles—liquid fingerprints. Larger tabular and irregular liquid-filled cavities—some with gas libellae.
Victoria	**Chikwanda**	1.579	1.584	0.005	'Peppering' by minute liquid inclusions as in Novello material. Fan-shaped healed fissures. Ragged colourless mica. (Martin 1963).
Buhera	**Sabtri**	1.580	1.585	0.005	Material not of gem quality. Phlogopite platelets common. 'Peppering' by liquid droplets. The peppering is crystallographically controlled—more or less parallel to (0001). Healed fissures.
Soti Source	**Mush**	1.583	1.587	0.004	'Peppering' and tubular negative crystals parallel to the prismatic faces. Colour zoning evident. Fort Victoria characteristics. No mineral inclusions noted. The material is not of gem quality.
Filabusi	**Coen's Luck**	1.583	1.587	0.004	'Peppering' and 'feathers' with two-phase inclusions. Amphibole is common as an inclusion; unlike the material from Mustard. Some amphibole is curved and acicular in form. Rare colourless mica. No euhedral opaque material that is found in the Mustard stones. Tourmaline occurs in matrix but rarely as an inclusion. Phlogopite inclusions are common.
Karoi	**I Wonder**	1.5835	1.5895	0.006	Prominent two-phase inclusions (20-30μm) each cavity containing a gas libella. The cavities are usually square or rectangular in outline and they are arranged in trails-reminiscent of Nihame (Mozambique) material. No gem quality material.
Victoria	**Chikwanda**	1.583	1.590	0.007	As for above Chikwanda.
Victoria	**Mayfield**	1.584	1.589	0.005	'Peppering'. Larger two-phase inclusions with irregular (tadpole-shaped) and polygonal forms. Rare brown mica platelets. Rare needle-like mineral not identified. Healed cracks and fan-shaped liquid inclusions. Colour zoning.
Belingwe	**Sandawana**	1.5843	1.5913	0.007	Acicular tremolite in dense bundles and masses, sometimes curved. It is finer in form than the Habachtal (Austria) material. Other mineral inclusions are:- limonitized garnet, haematite tablets, rutile, decomposed feldspar and magnetite. Parallel pattern of 'shadows' caused by 'fissure' system parallel to (0001). Two-phase inclusions with geometrical form are present and tabular negative crystals. 'Peppering' is present. 'Resorbed garnet'—clusters of opaque material and liquid droplets around the garnet. SG 2.7436. (Gübelin 1958).
Shamva	**Makanga**	1.584	1.5905	0.007	No gem quality material. 'Peppering'; the cavities are rounded or irregular in form.
Victoria	**Renders**	1.585	1.590	0.005	'Peppering' very conspicuous. No mineral inclusions seen. No gem quality material.

Victoria	**Twin Star**	1.586	1.592	0.006	'Peppering' and 'fissuring'. Opaque rounded platelets. Colourless mica inclusions.
Belingwe	**Kanya Hlaza**	1.586	1.593	0.007	Myriads of tremolite needles, very characteristic, somewhat broad and blade-like although some are hair-like. 'Peppering' roughly parallel to (0001). Lacey, healed fissures. Fine 'fissuring'. Phlogopite platelets in some material, often with lozenge form. Feldspar euhedra common in samples containing mica. Rare rutile euhedra.
Belingwe	**Maharani**	1.5875	1.5940	0.006	Very prominent amphibole inclusions, as with all Belingwe material. Variable in size up to 0.53 mm in length and 0.09 mm wide, often opaque material is present within the amphibole. Patches of liquid droplets, some of which are two-phase-'peppering'. No other mineral inclusions were seen other than the amphibole.
Belingwe	**Sandawana**	1.5884	1.5955	0.007	As for above Sandawana.
Filabusi	**Flame-Lily**	1.5885	1.5910	0.004	Amphibole needles are fairly common, the form varies from acicular to stumpy. Phlogopite present in some material. The amphibole is usually fairly densely aggregated. Two-phase inclusions in rectangular and square outline cavities arranged in planar manner. Feathers of liquid inclusions. Iron-stained, healed fissures. Anhedral opaque material.
Belingwe	**Vidan**	1.589	1.594	0.005	To the author's knowledge, no material has been cut from these claims. The colour and inclusions are typical of Belingwe material. 'Peppering'. Tremolite needles are common and phlogopite platelets were noted but are rare. Iron-stained healed fissures. Rare feldspar euhedra were noted.

V CONCLUSIONS

From this preliminary examination of emeralds from Rhodesia, although only a limited amount of material was available for comparative purposes, it is considered that a basis does exist for identifying the stones from a particular geological province. Local variations in optical constants and mineral inclusions are not considered valid for distinctions to be made about individual deposits within the geological province.

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COPPER BEARING AVENTURINE ZEOLITE: AN OCCURRENCE IN INDIA

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In 1969 Mr M. G. Brahmbhatt, then Assistant Geologist, reported a native copper occurrence near Jalampura (23°22′47″N: 73°9′30″E) and reported as under:

'Copper occurs as native copper near Jalampura village. In a well section about 0.5km N. 60° of Jalampura village the presence of native copper is noticed in excavated material. Between two different lava flows there is a loose formation in which such mineralization is observed at a depth of about 18 metres (approximately).'

The present author visited the area and found that the native copper occurrence occurring at the above area has the significance that, for the first time in India, cuttable transparent zeolite with native copper inclusions is reported. Similar occurrences are also rare; perhaps as a spangled gem this may be a unique occurrence. Some of the zeolites which contained more copper inclusions and showed a spangled appearance were cut as cabochons. A spangled effect similar to aventurine structure was noticed in them.

Zeolite crystals occur as cavity fillings and veins in loose intraformational pyroclastic material. Thin blebs and wires of native copper are found in fully transparent to somewhat fractured whitish crystals of analcime associated with above rocks. Brahmbhatt states that copper mineralization evolved during the time of crystallization and native copper occurs as hydrothermal and metasomatic deposits filling cracks, fractures, and as replacement in basic flows.

The transparent oily-looking zeolite posed identification problems. Earlier the mineral was presumed to be a variety of quartz (cristobalite). Later on work at the Institute of Geological Sciences in London by E. A. Jobbins showed that the enclosing material has RI≈1.487 with some grains showing anomalous birefringence of the order of 0.001, and he reported that it was analcime. Further work on samples in India showed that the almost

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copper-free transparent host mineral has the following chemical composition and has given the following x-ray data:

Chemical Composition (Host Mineral)		*X-ray Data Host Mineral*		
		Peaks in order of their intensity d values in Å	Intensity	Remarks
SiO_2 -	54.52			
Fe_2O_3 -	0.55	1. 3.42	8.3	Sharp peak
AL_2O_3-	22.25	2. 5.60	5.1	,,
TiO_2 -	0.15	3. 2.91	4.1	,,
CaO -	2.67	4. 9.8	2.6	diffused composite peaks at less than 9.8
MgO -	0.25	5. 1.74	1.35	Sharp peak
L.O.I. -	8.04	6. 2.68	1.38	,,
Na_2O -	10.96	7. 4.82	1.2	,,
K_2O -	0.06	8. 1.901	1.15	,,
Cu -	0.81			
Total -	100.26			

(Analyst: Mr H. K. Navadia under guidance of Mr V. G. Malkan)

Thus the copper-bearing mineral is Analcime.

DISCUSSION ON THE WORD 'AVENTURINE'

A discussion on whether to call these stones 'aventurine zeolite (analcime)' is perhaps necessary. Herbert Smith (1958) indicates that aventurine structure is reminiscent of a glass containing copper crystals. While describing the aventurine structure in quartz he states that when the included substance consists of mica, haematite or other flaky mineral the result is a vivid spangled appearance.

In the market it is freely available as an artificially created stone of glass in which copper filings appear to have been added.* Natural aventurine quartz and feldspars are encountered frequently. The vivid spangled appearence is often caused by haematite or mica.

Possibly the term aventurine is restricted to these two minerals only (Ostwald 1955). Sinkankas (1959) however gives aventurine willemite occurrence in U.S.A. and uses the term aventurescence in the same sense, defining the term as 'Reflections of light from numerous small wafer-like inclusions of foreign minerals within a host gemstone, which act like tiny mirrors and give rise to the effect known as aventurescence, and such stones are called aventurines. The minute brilliant spangles are usually exceedingly thin crystals of haematite, goethite, or mica.'‡

In the present sample the spangled effect is evident in the samples which are rich in copper. The effect is mainly caused by flat sided 'veinlets' of copper acting in a manner similar to flakes: less commonly reflections by flakes are also noticed. The present author and Mr Sinkankas prefer the term 'aventurine zeolite' for the above gem. Hence the term aventurine is used realizing that this sample may not be termed as aventurine *in sensu stricto.* The reason for use of the term is the spangled effect seen in the sample.

OTHER OCCURRENCES

Looking for similar occurrences, we find that

(1) Native copper occurrences have been reported from Keweenaw peninsula in North Michigan and also at White Pine, Michigan (Lake Superior), Arizona, and New Mexico in the U.S.A., Chile, Bolivia, Mexico, etc.

(2) Pinkish prehnite, pink colour being imparted by finely disseminated blebs of native copper, has been reported by Surdam (1968) from Vancouver Island. Stoiber and Davidson also reported a similar occurrence in the Michigan copper district.

(3) Recently in the peninsula of Saurashtra, Gujarat State, India, the Directorate of Geology and Mining has reported native copper occurrences at villages:

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*The copper inclusions are usually produced by reduction in the glass-making process.

‡Dr Joel Arem in his *Encyclopedia of Gemstones* (Van Nostrand, 1977) refers to 'aventurescence' as 'sparkly effect due to reflection off parallel included flakes'.

(i) Raipur 21°25′48″N: 70°26′0″E

(ii) Isharpur 21°30′10″N: 70°33′0″E and

(iii) Choklu 21°36′25″N: 70°32′05″E

all in Junagadh district. The available information on these occurrences shows that they are all similar and the common factors are as follows:

(a) The occurrence of copper is confined to a depth of approximately 50′-60′ beneath the surface. These have been confined from the debris of well cuttings in the area.

(b) The occurrence is associated with compact, grey, amygdaloidal, highly weathered basalt.

At the occurrence near Raipur small disseminations of the native copper in infillings of zeolites can be seen. (The author wishes to take up work on these at an early date).

(4) Roy (1953 a and b) states that a native copper occurrence near Mojdam contains copper infillings in minor calcite veins and infillings of various types of zeolites. It is noted that so far fully transparent cuttable material has not been reported. (Sinkankas, personal communication).

CONCLUSIONS

For the first time in India, a copper-bearing zeolite is cut as a gem which resembles aventurine in structure. If fully transparent zeolites are encountered with sizable native copper they can be cut as cabochons resembling 'goldstone' (artifically created stone of glass with included copper). Other possible occurrences in India and U.S.A. are also pointed out. The author has noticed that samples having more copper are more pleasing and give a spangled appearance similar to aventurescence.

ACKNOWLEDGMENTS

Thanks are due to Dr R. T. Shukla for permission to publish this paper. Thanks are also due to Shri Kantilal Rajput for preparing cabochons cut out of the samples. The author expresses his gratitude to Dr A. B. Mukherjee, of the Indian Institute of Technology, Kharagpur, for interpreting the x-ray data.

It is a pleasure to acknowledge the generous assistance received from Shri K. S. Patel and Shri B. K. Jhaveri for general help during the work.

Thanks are also due to Mr E. A. Jobbins, of the Institute of Geological Sciences, London, and Mr John Sinkankas, of U.S.A., for correct identification and discussion of the paper.

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A VISIT TO SRI LANKA, TAIWAN AND THAILAND

By K. W. FINDLAY, B.Sc(Eng.), C.Eng., F.I.Chem.E., F.I.Mech.E., F.G.A.

Some three thousand years ago the Queen of Sheba is alleged to have been adorned with jewels from Sri Lanka given to her by King Solomon when his trading ships returned from the East. Later Ptolemy, twenty-one centuries ago, mentions beryl, sapphires and gold from that island, and Marco Polo (thirteenth century A.D.) describes a fantastic ruby possessed by the King of Sri Lanka.

There seems no doubt that Sri Lanka, (previously Ceylon, formerly Taprobane and also Serendip) has been a source of some of the finest gems for three thousand years, and today it is still a source of an enormous variety — andalusite, beryl (aquamarine), chrysoberyl (alexandrite and cymophane), cordierite, corundum (ruby and sapphire), feldspar (moonstone), garnet (almandine, hessonite and pyrope), kornerupine, quartz (amethyst and cat's-eye), sinhalite, spinel, topaz, tourmaline, zircon.

It would appear that the method of recovery has changed little over the millenia. There are three types of gem-bearing alluvial deposits or 'illam'—those in which the gems occur in relatively shallow soils, those in river course gravels and those in the lower gravels lying on bed rock. Pits or shafts up to 30m deep are sunk to the gem-bearing layers and these are excavated by a type of hoe and hoisted to a surface dump in a wicker basket by using a windlass. The mining and hoisting are done in the morning and after lunch the same team carries out the washing, concentration and sorting. Using the hoe, batches from the dump are scraped into a hemispherical basket, which is handed to the washers who stand waist deep in muddy water, contained in a trench. The basket is given a rotary and jigging motion so that the higher specific gravity minerals settle to the bottom of the basket, whilst the lighter gangue can be flicked over the edge of the basket into a waste dump. When the concentrating process has eliminated a large proportion of waste the basket is taken out of the water and the contents raked over by hand to pick out the potential gem material, by a sorter with an experienced and uncanny eye. One of the few

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Fig. 1. Washing gem gravel, Sri Lanka.

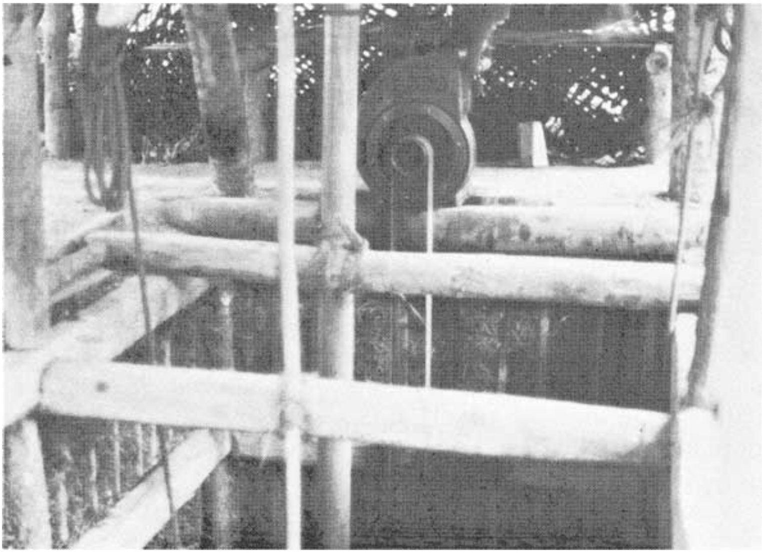

Fig. 2. Pit head, Rakwan river area, Sri Lanka. Lister engine for driving pump.

Fig. 3. Ancient method of polishing, Sri Lanka.

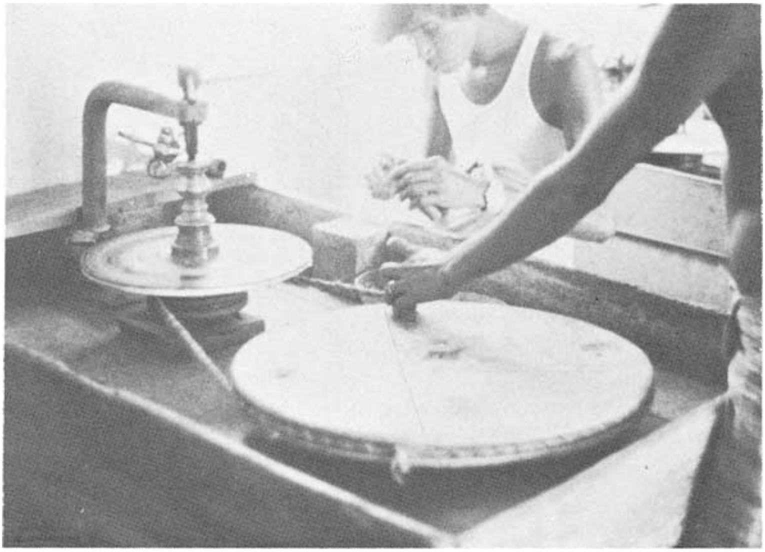

Fig. 4. Polishing lap, Sri Lanka.

modern improvements is the dewatering system. Today a centrifugal pump, driven by a petrol or diesel engine, is used.

Some gems are still polished by ancient methods—the stone being held in the left hand against a leather pad mounted on an oscillatory-rotating wooden disc, attached to one end of a horizontal shaft over which an affixed concentric wooden cylinder is rotated by a bowstring reciprocated by the right hand. An improvement used today is a vertical spindle lap hand-powered by an assistant.

All gem lands are under control of the State and leases are awarded by the tender system. The lessee pays the lease fee, and provides all the equipment and the consumable stores and takes half the proceeds of sale of rough gems as his share, whilst the team of workers who provide the labour divide the other half amongst themselves. Restrictions do not allow for the export of any rough stone which could be faceted and be of commercial value. Certain mineral specimens for study purposes or collectors' items may be granted an export clearance.

Buddhism is almost universal in Thailand whereas only two thirds of Sri Lankans are adherents. In Bangkok, Thailand, there are two images of Buddha which are rather outstanding.

One called the Emerald Buddha has been described as being 61 cm high of translucent green jasper, but another more comprehensive and probably more reliable description is that it has a lap width of 48.3 cm and its height from the base to the top of its head is 66 cm and the crystal belongs to the monoclinic system in the pyroxene group, its hardness is between 6.5 and 6.7 and its specific gravity is between 3.33 and 3.35.* That is the strongest indication that it is Jadeite.

Then there is the Gold Buddha which is reputed to have a mass of 5000 kg of pure gold. This statue is some 2.44 m high and about 1 m across the lap. The remarkable aspect is that it is housed in a very small temple just off the road and is unguarded: the value at the present gold price would be nearly 22 million U.S. dollars.

Taiwan Jade, which is really nephrite, is becoming an increasingly important minor industry. Carvings, figurines, statuettes, bead necklaces and bangles are all processed in small factories, some adapted from residential flats which are still used

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*Printed on the back of a picture-postcard of the Emerald Buddha, in winter attire, sold at the Grand Palace, in the grounds of which the Wat (temple) Phra Keo is located.

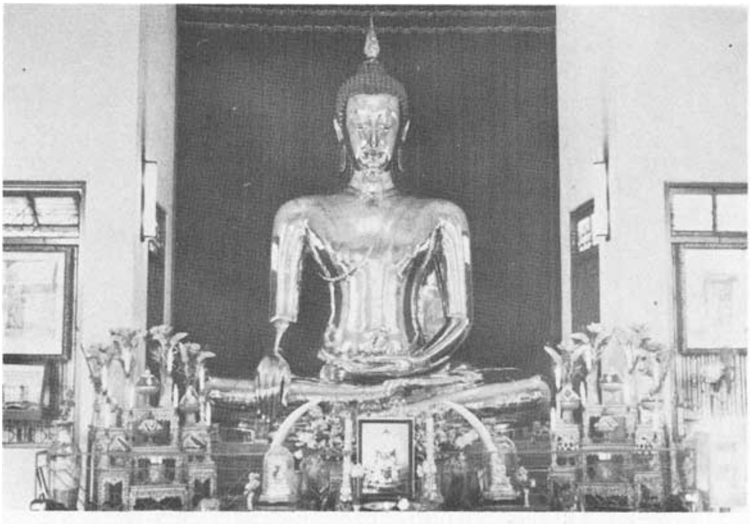

Fig. 5. Gold Buddha, Wat trimit, Bangkok.

for sleeping as noted by the beds in cubicles or against a wall. Large slabbing is carried out on a circular saw in a lean-to shelter, while the finer cuts are made indoors. Cabochon grinding and carving is done by small groups in very low-intensity artificial illumination, using the old type of cord-driven dentist's drill. Modern electric vibro-polishers are in use, and, although still a cottage-type industry, there is considerable technical progress.

The Taiwan coral industry has been long established, since they have considerable reefs of coral along the shore. Because the pink coral is sparse and more beautiful than the white, the white variety is stained pink. No amount of enquiring could elucidate the nature and ingredient of the dying process, even from I.C.I. (China) Ltd's Taipei branch, who carry large stocks of dyes for the textile industry. The coral processing units appear well illuminated and equipped with modern machines. Many females are employed, particularly in drilling and stringing the beads.

Silver-smithing both at Kandy in Sri Lanka and Chiang Mai in Thailand is aimed at tourist merchandise, and naturally the rice-bowls, platters etc. are embossed in oriental designs. Being unable to purchase silver sheet, bar or wire and not having rolls, they have to hammer ingots into sheet or bar from which they raise the hollow-ware or flatware. Embossing is carried out on all items and

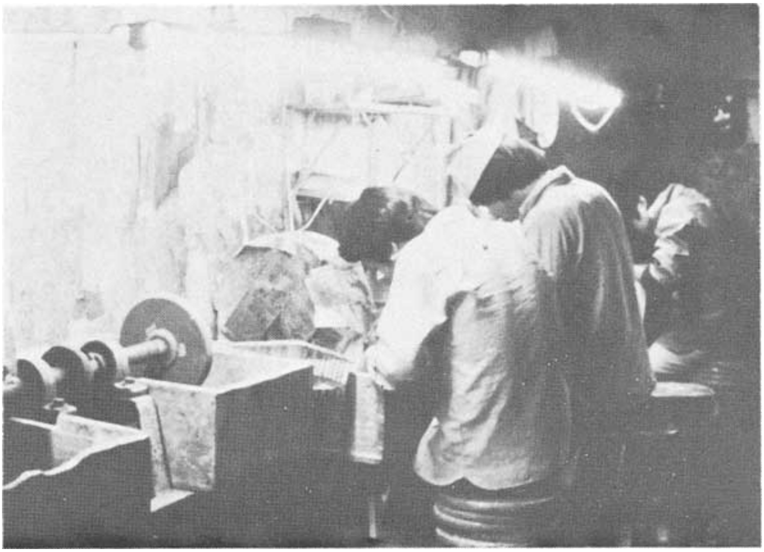

Fig. 6. Polishing nephrite, Taipei, Taiwan.

Fig. 7. Assembling nephrite necklace, Taipei, Taiwan.

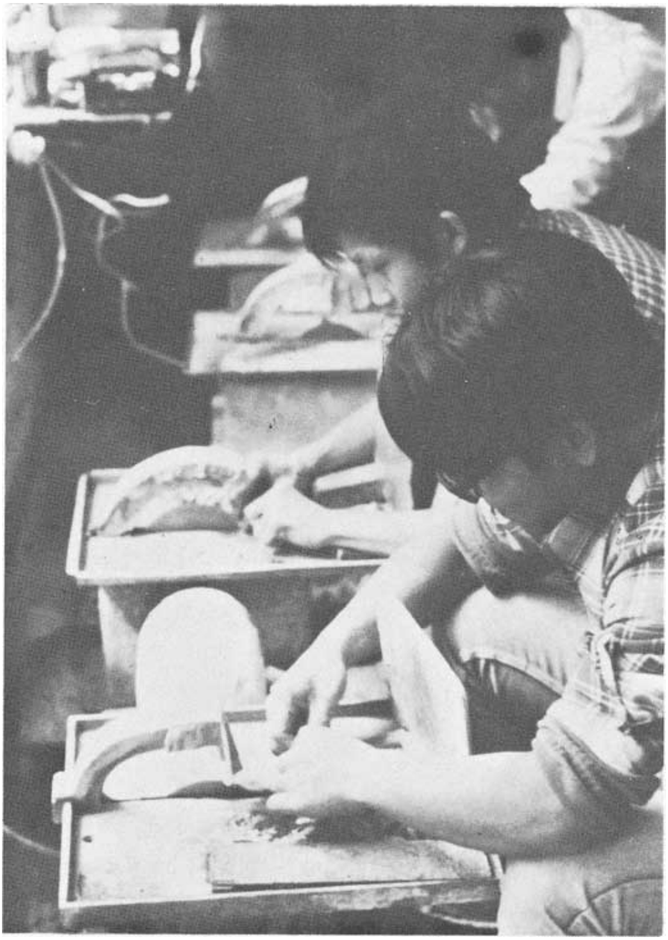

Fig. 8. Cutting coral, Taipei, Taiwan.

no polishing. Hall-marking is unknown—the name Thai Silver is supposed to be enough. The starting material is thought to be silver coins from India, but many details of the craft are held secret.

As usual a first trip is too short to delve into all the mysteries of the East, so a second visit is desired to seek the answers.

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GEMMOLOGICAL ABSTRACTS

ALEKSEYEVKIY (K. M.), NIKOLAYEVA (T. T.). (New data on the possible primary sources of Timan diamonds.) Doklady Acad. Sci. USSR (Earth Science Section), **204**, 925-6, 1972.

Kimberlite is indicated from the northern Timans by the presence of pyrope which in the circumstances most favourable for diamond occurrence are coloured lilac and green. Orange and red pyropes are not thought to be indicators of possible diamond occurrence. M.O'D.

ANDERSON (B. W.). See *Diamond Lectures* below (p. 210).

ANDRYCHUK (D.). *On the light dispersion by faceted YAG gemstone.* Lapidary Journal, **31**, 8, 1850-6, 1977.

Shows mathematically that dispersion can be enhanced to some extent by the lapidary, but that it also depends upon the physical nature of the material. M.O'D.

ASSCHER (E.). See *Diamond Lectures* below (p. 210).

BAGSHAW (A. N.). *Diverse structures based on the Fd3m space group.* Zeitschrift für Kristallographie, **144**, 53-63, 7 figs, 1976.

Examines 19 types of structure, including those of diamond, spinel, fluorite and cuprite. M.O'D.

BANCROFT (P.). *A new 'Lady' is born.* Lapidary Journal, **31**, 8, 1702-4, 8 figs, 3 colour plates, 1977.

Describes the cutting of the world's largest faceted gemstone, a Brazilian topaz of 21327 ct. The colour is light blue. M.O'D.

BANK (H.). *Durchsichtige, schleifwürdige, Hell-gelb-braune Enstatite aus Tansania.* (Transparent cuttable light yellow to brown enstatites from Tanzania.) Z. Dt. Gemmol. Ges., **26**, 4, 206, 1977.

The new material was found amongst some scapolites, mainly because of its definite cleavage. It was shown to be enstatite, very clear, cuttable, but difficult to cut because of strong cleavage. E.S.

BANK (H.). *Durchsichtiger, schleifwürdiger Hauyn aus der Eifel.* (Transparent, cuttable Hauynite from the Eifel.) Z. Dt. Gemmol. Ges., **26**, 4, 207, 1977.

Hauynite is found in Italy and the Eifel, a district west of the Moselle—the piece described was found by the author in a basalt quarry. E.S.

BANK (H.), MAES (J.). *Blau-rot und blaugrün-rot changierende Granate aus Ostafrika und Ceylon (I).* (Blue to red and blue-green to red colour changing garnets from East Africa and Sri Lanka. Pt. 1.) Börsenbulletin, Idar Oberstein, **12**, 1977.

To be continued in next issue. This introductory article deals mainly with the alexandrite-garnet described by Crowningshield in 1970, giving chemical analysis, and a similar garnet described in 1975 by Jobbins giving details of absorption spectra. E.S.

BANK (H.), OKRUSCH (M.). *Über die Entstehung von Rubin und seine Vorkommen.* (On the genesis and origin of rubies.) Börsenbulletin, Idar Oberstein, **12**, 57-9, 8 illus., 1977.

Article in German and English giving a short explanation of the genesis of rubies and shortly describing various occurrences, such as Burma, Siam, Afghanistan, Campolungo, Ceylon, Pakistan, Kenya and Tanzania, mainly the Ngorongoro crater and the Umba valley in Tanzania and the Tsavo National Park in Kenya. E.S.

BANK (H.), SCHMETZER (K.), POUGH (F.). *Blauer durchsichtiger Dumortierit aus Brasilien.* (Blue transparent dumortierite from Brazil.) Z. Dt. Gemmol. Ges., **26**, 4, 205, 1977.

The authors compare the blue orthorhombic dumortierite from Brazil with a brown crystal from Ceylon, the data for pleochroism, RI, DR and optimum angle of axes being different for each variety. E.S.

BARINSKY (R. L.), KULIKOVA (I. M.). *Metamict transformations in some niobates and zircons according to x-ray absorption spectra.* Physics and Chemistry of Minerals, **1**, 325-33, 4 figs, 1977.

It is concluded that the nature of the first coordination sphere changes in zircons (though not in niobates) during metamict decay. Difference in decay processes is probably due to different types of chemical bonds between oxygen and niobium and oxygen and zirconium atoms. In niobates directional covalent bonds are formed between niobium (an anion) and oxygen which do not disintegrate during decay; zirconium, a cation in zircon, forms mainly ionic bonds with oxygen, which do disintegrate. M.O'D.

BEDNORZ (J. G.), SCHEEL (H. J.). *Flame-fusion growth of* $SrTiO_3$. Journal of Crystal Growth, **41**, 5-12, 1977.

Exact growth conditions for the production of optical quality crystals are discussed. Overflow problems previously encountered when the crystal had reached a certain size can be adjusted by controlling the $SrCO_3$ excess in the starting powder. M.O'D.

BLOCKLEY (J. G.). *The Ord Range tiger-eye deposits.* Geol. Surv. Western Australia Ann. Rept for 1975, 108-12, 3 figs, 1976.

Attractive tiger-eye opal formed from crocidolite and set in red, brown and black jaspilite is mined from Archaean iron formation in the Ord Range near Mt Goldsworthy. The deposits appear to be the only recorded occurrences of crocidolite in Archaean iron formation. J.D.L.

BLOUNT (A.), SHULMAN (W.). *Twinning in minerals.* Mineralogical Record, **8**, 5, 350-61, 1977.

Reviews the phenomenon of twinning by crystal system, with illustrations. M.O'D.

BORNMANN (S.), HERGT (R.). *Präparation und Charakterisierung von Granatkristalloberflächen.* (Preparation of single crystal garnet substrates.) Kristall und Technik, **12**, 1, 47-57, 15 figs, 1977.

Describes the growth of gadolinium gallium garnet as a substrate and its nature as a brittle material. Polishing with iron oxide and diamond are investigated as is damage evidence to which x-ray topographic, double crystal spectrometry and selective etching techniques are applied. M.O'D.

BOSCARDIN (M.), MOSELE (G.). *Zircone del Vicentino.* (Zircon from Vicentino.) La Gemmologia, **3**, 2, 13-17, 2 figs, 1977.

The locality described is referred to Tav.top.IGM 1:25000,F°37,III SO Thiene, III NO Caltrano (grid references to the Italian geological survey). Typical crystal forms are illustrated. Corundum, colourless beryl, spinel, topaz and olivine are also found in the area. M.O'D.

BOSSHART (G.). *Kubisch stabilisierte Zirkonoxide.* (Cubic stabilized zircon oxides). Z. Dt. Gemmol. Ges., **26**, 4, 210-20. 3 tables, 1 graph, bibl., 1977.

Cubic stabilized zircon oxides are one of the newer diamond imitations with high refractive index and of medium price range. The author deals with the crystallization method which is a type of 'melt method' and describes physical properties such as inclusions, scratch hardness and wear resistance, absorption, chemical and crystal structure. Hints are given on recognizing this material even if set in rings. The polish of the examined stones did not come up to the polish of a diamond, and the author suggests that the pavilion angles and the width of the girdle should be decreased. It seems likely that in the future zircon oxides with other stabilizers than Y_2O_3 and CaO will come on the market, thus increasing the diamond imitation varieties. E.S.

CANNON (M. C.). *Diamond discovered along Colorado-Wyoming border.* Lapidary Journal, **31**, 5, 1220-4, 1977.

A kimberlite pipe with diamonds has been located on the Colorado-Wyoming border. The largest crystal so far recovered measures 1.0 mm by 1.5 mm. M.O'D.

CASSEDANNE (J.-P.), (J.-O.). *Les améthystes d'Irai.* (Amethyst from Irai.) Revue de Gemmologie, **53**, 12-15, 10 figs, 2 colour plates, 1977.

Describes a location for amethyst in the state of Rio Grande do Sul, Brazil. Irai lies north-west of Porto Alegre and south-west of São Paulo, close to the Uruguayan border. Amethyst occurs in a mineralized basalt and is recovered as geodes. M.O'D.

CASSEDANNE (J.-P.), (J.-O.). *Axinite, hydromagnesite, amethyst and other minerals from near Vitória de Conquista (Brazil).* Mineralogical Record, **8**, 5, 382-7, 1977.

The area described is in southern Bahia, the geology consisting of a gneissic basement rock with mica schists and quartzites, amphibolic lenses and pegmatitic and ultrabasic intrusions. Axinite is recovered from an amphibolitic zone lying on quartzite. Crystals are usually found as flat aggregates on a hornblende matrix; some parts are of gem quality. The colour is chestnut with a tinge of light purple; specific gravity is 3.26, hardness 6.5, refractive indices 1.676, 1.684, 1.687, with a birefringence of 0.011. Emerald, of poor quality, is found in the area at Açude Socêgo, north-west of Vitória da Conquista; it is found in contact with a pegmatite and in association with quartz, feldspar and black tourmaline. Density and refractive indices (2.80; 1.576, 1.658) are slightly higher than those shown by emerald from Carnaiba in the same state. A green opal, thought to be coloured by nickel, is found in the Fazenda Brejinho, north-east of Vitória da Conquista. Quartz, both in the rose and amethyst varieties, are found in the area. Amethyst from Montezuma is heated to give a green colour and is then known as 'peridine'; amethyst from Coruja is heated to an orange or a yellow-brown and such stones are traded as 'Bahia topaz'. M.O'D.

CASSEDANNE (J.-P.), (J.-O.). *Les grenats de Poaia/Bresil.* (Garnets from Poaia, Brazil.) Revue de Gemmologie, **52,** 2-4, 1977.

The area is situated north-north-west of Governador Valadares in the state of Minas Gerais. The location is in a lenticular pegmatite and the garnet occurs in irregular lumps, mingled with some tourmaline and albite. The colour ranges from brown through rose and orange. Refractive index is 1.810, hardness about 7, density 4.24. Material is sold at around 40 cruzeiros a gram. M.O'D.

CROWNINGSHIELD (R.). *Developments and highlights at GIA's Lab in New York.* Gems & Gemology, **XV**, 10, 306-14, 17 figs, 1977.

Some additions to recorded facts about treated diamonds are made. A number of pinks showed the Cape spectrum line at 4155Å. In Brazilian rough this line was found in all stones which fluoresced blue in long UV. Some comments on black diamonds—any showing green 'windows' or reflections from cracks are treated stones. A brown diamond was found to be type IIB, apparently laminated with a non-conducting type in alternation. Other anomalous spectra of diamond mentioned—a valuable up-dating of data on this subject.

An insect-like inclusion in diamond; comments on the dichotomy of meaning in the term 'opalescent'; strange natural-looking inclusions in an orange synthetic spinel; further unusual inclusions; a conchoidal fracture and an over-large natural extending from girdle to cutlet in diamond are described and illustrated. 'Snow-cloud' inclusions in emerald and surface 'tarnish' on another beryl; two star quartz cabochons with brilliant multiple stars (abstractor described such a stone in 1951*); a Russian synthetic quartz which is half yellow and half green and a 'hauntingly beautiful' opal-like triplet of aragonite fossil capped with quartz, known as Calcentine, are all illustrated and described. 'Emerald Nova' proved to be stained quartzite. R.K.M.

CROWNINGSHIELD (R.). *Developments and highlights of GIA's Lab in New York.* Gems & Gemology, **XV**, 11, 345-9, 15 figs, 1977.

Cubic zirconia, as the latest and probably the best diamond imitation, is discussed. A light transmission effect which shows pavilion facets clearly in dispersed yellow, orange or red colour, is illustrated and suggests a possible testing factor. A GGG simulant of diamond, which had been worn in a ring for three years, showed considerable wear and is considered unsuitable for daily use. Wear and inclusions in diamond are illustrated and mossy patches seen on surface of radium treated green diamonds described. Unusual cultured pearls described and illustrated, including non-nucleated sea-water cultured and also un-stained black cultured pearls from a Pacific source. A yellow diamond crystal from the States only known pipe mine at Murfreesboro, Arkansas, weighed 4.23 carats. Another weighing over 16 carats has been reported. R.K.M.

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*Gemmologist, 1951, XX, 235, 28-30.—Ed.

CROWNINGSHIELD (G. R.). See *Diamond Lectures* below (p. 210).

DAVIES (G.). *The H3 centre.* Diamond Research, 15-24, 16 figs, 1977.

Discusses the properties of the H3 centre which if present in a colourless diamond will turn it yellow. Green light is emitted on irradiation with UV or charged particles. The H3 centre is the defect formed when radiation damage centres are trapped by the A form of nitrogen. M.O'D.

DHAMELINCOURT (P.), SCHUBNEL (H.-J.). *La microsonde moleculaire à laser et son application à la mineralogie et la gemmologie.* (The laser molecular microprobe and its application to mineralogy and gemmology.) Revue de Gemmologie, **52**, 11-14, 1977.

This is part one of a series of articles. The use of the laser to generate photons and the investigation of their behaviour by Raman methods represents an advance on previous work using electronic and ionic microprobes. Several characteristic Raman spectra (including one of a phlogopite inclusion in a Madagascan sapphire) are illustrated together with a schematic diagram of the apparatus used. M.O'D.

FARINA (M. S.). *Nota su una perla cresciuta nelle acque del fiume Po.* Note on a pearl formed in the waters of the river Po.) La Gemmologia, **3**, 1, 25-35, 1977.

The pearl was found in a mollusc of the Lamellibranchae class of the order Heterodontae, group Integripalleatae of the Unionidae family genus Unio. The pearl weighed 2.7440 g and fluoresced dark violet under long-wave ultraviolet light, yellowish under short-wave. Surface structures were observed and radiographs are shown. M.O'D.

FUENTES (J. C.), TUCCILLO (R.). *Contribution to the gemological analyses of Argentine fluorite.* Gems & Gemology, **XV**, 10, 290-4, 4 figs, 1977.

A general survey of RI, SG, x-ray and UV fluorescence and spectroscopic analyses of fluorite from seven central Argentine sources and comparisons with Co. Durham and Blue John material in England. A very convincing green plastic carved imitation is mentioned. R.K.M.

FUJISAKI (Y.). *Changes of the concept of gemstones in future.* Journ. Gemm. Soc. Japan, **4**, 2, 60-7, 1977. (In Japanese.)

The supply of gemstones is gradually declining and it may be necessary to modify the conception of gem material in future. Gem diamonds are shown to be less easily recovered than a few years previously. Inclusions in diamond are especially important in grading, since it is by their presence that serious differences in evaluation arise. M.O'D.

GARRETT (J. D.), IYER (M. N.), GREEDAN (J. E.). *The Czochralski growth of $LiBO_2$ and $Li_2B_4O_7$.* Journal of Crystal Growth, **41**, 2, 225-7, 2 figs, 1977.

Large single crystals of $LiBO_2$ and $Li_2B_4O_7$ have been grown using the Czochralski pulling technique. $Li_2B_4O_7$ boules are prone to severe cracking. Preferential growth along (010) was observed in $LiBO_2$. M.O'D.

GRAMACCIOLI (C. M.). *Die Mineralien von Baveno.* (The minerals of Baveno.) Lapis, **3**, 2, 5-10, 9 figs (5 colour), 1978.

Describes the mineral locality of Baveno in northern Italy with a list of the minerals found there; these include the well-known twinned crystals of orthoclase as well as gadolinite, fluorite, babingtonite and epidote. A map is included. M.O'D.

GÜBELIN (E. J.). *Analytical results of poly-mineralic sulfide inclusions in diamond.* Gems & Gemology, **XV**, 11, 322-7, 9 figs, 1977.

Electron probe investigations of bright colourless crystals surrounded by black inclusions in Ghana diamonds reveal them to be olivine, while the black material is shown to be of mixed mineral content, chiefly sulphides plus, in one instance, a silicate. Bearing on diamond origins and outer mantle evolution is discussed. Analysis by probe of elements in two inclusions is confused by printing *three* lists.
R.K.M.

GÜBELIN (E. J.). *Djevalite-una nuova imitazione del diamante.* (Djevalite, a new diamond imitation.) La Gemmologia, **3**, 2, 5-12, 3 figs, 1977.

Gives the outstanding features of djevalite, a trade name for zirconia in its cubic form, with a table of other diamond-imitating materials and illustrations of typical inclusions of minute gas bubbles. M.O'D.

HAMMOND (B. R.). *The Hixon Collection.* Gems & Gemology, **XV**, 9, 288, 1977.
See *The Hixon Collection* below (p. 211).

HANNEMAN (W. W.). *L_H—a new gemological property.* Gems & Gemology, **XV**, 10, 302-5, 4 figs, 1977.

This is effectively an account of the Jeweler's Eye reflectometer adapted to determine a numerical value for lustre. The claim that lustre itself is a new property is not tenable, but the arbitrary scale of values for lustre given by the instrument does provide a new gemmological constant. Among high-lustre gem materials the L_H range runs from silicon carbide 5 to YAG 1, with diamond at 4. Gems with vitreous lustre are accommodated on a separate section of the scale. Any reading must depend upon the degree of polish on the surface tested, so a poorly polished stone may read low. The scale shown in Figure 1 is that of the Jeweler's Eye reflectometer: that of the Lustermeter (Figure 2) is far simpler. R.K.M.

HEWITT (C. G.). *Adventures with Virgin Valley opals.* Lapidary Journal, **31**, 9, 1994-8, 1977.

Account of prospecting in the Virgin Valley region of Navada with details of a process said to halt crazing in some specimens. M.O'D.

HUDSON (P. R. W.), TSONG (I. S. T.). *Hydrogen impurity in natural gem diamond.* Journal of Materials Science, **12**, 2389-95, 2 figs, 1977.

Five natural gem diamonds including types 1A, 1B and 2A were investigated by ion beam spectrochemical analysis to determine total hydrogen impurity concentration. Hydrogen was found in all the specimens, but the concentration did not correlate with any defects observed. M.O'D.

HUDSON (S.). *Hunting the hexagons: in search of Georgia beryl.* Lapidary Journal, **31**, 5, 1116-28, 1977.

Beryl is found in the Mountain and Piedmont regions of the state and is usually associated with mica pegmatites. They occur in the feldspar or quartz near the

central core of the pegmatite. Colours found include green, yellow and blue. Some blue is of gem quality. A history of beryl mining and a bibliography are included.
M.O'D.

JENKINS (W .J.). *A soudé emerald from Colombia.* Lapidary Journal, 31,7, 1630-2, 2 figs, 1977.

Describes a cut stone fashioned from an aquamarine crystal cut in two places and cemented together again with green cement. The stone was said to have been purchased in Colombia. M.O'D.

LIDDICOAT (R. T.). ***Developments and highlights at GIA's Lab in Santa Monica.*** Gems & Gemology, XV, 10, 295-301, 12 figs, 1977.

Specimens of colourless phosgenite, a 41.7 carat 'exceedingly radio-active' ekanite and a reddish brown cat's-eye which proved to be anthophyllite are reported. A dyed green stone looking like jadeite was found to be wollastonite. Diamonds with a macle inclusion, purple banding, various 'naturals', a stone 'inked' to improve colour and another with quite exceptionally abraded facet edges are described. The effect of grain lines on clarity is discussed. R.K.M.

LIDDICOAT (R. T.). ***Developments and highlights of GIA's Lab in Santa Monica.*** Gems & Gemology, XV, 11, 328-33, 9 figs, 1977.

An apparently fine-coloured emerald crystal proved to have been core-drilled; space between core and outer crystal filled with green cement. A genuine emerald cabochon found to have strong zoning between fine green and colourless areas. A green cameo head was found to have been carved from a synthetic spinel triplet so that colour cement was retained only behind carved head. Green glass with strong swirling reminiscent of byssolite fibres in demantoid is illustrated. Scratch test to prove diamond demonstrably dangerous if diamond point is used, since diamond *will* scratch diamond. Early flame fusion synthetic ruby showed angular inclusions as well as curved striae. A multi-crystalline semi-fibrous green stone with tourmaline indices but no dichroism still proved to be tourmaline. A deep amethyst-coloured spodumene is described but it is not certain that it is a natural colour. R.K.M.

LIDDICOAT (R. T.). ***Comments on the Hixon collection.*** Gems & Gemology, XV, 9, (2pp.-front and back flyleaves), 1977.

See *The Hixon Collection* below (p. 211).

LIEBER (W.). *Worin sich Kristalle miteinander messen; die Härte von Mineralien.* (Wherein crystals contest with each other—mineral hardness.) Mineralien Magazin, 1, 2, 134-7, 1977.

Reviews Mohs's scale and the physical basis for the hardness of crystals.
M.O'D.

LOWER (J. N.), WELBOURN (C. M.). ***EPR studies of irradiated diamonds.*** Diamond Research, 5-10, 7 figs, 1977.

Discusses the room-temperature EPR spectrum of irradiated type IIa diamonds with special reference to impurity interstitial complexes. M.O'D.

Manutchehr-Danai (M.). *On the turquoise deposits of Nishabur (N.E. Iran).* Gems & Gemology, **XV**, 10, 315-19, 2 figs, 1977.

A historical and geological account of this extremely important source of fine gem turquoise, first worked well over two thousand years ago and still in production today. R.K.M.

Mateika (D.), Flisikowski (P.), Kohler (H.), Kilian (R.). *Automatisierte Kristallziehanlage für das Czochralski-Verfahren.* (Automatic crystal-pulling equipment for Czochralski growth.) Journal of Crystal Growth, **41**, 2, 262-74, 12 figs, 1977.

An adaptation of the Czochralski pulling technique for automatic crystal production is described and illustrated. Gadolinium gallium garnet has been successfully grown with this apparatus. M.O'D.

Mir-Mohammedi (A.), Pilger (A.). *Türkis, Stein des Himmels.* (Turquoise, stone of Heaven.) Mineralien Magazin, **2**, 108-13, 11 colour figs, 1978.

Describes the occurrence of turquoise in Iran, illustrating cut and rough specimens of varying colours. A map covers the area. M.O'D.

Mitchell (R. S.), Giardini (A. A.). *Some mineral inclusions from African and Brazilian diamonds: their nature and significance.* Amer. Mineral., **62**, 756-62, 1977.

Inclusions of forsterite, enstatite and quartz from well-crystallized diamonds from Brazil and inclusions of barite, biotite with chlorite, chlorite with biotite with garnet, chlorite with calcite, omphacite, pyrrhotite and pyrrhotite with chalcopyrite from well-crystallized African diamonds have been noted. M.O'D.

Nassau (K.). *Irradiation colours in topaz, quartz and beryl.* Gems & Gemology, **XV**, 11, 350-1, 1977.

A short but important paper since it establishes authoritatively that irradiated blue topaz is colour stable, while the so-called Maxixe type deep blue beryl, which is probably also irradiated, is by no means stable and will fade on prolonged exposure to light. R.K.M.

Nassau (K.). *Anmerkung zu 'Über die Färbungsursachen Natürlicher Citrine'.* (Note on 'About the causes of colour in natural citrines'.) Z. Dt. Gemmol. Ges., **26**, 4, 222, 1977.

The author refers to an article by Lehmann (abstracted on p.131 above) in which citrine is called 'burnt amethyst' and the greenish-yellow variety is called 'citrine', which seem contrary to gemmological usage. E.S.

Nikol'skaya (L. V.), Novozhilov (A. I.), Samioilovich (M. I.). (The nature and colour of a new alkali calcium silicate from eastern Transbaikal.) (In Russian—from a translation by M. Fleischer.) Izvest.Akad.Nauk SSSR, Ser. Geol., **10**, 116-20. 5 figs, 1976.

A deep violet alkali silicate has been given the name charoite. It occurs in conjunction with another new mineral, tinaksite. Mn and Fe have been found by spectroscopic analysis. Colour may be due to Mn^{3+} occurring in deformed 6-fold coordination although Mn^{2+} and Fe^{3+} may also influence it. M.O'D.

O'LEARY (B.). *Fire forever.* Lapidary Journal, **31**, 7, 1498-510, 22 figs (21 colour), 1977.

A history of opal mining in Australia with coloured illustrations of notable stones. Particular reference is made to opal mining near the town of Ballina on the northern coast of New South Wales: opal in this locality is of volcanic origin and when first mined was believed to be unstable. Some opal from this area is stated to have been found in liquid form. M.O'D.

PARKIN (K. M.), LOEFFLER (B. M.), BURNS (R. G.). ***Mössbauer spectra of kyanite, aquamarine and cordierite showing intervalence charge transfer.*** Physics and Chemistry of Minerals, **1**, 301-11, 4 figs, 1977.

Blue kyanite from Elovyi Klavoloke, ASSR, has been shown by Mössbauer spectroscopy to contain both Fe^{2+} and Fe^{3+}; green kyanite from Kenya contains mostly Fe^{3+}. Both Fe^{2+} and Fe^{3+} are found in blue beryl from Colorado. No Fe^{3+} could be found by this method in either cordierite from the Malagasy Republic or high-iron cordierite from Dolni Bory, Velke, W. Moravia. The blue colour of aquamarine and cordierite had previously been attributed to charge transfer between adjacent Fe^{2+} and Fe^{3+} ions, that in blue kyanite to transfer between Fe^{2+} and Ti^{4+}. M.O'D.

PETROV (I.). ***Farbuntersuchungen an Topas.*** (Colour investigation of topaz.) N. Jb. Miner. Abh., **130**, 3, 288-302, 1977.

Colour in topazes was investigated by means of polarized absorption spectra within ultraviolet and visible light. Yellow topaz is characterized by colour centres, reddish-brown stones by two centres (red and yellow). Violet-coloured stones show absorption bands (three each in two groups) which can be correlated to Cr^{3+} occupying Al positions. Orange stones obtain their colour from a mixture of yellow and violet, and blue stones from a mixture of green and yellow, the colour in each case being that derived from the operation of a colour centre. M.O'D.

PETROV (I.), SCHMETZER (K.), BANK (H.). ***Orangefarbene Topaskristalle bei Ouro Preto, Minas Gerais, Brasilien.*** (Orange-coloured topaz crystals from Ouro Preto, Minas Gerais, Brazil.) Aufschluss, **28**, 219-20, 1977.

Illustrates crystals on which the {001}, {112}, {011} and {113} forms are prominent. M.O'D.

PETROV (I.), SCHMETZER (K.), BANK (H.). ***Violette Topase aus Pakistan.*** (Purple topaz from Pakistan.) N. Jb. Miner. Mh., **10**, 483-4, 1977.

Transparent crystals of purple topaz, associated with quartz and calcite, have been found in the Mardan district of Pakistan. Crystals display prismatic habit and show (110) and (120), with (011), (012) and (112); sizes range up to 2cm × 0.5cm. Refractive index is 1.632, 1.633 and 1.641, suggesting an OH-rich stone with about 15% F. M.O'D.

PETROV (I.), SCHMETZER (K.), EYSEL (H. H.). ***Absorptionsspektren von Chrom in Topas.*** (The chromium absorption spectrum in topaz.) N. Jb. Miner. Mh., **8**, 365-72, 1977.

The absorption spectrum of purple topaz results from d-d transitions of Cr^{3+} in Al lattice positions. Two strong bands are each split into three components and this is explained by the symmetry of the (Al,Cr)-O_4-F_2 coordination polyhedron. M.O'D.

QUIGLEY (D.). ***Botswana elevation in diamond league.*** The Times newspaper, no. 60274, p.26, 12th April, 1978.

Botswana is to become the third largest diamond producer in the world. De Beers Consolidated Diamond Mines is to develop a new mine at Jwaneng in the Kalahari region, which is to begin producing at the rate of 3.5 × 10^6 ct a year from 1982, increasing to 6 × 10^6 ct a year. Production from existing mines at Orapa and Letlhakane should reach 4.8 × 10^6 ct this year. Indications are that Jwaneng will have a higher proportion of gemstones to industrials than Orapa (*ca.* 14%) but lower than Letlhakane (*ca.* 40%). J.R.H.C.

RADCLIFFE (D.), PEACOCK (S.). *Fire agate.* Lapidary Journal, **31**, 5, 1096-108, 1977.

Fire agate is mined in the Central Mesa of Mexico and most is found in chalcedony in a fine-grained rhyolitic rock. Coloured illustrations are given. M.O'D.

RAGER (H.). *Electron spin resonance of trivalent chromium in forsterite,* Mg_2SiO_4. Physics and Chemistry of Minerals, **1**, 371-8, 4 figs, 1977.

A forsterite crystal was grown and doped with Cr_2O_3 in different concentrations. Spin resonance showed that the chromium ions are located at both the M1 and M2 positions. M.O'D.

RIBBE (P. H.), GIBBS (G. V.), HAMIL (M. M.). *A refinement of the structure of dioptase.* Amer. Mineral., **62**, 807-11, 6 figs, 1977.

A crystal from Renéville, Zaire, was used for analysis and was shown to consist of puckered trigonal rings of six water molecules between puckered rings of six silicate tetrahedra bonded laterally and vertically by Cu. M.O'D.

ROWCLIFFE (D. J.), FRÜHAUF (V.). *The fracture of jade.* Journal of Materials Science, **12**, 35-42, 11 figs, 1977.

The high resistance of jade to crack propagation is due to the fibrous microstructure in which individual fibres are intermeshed. SEM photographs are included. M.O'D.

SCELLS (G.). *Some north Queensland gem fields visited.* Lapidary Journal, **31**, 10, 2228-34,b14 figs, 1978.

Describes with maps the localities for topaz, peridot, moonstone and agate in north Queensland. M.O'D.

SCHÄFER (W.). *Wo man die grünen Steine findet. Zwei europäische Smaragdvorkommen.* (Where you can find green stones. Two European emerald locations.) Mineralien Magazin, **5**, 207-16, 1977.

Describes with coloured illustrations and maps, the locations for emerald in the Habachthal (Austria) and Eidsvoll (Norway). M.O'D.

SCHMETZER (K.), BANK (H.). *Zur Nomenklatur ostafrikanischer Turmaline.* (Towards an East African tourmaline nomenclature.) Z. Dt. Gemmol. Ges.,

26, 4, 208-9, 1977.

Green tourmalines from East Africa are often described as chrome-tourmalines but are to a large extent coloured by vanadium. It is easy to differentiate between these by a simple spectroscopic examination. Dravite and uvite are magnesium-aluminium tourmalines. E.S.

Schmetzer (K.), Ottemann (J.), Bank (H.), Krupp (H.). *Blaugrüne Kornerupine aus Kenia und Tansania.* (Blue-green kornerupines from Kenya and Tanzania.) Z. Dt. Gemmol. Ges., **26**, 4, 202-4, 1977.

This is a preliminary report on the green, blue-green and blue kornerupines from Kenya and Tanzania which vary in their optical properties considerably from those found in the Kwale district in Kenya. The stones are mostly cut and polished but recently a rough lot reached the European market. The Kwale kornerupines are distinctly green and show different pleochroism from the newer stones. E.S.

Schubnel (H.-J.). *Les diamants d'Indonésie; notes de voyage.* (Indonesian diamonds: notes of a visit.) Revue de Gemmologie, **53**, 9-11, 7 figs, 3 colour plates, 1977.

An account of diamond workings in the vicinity of the town of Bandjarmasin, Borneo. M.O'D.

Schubnel (H. J.). *World map of gemstone deposits: explanatory note.* Bur. Rech. Géol. Minières, Orléans, 2pp, 1 coloured map (1:40 000 000), 1975. Fr 31.30.

On the equi-areal map, the symbols indicate both the gem material and the geological nature of the deposit. R.A.H.

Schwarzmann (S.). *Familie Feldspat.* (Feldspar family.) Lapis, **2**, 10, 20-23, 1977; **2**, 12, 28-31, 14 figs, 1977.

Includes illustrations of lunar rock formations as well as coloured photographs of orthoclase, adularia and microcline. Illustrates twinning in the feldspar group of minerals; some types are illustrated in colour. M.O'D.

Sellschop (J. P. F.), Annegarn (H. J.), Madiba (C.), Keddy (R. J.), Renan (M.J.). *Hydrogen in diamond.* Diamond Research, 2-4, 7 figs, 1977.

Infrared studies show two very sharp lines in some natural diamonds. In synthetic stones there is no evidence for hydrogen. M.O'D.

Shaw (J. L.). *The Royal Ontario Museum in Toronto, Ontario, Canada.* Lapidary Journal, **31**, 7, 1512-22, 13 figs, 1977.

Describes the gem and mineral collections of the Museum with brief notes on its history. M.O'D.

Shimada (S.), Kodaira (K.), Matsushita (T.). *Crystal growth of bismuth titanates and titanium oxide from melts in the system* Bi_2O_3-V_2O_5-TiO_2. Journal of Crystal Growth, **41**, 2, 317-20, 4 figs, 1977.

Single crystals of $Bi_4Ti_3O_{12}$,$Bi_2Ti_3O_{12}$,$Bi_2Ti_4O_{11}$ and TiO_2 have been grown from the melt with various compositions in the system Bi_2O_3-V_2O_5-TiO_2. M.O'D.

Sinkankas (J.). *Historical notes on South American gemstones.* Gems & Gemology, **XV**, 11, 334-44, 1977.

A general review of the gem mining history of the South American continent with some interesting side-lights on the historic Spanish attitude to the vast wealth of emeralds plundered from the natives by the conquistadores. Diamonds and other gems are delt with in some detail. R.K.M.

Sobolev (N. V.) *et al.* (Coesite, garnet and omphacite inclusions in Yakut diamonds — first finding of coesite paragenesis.) Doklady Academia Nauk SSSR, **230,** 1442-4, 1976.

Coesite with garnet and omphacite have been encountered as inclusions in diamonds from the Anabar deposits, Yakutia. M.O'D.

Sobolev (N. V.), Botkunov (A. I.), Bakumenko (I. T.), Sobolev (V. S.). (Crystalline inclusions with octahedral faces in diamonds.) Doklady Acad. Sci. USSR (Earth Science Section), **204,** 117-20, 4 figs, 1972.

Diamonds from the Mir kimberlite pipe show pyrope, pyrope-almandine, chrome diopside, olivine, chromite, enstatite and ilmenite as inclusions. These have been thought to be the fillings of growth pits on the faces of diamond crystals by syngenetic materials. Nuclei of these materials appear to fall into the pits and since they grow faster than diamond fill the pits giving inclusions with the morphology of diamond. M.O'D.

Sugitani (Y.), Tagawa (K.), Kato (K.). ***Optical absorption spectra of iron (III) and chromium (III) doped in synthetic yttrium-aluminium garnet (YAG).*** Mineralogical Journal (Japan), **7,** 445-55, 4 figs, 1974.

Peaks noted from Fe^{3+} and Cr^{3+} have been assigned to d-d transitions of the metal ions in octahedral and tetrahedral sites in YAG. M.O'D.

Trossarelli (C.). *Confronto fra il rubino naturale, il rubino Verneuil e un nuovo rubino cristallizato in fondente.* (Comparison between natural, Verneuil and a new flux-melt-grown ruby.) La Gemmologia, **3,** 1, 9-24, 1977.

Typical inclusions of all three types of ruby are illustrated; the flux-melt-grown stone had RI 1.762 and 1.770 with a DR of 0.008; specific gravity was 4.00. Opaque inclusions with a metallic lustre were noticed, but their true nature was not established. Platinum was thought to be a possibility. M.O'D.

van den Berge (G.). *Spectroscopie.* (Spectroscopy.) Bull. Soc. Belge Gemm., **3,** 1-2, 1977.

General survey, in Flemish, of the spectroscope and its applications. M.O'D.

Varshavskii (A. V.). ***Stacking faults in natural diamonds.*** Soviet Physics-Crystallography, **22,** 3, 376-7, 1977.

Development of a fine zonal structure along the {111} planes in natural diamond is thought to be at least one of the causes of anomalous birefringence. The structure also appears in luminescence and optical density. M.O'D.

Vogt (H.-H.). ***Nicht nur Amethyst Edelsteinparadies Brasilien.*** (Not only amethyst comes from the paradise of gemstones, Brazil.) Mineralien Magazin, **2,** 1, 40-43, 13 figs (6 colour), 1978.

Describes with a small-scale map the main gem-producing areas of Brazil. Topaz, aquamarine and other stones are mentioned. M.O'D.

WATANABE (K.), SUMIYOSHI (Y.). *Growth of corundum single crystals from* $Na_3AlF_{6-x}Li_3AlF_6$ *system fluxes.* Journal of Crystal Growth, **41**, 1-4, 1977.

Corundum crystals were manufactured by the temperature gradient method giving the habit c(0001), n(22$\bar{4}$3) and r(10$\bar{1}$1). Growth rate decreased with increase of Li_3AlF_6. M.O'D.

WEININGER (H.). *Ein bemerkenswerter Scheelit-Fund von der Rauris, Salzburg.* (A notable scheelite discovery in the Rauris, Salzburg.) Lapis, **2**, 9, 26-27, 1977.

Crystals of scheelite have been found in the Rauris area of Austria in association with pericline. M.O'D.

WILSON (M. M.). *Brazil, paradise of gems.* Lapidary Journal, **31**, **6**, 1302-16, 1977.

Gives a general description of the gem materials to be found in Brazil with a map and illustrations in colour. M.O'D.

ZWAAN (P. C.), KOREVAAR (H. J.). *Cordierit-Katzenaugen—vermutlich aus Indien.* (Cordierite cat's-eyes, probably from India.) Z. Dt. Gemmol. Ges., **26**, 4, 197-201, 5 illus., bibl., 1977.

Four cordierite cat's-eyes are described. The origin is probably India, although they were bought in Indonesia. All four have the typical grey-violet/blue colour, like the Ceylonese star corundums, but show no asterism but a very definite cat's-eye effect. It seems that this effect is caused by the fibrous structure which is probably built up by a series of microscopic tubes. E.S.

Diamond Lectures (XVI International Gemmological Conference, the Netherlands, 1977). The Hague, Dutch Diamond Publicity Committee. Unpaginated and undated.

This leaflet of 8 pages contains three talks given at the Conference in October, 1977, as follows:

(1) CROWNINGSHIELD (G. R.). *Diamond quality grading in the U.S.A.*

Describes the development of diamond grading by the GIA from 1949: they were much concerned with artificially coloured diamonds, particularly after treated yellow diamonds appeared in 1952: they made formalized reports to an Italian dealer from 1955 and later offered their services across the board: also describes in considerable detail how the GIA laboratories deal with the '4Cs'.

(2) ANDERSON (B. W.). *Some experiences with industrial diamond.*

Describes procedures used in the London Laboratory, (1) shortly after World War II when asked to analyse and report on a number of different so-called diamond powders (sometimes derived from floor-sweepings of diamond workshops) and (2) in modern times to check purity/grain-size of a diamond powder from an unestablished source. Synthetic diamond grits are easily recognizable, consisting of tiny complete crystals, usually brownish and with traces of magnetism. A note is added on carbonado and another describes the testing of a consignment of low quality boart weighing 4585ct and consisting of over 5000 pieces.

(3) ASSCHER (Edward). *Fancy colour diamonds.* 3 coloured illus.

Recounts the history of the French Blue (or Hope): discusses the 104.52ct yellow cushion-shaped diamond sold in 1971 for Fr(S) 1 900 000 (the sale later being cancelled following Dr Gübelin's judgement that its colour was due to cyclotron treatment): considers the green marquise of 1.22ct, finally submitted to B. W. Anderson and by him to Reading University where it was shown to be irradiated: tells the story of the Goudvis, a deep ruby-red emerald-cut diamond of 5.05ct: denies that Joseph Asscher fainted when he cleaved the Cullinan. J.R.H.C.

Die Diamantvorkommen der Elfenfeinküste, IV. (Diamond locations in the Ivory Coast.) Goldschmiede Zeitung, **75**, 1, 57-78, 1977.

Describes diamonds from the Seguela district of the Ivory Coast and compares them, with their properties, with those from other deposits in West Africa. Diamonds from the Tortiya deposit are also discussed. M.O'D.

Gemmologische Untersuchungspraxis. (Gemmological practice.) Z. Dt. Gemmol. Ges., **26**, 4, 224-7, 1977.

This includes four short notes. The first by H. Bank and K.-G. Leyser reports on an apatite which was sold as a herderite. The second by H. Bank and J. Maes gives an example of blue to red changing garnet from East Africa being accepted as spinel: it was mixed crystal of pyrope and spessartite. The third also by H. Bank and J. Maes, reports a similar mistake in which greenish-blue to red changing garnet from Ceylon was thought to be alexandrite. The last, fourth, note by H. Bank reports on rough and cut glass offered by a dealer from Moçambique as tourmaline. E.S.

The Hixon Collection. Gems & Gemology, **XV**, 9, 258-87 (272 = 5 pp.), 17 colour plates, 1977.

A special issue of this journal consisting of 187 coloured illustrations of gems which have been presented to the Natural History Museum of Los Angeles County by Mr F.C. Hixon, a finance expert of that city, with details of size, weight and specimen number of each on the facing page. Twelve of the specimens appear twice so there are upwards of 25 stones in the full collection (more than 200) which are not illustrated. The issue bears signs of hurried preparation and colours are often unconvincing and sometimes strange for the stones depicted. The collection (valued at $1 million plus) is apparently intended as a working collection with access for the G.I.A. and others (?) in a special laboratory area within the museum. There is a stated attempt to cover 'as complete a colour spectrum as possible . . . for each species'. The stones illustrated scarcely do this. Abstractor knew, in bygone years, a collector who worked on this basis and reached over nine hundred specimens without exhausting its possibilities. However there are several outstanding specimens in the collection in spite of it having apparently been conceived and collected in a short space of time. There is much to be said for the American system of taxation which allows such donations to major public collections to be off-set against tax due. R.K.M.

Künstlerfarbe und Schmuck Lasurstein oder Lapislazuli. (Artist's colour and jewel; azure stone or lapis lazuli.) Mineralien Magazin, **1**, 2, 82-3, 1977.

Includes coloured photographs of lapis lazuli with an account of its properties and uses. M.O'D.

Opal as an investment. Lapidary Journal, **31**, 7, 1492-3, 14 colour illus, 1977.

A brief account of the present-day prices obtaining for fine-quality opal with illustrations of celebrated pieces and mining scenes. M.O'D.

NOTE: *Mineralien Magazin* (ISSN 0341-907X) is a new periodical published by Kosmos-Verlag, Postfach 640, Stuttgart, West Germany. Annual subscription DM 40.80.

BOOK REVIEWS

AREM (Joel E.). *Colour encyclopedia of gemstones.* Van Nostrand Reinhold, New York and London, 1977. pp. xxvii, 147. 64 pages of colour plates. $35.00.

This eagerly-awaited book resembles in format Roberts *et al.,* 'Encyclopedia of minerals', although it is, of course, a smaller work. Over 220 mineral specimens are reviewed and more than 185 of these are illustrated in colour. Preliminary matter covers gemstone origin, crystallography, types of rock, methods of identification, sources of data, explanation of technical terms, a short bibliography, a single page indicating mineral groups (pyroxene, amphibole, zeolite, etc.), a table of the elements and an index. The major portion of the book is taken up by descriptions of the individual species, which contain, as well as the expected constants, sizes of stone likely to be encountered, 'comments' in which the author includes details of usage, historical notes and other matters of interest and a note on the derivation of the name. Amongst these pages of description lie the colour plate sections, four in number, with each page holding at least four pictures and often more. Naturally pictures cannot face the descriptions of the materials to which they pertain but it would be unreasonable to expect this in a work of this kind. Some of the reproduction (in my copy) is a trifle blurred but in all other respects the standard of production is excellent.

What we have is a book in which the gemmologist can turn to the material in question and see virtually at a glance any important feature he needs. It cannot be used as an identification book pure and simple, since there are no tables, but this was not, in any case, the intention of the author and publishers. The sheer amount of information given is likely to make the enthusiast intoxicated with the riches contained in it; the information is accurate and, particularly in the case of the important stones, up-to-date. Just over three whole pages are devoted to beryl and details of the latest reported occurrences are given; as with other important stones, notes on important known specimens are given with size and present whereabouts. Many notes are given on species scarcely ever seen outside museums; these include chondrodite (from the Tilly Foster mine, Brewster, New York), chiolite (from Greenland and the U.S.S.R.), dickinsonite (from two localities in the United States) and so on. Many of these rarities are illustrated, and so we can see, often for the first time, what they look like.

Dr Arem's introductory matter is typical of the whole of his writing; quick and with no wasted words, it encourages the reader to think ahead, and the details are prominent rather than lost in verbiage. No doubt a meticulous sifting would produce the odd error or misprint but to do this would prevent this reviewer, at least, from devouring the whole book as all readers will wish to do. In this case the 'fool's gold' so often retrieved by the reviewer can safely be cast aside in favour of the true merit of the work as a whole.

The section on diamond is missing from the first printing; intending purchasers should check. M.O'D.

GALL (Robert A. P.). *The Diamond Dictionary.* 2nd edn. Gemological Institute of America, Santa Monica, Cal. 90404, U.S.A., 1977. pp.342. $16.95.

The second edition of this reference book, although physically thinner than the first—which appeared a suprising 17 years earlier—has in fact 27 more pages. There is a different 'flavour' to the text because the author is a research scientist, whereas the first edition was a *compôte* of the work of several members of the G.I.A. staff, based on their courses. The new writing is concise and objective, and fortunately the author has resisted any temptation he might have had to be too academic and has retained the strong gemmological flavour, enhanced with microscope polaroid pictures from the New York and Californian laboratories, as well as some commercial content. The dictionary is also a useful reference source for famous (and some not so famous) diamonds. In all, it remains a unique and even more valuable production. E.B.

HUNGER (Rosa). *The Magic of Amber.* N.A.G. Press Ltd, London, 1977. pp.131. 16 colour plates, 47 black-and-white illustrations. £5.95.

'The Magic of Amber' is a very personal record of a lifetime spent in the trade against a background of centuries of history, rather than a factual and gemmological account of the red-gold fossil resin. Mrs Rosa Hunger was virtually born into the world of amber, and at her own request, it is said, joined her father Arthur Charatan at Sac Frères when she was only fourteen. Her approach to the subject is one of affection rather than one of scientific investigation. One can look in vain for specific gravities, hardness, chemical properties and the other vital statistics beloved of gemmologists, other than the most obvious notes on amber and its imitators. This is rather a pity, for 'The Magic of Amber' is one of the few books on the subject to have been written for many years.

Indeed, in relating the early history of the gem material, Mrs Hunger's rather awed view of science makes her contradict herself more than once. Having stated that the 'scientific study of the zoology and botany of amber has only begun within the last fifty or sixty years', a couple of paragraphs later she reports on the investigations made as long ago as 1830 by German naturalists and later follows it with suggestions that Pliny knew a good deal about 'electrum'. She also has the amateur writer's rather naive habit of referring back to previous chapters, as though the reader might have missed a point or an argument—though unfortunately she does not describe the cogent illustrations in detail or give owner or provenance, except in a short list of acknowledgements, so that the enquiring reader is unlikely to discover where the best collections are to be seen. The colour plates are, however, very fine, though the rest are very smudgily reproduced. Likewise, the index is sketchy and not very helpful, while the large type, comforting to tired and ageing eyes, really seems designed to pad out a slim volume into one of more substance than it in fact contains. Why, for example, should not amber have been used for 'sewing and crocheting implements' in the 19th century? And what were they like? A list of museums abroad where fine amber can be seen and studied would have been a welcome addition to the book—but perhaps one is quibbling to ask for more opportunity to judge the Baltic gem material by its practical being rather than by the rather sugary alchemy of its magic in fable and poetry. J.B.

KUEHN (R. L.). *The guide to colored gems.* R. Lary Kuehn Productions, Dallas, (Tex., U.S.A.), 1977. 90 leaves. Price on application.

This is a simple guide to the commoner gemstones prepared with the jeweller in mind. Information is given on the colour and durability of gemstones, their availability and legends surrounding them; 'selling keys' (points of general interest) are also included. Blue zoisite is said to be unaffected by ultrasonic cleaning,which is not the case. M.O'D.

LEWIS (D.). *Practical gem testing.* N.A.G. Press Ltd, London, 1977. pp.149. About 180 figs and 50 spectra. £7.50.

In an effort to present the subject for those 'who do not have time or inclination to make a fuller study' much basic gemmological theory has been omitted. Such a work needs to be written with care if possible costly errors of identification are to be avoided.

The general format relegates most of the illustrations to the inside column of each page. This leaves quite a lot of blank paper and results in a rather awkwardly shaped volume.

The first section of the book describes instruments, including some exotic and perhaps unnecessarily expensive items, and gives simple information on their use. The second part deals with testing procedures for each gem. These are occasionally inadequate, e.g. stained turquoise is ignored; irradiated diamonds are not mentioned; synthetic alexandrite is glossed over too briefly. The alphabetic gem order eliminates the need for indexing but separates aquamarine, emerald and morganite (heliodor is missing).

Some of the many illustrations suffer from a generally sooty quality of reproduction. One picture of a 'Garnet-topped ruby doublet' (which it quite evidently is not) is inverted and used again on the next page with a different description. On the same page an obvious garnet-topped doublet is titled 'synthetic ruby' although further description puts the matter right. A red spinel spectrum is described as 'showing copper sulphate'.

The author misuses some terms. 'Loupe' simply means a lens and should not be reserved for the type held in the eye. Observation of absorption spectra is not 'spectrum (or spectroscopic) analysis'. Similarly 'microscopic analysis' is a misnomer for the examination of gem inclusions. Cotton should not be advocated for gem suspension in hydrostatic weighing: it absorbs water and vitiates the result. The text on distant vision RI refers to a wrong diagram. The use of 'physical features' when 'physical constants' are meant; of 'intermediary' for 'intermediate'; 'alternatively' for 'alternately'; 'interesting' for 'intersecting' and such misspellings as 'monobromonapthalene' and 'sausserite' are part of a tendency to lax expression which might have been corrected by more careful proof reading or editing.

Opal doublets and the effect seen in rose quartz stars are inaccurately described. The doublet is a slice of transparent opal cemented to a black onyx base (it simply would not pay to slice *black* opal) or to potch or other material using a black adhesive. The star stones show an image of the light source at the centre of the star, not 'at the centre of the stone'.

The dichroscope and Chelsea filter are disparaged, yet each, in intelligent hands, can be a valuable aid even today. R.K.M.

Nitsche (R.), Räuber (A.). *Information Über Kristallzuchtung.* (Crystal growth information.) Deutsche Gesellschaft für Kristallwachstum und Kristallzuchtung, Heidelberg, 1976. Various pagings. Price on application.

Gives details of crystal growth enterprises in the Federal Republic of Germany with lists of materials, growers, sizes, etc. M.O'D.

O'Leary (B.). *A field guide to Australian opals.* Rigby, Adelaide, S. Australia, 1977. pp.159. All figs in colour. $12.95.

The major part of this most attractive book consists of a listing of the various types of white and black opal, each type being illustrated in colour, sometimes with several examples. This is most useful to the interested reader, who will have often encountered such terms as 'contra luz' without being able quickly to find out their meaning. Around this section is a general account of the history of Australian opal mining, an attempt to place the types and colours of opal according to their value and a section of maps of the main opal-bearing locations. The text is clear and quite free from the common anecdotes and legends which quickly become wearisome; anyone starting to collect opal would do well to obtain this book, which is very low-priced. M.O'D.

Pearl (R. M.). *Atlas of crystal stereograms.* Earth Science Publishing Co., Colorado Springs, Col., U.S.A., 1976. pp.80. Diagrams in text. $1.25.

This book is supplied with a pair of stereoscopic lenses mounted in a cardboard viewer and each of the crystal diagrams is repeated so that a stereoscopic image can be obtained by the reader. All crystal systems are represented and arranged in descending order of symmetry; they are not necessarily labelled to represent actual minerals but this is not the purpose of the excellent small book. M.O'D.

Vergnoux (A. M.). *Documentation sur les synthèses cristallines, Belgique, Espagne, France, Italie.* (Documentation on synthetic crystals, Belgium, Spain, France, Italy.) A. M. Vergnoux, Limoges, 1976. Various pagings. Free (except for postage).

A directory of crystal growers and the materials they produce covering the countries listed. Materials and growers are separately indexed. M.O'D.

First European Conference on Crystal Growth, Zürich, 1976. North Holland Publishing Co., Amsterdam, 1977. pp.xvi, 916. £68.49.

Forming Vol. 2 of 'Current topics in materials science', this volume contains important chapters on developments in the melt-growth of laser materials; LiYF$_4$ doped with Nd^{3+} with the scheelite structure is a fairly recent arrival on this scene, as well as the garnet types Gd$_3$Sc$_2$Al$_2$O$_{12}$,Lu$_3$Al$_5$O$_{12}$, Gd$_3$Sc$_2$Ga$_3$O$_{12}$.YAG and YAlO$_3$ have also been doped with Ho^{3+}. A chapter on new experimental developments in flux growth outlines how this and the Czochralski methods have been combined. In general the basic problem with flux growth is the slow rate and the consequent frequent crystal imperfection, together with container problems aggravated by corrosive contents. M.O'D.

ASSOCIATION NOTICES

GIFTS TO THE ASSOCIATION

The Council of the Association is indebted to the following for their gifts:

Mr Murray Burford, G.G., Mississauga, Ontario, Canada, for a copy of the paper *Diamond U.S.S.R. and North America. A Target for Exploration in Ontario,* by J. Satterly.

Mr R. Holt, F.G.A., London, for a copy of *Gem Cutters Craft,* by Leopold Claremont (dated 1906).

Mr J. Alan Fleming, F.G.A., of Roughgems Ltd, London, for a slab (155 × 105 mm) of charoite from the Charo River area in the Murun Massif, north-west Aldan, Yakutsk, U.S.S.R. (it is deep purple material of first class quality—see pp. 1-4 above), and also for a diamond crystal embedded in mother-rock, which comes from the Mir Pipe, Yakutia area, Siberia, U.S.S.R.

NEWS OF FELLOWS

Professor Dr Karl Schlossmacher, Hon. F.G.A., attained the age of 90 on the 10th July, 1977, when a special issue of *Gold Silber Uhren Schmuck* was published in his honour.

Mr Michael O'Donoghue, M.A., F.G.S., F.G.A., gave a talk to the Gemmological Society of Denmark in Copenhagen on 8th April, 1978; a variety of topics were introduced and specimens displayed.

MEMBER'S MEETINGS

London

At the meeting held on 4th April, 1978, at the Central Electricity Board Cinema, Newgate Street, London E.C.2. at which Mr Peter Read, C.Eng., M.I.E.E., M.I.E.R.E., F.G.A., F.I.S.T.C., gave a talk on 'New Gemmological Instruments and Techniques', the talk included a review of electronic reflectivity meters, colorimeters, horizontal-format microscopes and methods of diamond 'finger-printing'. It also covered the application of research techniques such as E.S.R. spectrometry, x-ray topography, electron microprobe analysis and cathodoluminescence. The talk was illustrated with slides and a number of instruments were displayed including the new Hanneman 'Diamond Eye' (which is very useful for detecting stones such as YAG, GGG, cubic zirconia and strontium titanate). Looking to the future, Mr Read referred to the possible use of a small computer (using a microprocessor) which could compare test-readings fed into it with information stored in its memory-bank and read out an identification.

This talk will be published in the *Journal* in full at a later date.

North-West Branch

On the 15th March, 1978, members viewed the private collection of gemstones of Mr John Pyke, F.G.A.

A visit to the Liverpool Museum to see the Jewellery Collection was arranged on the 27th April, 1978.

South Yorkshire & District Branch

A meeting was held on the 17th April, 1978, in the Sheffield City Polytechnic, when Mr E. A. Jobbins, B.Sc., F.G.A., gave an illustrated talk entitled 'The Gemstones of South East Asia'.

ANNUAL GENERAL MEETING

The 45th Annual General Meeting was held at Saint Dunstan's House, Carey Lane, London EC2V 8AB on the 11th May, 1978.

The Chairman, Mr Norman Harper, welcomed members and said how pleased he was that the Association had completed yet another successful year and that the number of entries for the examinations surpassed previous years. However, the poor results in the 1977 examinations had caused the Council to give serious consideration to this matter and a special sub-committee under the chairmanship of the President, Sir Frank Claringbull, had been set up. Its object was to review the examinations and related educational work in the light of the current situation. The committee will be reporting to the Council later in 1978.

Mr Harper expressed his thanks to the members of Council, Branch Chairmen, Examiners and Instructors, all of whom give up a lot of time for the Association. There was a special thank you to Mr Chisholm who did such an excellent job in producing the *Journal,* also to Mrs Mary Burland who did the work behind the scenes preparing copy for the printers.

Reference was made to the many members who had made gifts of various kinds to the Association. The Chairman also mentioned the excellent opal picture given by the Gemmological Association of All Japan and invited members to look at the picture after the meeting.

There was a special mention for Mr F. S. H. Tisdall who had done so much for gemmology in the Midlands area and who had now retired from class teaching.

The Chairman then proposed the adoption of the Annual Report and Accounts which was seconded by Dr G. Harrison Jones and duly carried.

Mr Harper then said that due to ill health he felt the time had come when he should vacate the Chair. He had enjoyed his thirteen years as Chairman but hoped that he would continue to be closely involved with the work of the Council and would continue to do his utmost for the benefit of the Association. He had pleasure in announcing that Sir Frank Claringbull had offered to continue as President, and he was re-elected. Mr Douglas N. King was elected Chairman and Mr David J. Callaghan, Vice-Chairman, and Mr F. E. Lawson Clarke re-elected as Treasurer.

Mr King expressed his thanks on being elected Chairman and said he would have a very difficult task to follow in the footsteps of Norman Harper. He extolled the many attributes of Norman and all that he had done for the Association and for gemmology, and he had the greatest pleasure in declaring him elected as a Vice-President. He said this honour was not lightly given and Mr Harper well and truly deserved this appointment.

Mr Callaghan expressed his appreciation of election as Vice-Chairman and said he would do his best to uphold the good name of the Association.

Messrs. M. Carr, P. Daly, N. W. Deeks and D. G. Kent were re-elected to the Council and Messrs. A. J. French, D. Inkersole and D. M. Larcher were elected.

The Chairman announced that Messrs. Hard Dowdy, Watson Collin & Co., Chartered Accountants, had signified their willingness to continue as auditors.

Finally the Chairman expressed his thanks to the National Association of Goldsmiths, and to the Worshipful Company of Goldsmiths for the assistance given by the Wardens in placing rooms in Goldsmiths' Hall at the disposal of the Association for meetings.

LETTERS TO THE EDITOR

From Mr A. E. Farn, F.G.A., Manager of the Gem Testing Laboratory of the London Chamber of Commerce and Industry.

Dear Sir,

Through the channels of the *Journal* I should like to say how sorry I am to hear of the retirement from office as our Chairman of Norman Harper through ill health.

I have been present at many meetings at which his delightful style and manner have carried the proceedings along in a most enjoyable manner. His pleasant *bonhomie* and general affability at these extremely friendly meetings are paralleled by his considerable concern for gemmology and our trade. He has worked very hard in his official capacity and achieved a distinction in launching the Gem Diamond course. We in the jewellery trade should be proud to have been represented and chaired by Norman Harper.

I do not think it would be fitting to allow Norman Harper's retirement to pass in silence. Speaking personally as a trade gemmologist, knowing how much work has to be accomplished in trade promotion and honorary office, I feel that Norman Harper has served us all well. I hope that he benefits from his retirement and that his health improves. I should like to conclude by saying a very sincere 'Thank you Norman Harper'.

Yours sincerely,
A. E. FARN

30th March, 1978. 36 Greville Street, London EC1N 8AU.

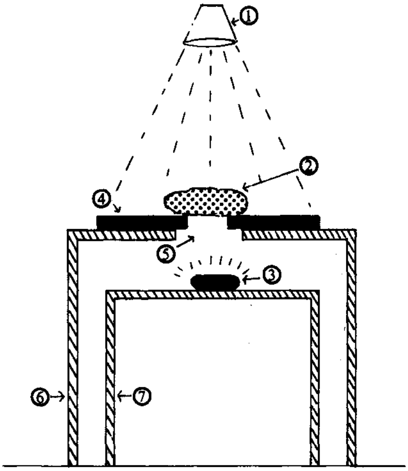
From Mr I. C. C. Campbell, F.G.A., Chairman of the Gemmological Association of Rhodesia.

Dear Sir,

An interesting article by M. J. O'Donoghue appeared in the *Journal* of July

1973 (XIII, 7, 263-4), titled 'Synthetic Quartz from the United States'. He covered numerous aspects in terms of the identification of such synthetics against their natural counterparts. This is based on possible inclusions that may exist in the synthetics (physical and optical constants being similar to those of the natural species, of course). The conclusion reached was—'As far as can be seen, the inclusions furnish the only possible clue to the origin, and as these can be found in some natural stones they cannot be completely diagnostic'. O'Donoghue very kindly forwarded to me a slabbed section of a crystal of yellow synthetic quartz (citrine) of the type spoken about. This section showed quite clearly the seed plate, which was of a colourless nature. The inclusions were also typical of those mentioned in his study.

Initially I did some simple comparison tests with this specimen and a number of natural quartz specimens to see what visual results could be obtained after subjecting the test pieces to short-wave ultraviolet (SW UV) irradiation under controlled conditions and with the use of a variable diaphragm (see sketch).



① SW UV light.
② Test specimen.
③ Scheelite.
④ Diaphragm. (Adjustable).
⑤ Hole in outer cylinder (approx. ½″ diameter).
⑥ Outer cylinder.
⑦ Inner cylinder (note that black (flat) colour was used on the inner surfaces of the outer cylinder and the outer surfaces of the inner cylinder).
⑧ Not shown in sketch: A suitably sized viewing hole cut out of the outer cylinder wall opposite the level of the scheelite. (The whole experiment being conducted in complete darkness).

SCHEMATIC LAY-OUT

The UV light was situated approximately ten inches above the specimen which, in turn, rested on a diaphragm; the latter was arranged on a closed-off unit (with a central hole punched through the top of it to allow the rays through). The side of the unit was open to observation of a piece of scheelite which rested directly below the punched hole. Scheelite, of course, fluoresces a whitish-bluish colour under SW UV. Experiments were carried out in complete darkness. It was observed that the natural quartz (colourless, brown, yellow and amethyst) allowed the SW UV rays through, and this was made evident by the fluorescing scheelite. The synthetized quartz did not, or if it did it was only very slight, because the reaction of the scheelite was nil. As I thought this was an interesting result and offered a potential form of identification of synthetic quartz, I repeated the experiment using transmission tests on slow photographic paper. The results confirmed the initial tests—the difference in transmission of the SW UV being noticeable.

At that stage I wrote to Robert Webster, with whom I had often corresponded on numerous subjects, telling him of the results of my tests. He replied with interest (correspondence on record) and offered to do more conclusive tests along similar lines. (I had no more examples of synthetic quartz for additional tests).

In due course I received a number of photographs of results together with comments from him. The details are as follows, the words in quotation marks being from Webster's letter to me: 'I fixed up a small short-wave UV lamp with filter about 17 inches above a dish of water and with selected stones of comparable size tried out the photo technique (pp. 310-11, Gems, Vol. 1, 1962).' At first the technique was disappointing, as an exposure of about 12 seconds was overexposed and a 4 second exposure was underdeveloped; but other similar exposures were more fully developed, and 'all these tended to show that your supposition was correct and at this stage I had hoped that a test for synthetic quartz had been found.' But further tests on cut stones did not give clear results. The next try was with a slow-acting bromide paper, which 'in all cases got clear results, with one exception.' This was supported by the photographic results which he sent to me. Nine stones were used—5 synthetic (two colourless of different cuts, one cobalt blue, one showing a seed-plate of unknown colour, one green) and four natural (one oval-cut citrine, two brilliant-cut brown, and one pale yellow which was flawed).

The photographic results showed the synthetic quartz, with one exception, in dark relief. The natural quartzes were all in pale (whitish to white) relief. The one exception was the synthetic green quartz which gave the same results as the natural stones. However, this shade of green colour, according to Webster, was not found in natural quartz. The stones were of various shapes and sizes and ranged (when looking at the photograph) from the smallest which measured 8 × 8 mm square to the largest (a slab) of dimensions 44 × 30 mm. Thicknesses are not known.

As the synthetic green quartz was an exception, one cannot say that these tests were conclusive and further tests with numerous other specimens (including amethyst) should be done. Nevertheless, it does suggest that this method may well be useful in such identifications.

It should be said also that obviously the photographic technique is rather critical. Webster died before he could finalize the matter. He also stated that he wanted to use my original technique as well—presumably on a more refined basis.

It is suggested that gemmologists who have a full range of synthetic quartz available could follow up this technique and see if anything more substantial will result. I should, of course, have liked to do the work myself, but I have tried for a considerable time (over 18 months to date) to get a *range* of synthetic quartz—but no joy! Synthetic quartz seems to be practically non-existent here—citrine being the only colour-variety seen.

Yours etc.
IAN CAMPBELL

9th May, 1978. Bulawayo, Rhodesia.

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